THE 11TH INTERNATIONAL CONFERENCE ON

CRYOCRYSTALS AND QUANTUM CRYSTALS

TURKU, FINLAND - 18-24 AUGUST 2016

Contents

Turun yliopisto
University of Turku

FEDERATION OF FINNISH LEARNED SOCIETIES
Delegation of the Finnish Academies of Science and Letters

JENNY JA ANTTI WIHURIN RAHASTO

CRYOIN
ENGINEERING

visitturku.fi

ACADEMY OF FINLAND

The 11th International Conference on Cryocrystals and Quantum Crystals (CC2016) is organized in Turku, Finland by the Department of Physics and Astronomy, Wihuri Physical Laboratory, and Congress Office of the University of Turku. Conference Chairs are Prof. Kalle-Antti Suominen and Dr. Sergey Vasiliev.

The Conference on Cryocrystals and Quantum Crystals (CC) dates back to 1979, when the first national USSR meeting dealing with cryocrystals and quantum crystals was organized in Viljandi, Estonia by V.G. Manzhelii (Verkin Institute for Low Temperature Physics and Engineering NASU) and A.F. Prikhot'ko (Institute of Physics NASU). The subsequent biannual meetings were held in Kharkov (Ukraine), Almaty (Kazakhstan), Donetsk (Ukraine) and Odessa (Ukraine).

Since the Almaty meeting in 1995 the CC Conference had acquired international status becoming an important international forum for presenting new results on physics and chemistry of atomic and molecular solids. The great merit in achieving of this goal belongs to Prof. Vadim Manzhelii and Prof. Horst Meyer, the co-chairs of the first International CC-1995.

The next two CC conferences were held in Poland, in Polanica Zdrój (September 1997) and in Szklarska Poręba (August 2000). The venues of the next CC conferences were Freising (Germany) in 2002, Wrocław (Poland) in 2004, Kharkov (Ukraine) in 2006, Wrocław (Poland) in 2008, Chernogolovka (Russia) in 2010, Odessa (Ukraine) in 2012 and the last meeting was held in the city of Almaty (Kazakhstan).

The scope of CC is wide, including, but not limited to:

- thermodynamic and mechanical properties of cryocrystals and quantum crystals
- order-disorder phenomena
- optical and neutron spectroscopy of cryocrystals
- high-pressure studies of cryocrystals and quantum crystals
- charged species in cryocrystals and quantum crystals
- phenomena at the surface of quantum fluids and solids
- impurity-helium condensates
- matrix isolation in cryocrystals
- ultrafast dynamics in crystals
- crystalline and amorphous films, nanoscale systems
- supersolid state
- new emerging materials
- technological applications and instrumentation

CC-2014 is a forum where ideas on various aspects of the physical, chemical and technological properties of solidified gases and other relevant materials are discussed and where top experts in the field meet.

Sponsors and Exhibitors

The organizers of CC11 wish to thank the following organizations for their contribution:

Federation of Finnish Learned Societies

City of Turku

Turku University Foundation

Jenny ja Antti Wihurin rahasto

Cryoin Engineering Ltd.

Academy of Finland, project 260531

Programme at a glance

17 August **Wednesday**	**18 August** **Thursday**	**19 August** **Friday**	**20 August** **Saturday**
	Opening 10:00–10:15	**Morning session 3** 09:00–10:30 09:00 **M. Eremets I06** 09:45 **S. Klotz I07**	**Morning session 5** 09:00–10:40 09:00 **E. Gordon I12** 09:40 **I. Silvera C03** 10:10 **P. Moroshkin C04**
	Morning session 1 10:15–11:00 10:15 **I. Silvera I01**		
	Coffee break 11:00–11:30	Coffee break 10:30–11:00	Coffee break 10:40–11:10
	Morning session 2 11:30–12:40 11:30 **Yu. Freiman I02** 12:10 **E. Yakub I03**	**Morning session 4** 11:00–12:30 11:00 **V. Nesvizhevski I08** 11:45 **S. Sheludiakov C02**	**Morning session 6** 11:10–12:10 11:10 **M. Brazhnikov C05** 11:40 **D. Shevchuk C06** 12:00 **A Chyhrin C07**
	Lunch 12:40 – 14:00	Lunch 12:30–14:00	Lunch 12:20–14:00
Registration **16:00–20:00**	**Afternoon session 1** 14:00–15:40 14:00 **A. Goncharov I04** 14:40 **R. Martoňák I05** 15:10 **L. Yakub C01**	**Afternoon session 3** 14:00–15:50 14:00 **P. Toennies I09** 14:40 **A. Vilesov I10** 15:20 **J. Eloranta I11**	Guided tour to the Turku Castle Free afternoon
	Coffee break 15:30–16:00	Coffee break 15:50–16:20	
18:00–20:00 **Get-together Party**	**Afternoon session 2** 16:00–16:40 Short presentations of posters. 4 min/poster, max 3 slides Posters P01–P09	**Afternoon session 4** 16:20–17:00 Short presentations of posters. 4 min/poster, max 3 slides Posters P10-P18	
	18:30–20:00 **Reception of the City of Turku** **Departure from Harjattula at 17:45**	**Poster session** 17:10–18:30	**19:00 Sauna**

21 August **Sunday**	**22 August** **Monday**	**23 August** **Tuesday**	**24 August** **Wednesday**
11:00-21:00 **Archipelago tour**	**Morning session 7** 9:00 – 11:50 9:00 **N. Prokof'ev I13** 9:40 **J. Beamish I14** 10:20 **J. Ahokas C08**	**Morning session 9** 9:00 – 10:50 9:00 **M. Strzhemechny I18** 9:40 **V. Khmelenko I19** 10:20 **R. Boltnev C13**	**Morning session 11** 9:00 – 10:40 9:00 **K. Kono I24** 9:40 **Lin Jui-Yin C17** 10:10 **J. Järvinen C18**
	Coffee break 10:50– 11:20	Coffee break 10:50– 11:20	Coffee break 10:40– 11:10
	Morning session 8 11:20–12:30 11:20 **I. Todoshenko I15** 12:00 **E Savchenko C09**	**Morning session 10** 11:20–12:30 11:20 **L. Mezhov-Deglin I20** 12:00 **L Duarte C14**	**Closing** 11:10–11:30
	Lunch 12:30–14:00	Lunch 12:20–14:00	
	Afternoon session 5 14:00–15:10 14:00 **A. Drobyshev I16** 14:40 **V. Efimov C10**	**Afternoon session 7** 14:00–15:20 14:00 **L. Khryaschchev I21** 14:40 **M. Ramos I22**	
	Coffee break 15:10–15:40	Coffee break 15:20–15:50	
	Afternoon session 6 15:40–17:00 15:40 **N. Krainyukova I17** 16:20 **E. Manzhelii C11** 16:40 **M. Barabashko C12**	**Afternoon session 8** 15:50–17:20 15:50 **O. Kirichek I23** 16:30 **P. Stachowiak C15** 17:00 **A Krivchikov C16**	
	Poster session 17:10–18:30	**Poster session** 17:30–18:30	

Harjattula - the conference venue

Harjattula is a conference centre located on the Kakskerta island, surrounded by beautiful nature, golf greens and the sea. Also accommodation has been reserved for the participants at Harjattula. The drive from the city centre of Turku to Harjattula takes about 20 minutes. Address: Harjattulantie 80.

Registration & information on-site

The Congress Office will be on-site for registration & information on:
Wednesday, 17 August at 16.00-20.00
Thursday, 18 August at 9.00-10.15

If you need to contact the organisers during the conference, kindly leave a message at reception of Harjattula or contact directly one of the members of Local Organizing Committee:
S. Vasiliev - chairman
J. Järvinen,
J. Ahokas,
S. Sheludiakov

Internet access

Username: harjattula
Password: harjattula

Lunch and coffee

Buffet lunch will be served in the restaurant Wanha Talli, in the same building as the conference. Coffee servings will be at the lobby of the auditorium.

Dinner

Dinner is available in Harjattula on Thursday, Friday, Monday and Tuesday evenings between 18.00 and 20.00. On Saturday evening, dinner is available at 18:30-20:00. The price for the dinner is 10 euros.

Posters

The poster area is located in the 2nd floor.

Smoking

Please note that smoking is allowed only in restricted areas, outside the reception building.

Local public transportation

If you fly to Turku, there is a regular bus from the Turku airport to city centre Market Square (distance approx. 8 km), bus line nro 1 which runs about every 20 minutes. Tickets à 3 eur can be bought from the driver (cash, preferably coins).

To get from Turku city center to Harjattula, take the bus number 15 (direction "Kakskerta") and get off at bus stop 1762 "Kaislahdentie". The bus travel takes about 30 minutes. More information about the local bus routes http://www.foli.fi/en.
All local buses stop at the Market Square, so there are a lot of bus stops. Bus number 15 to Harjattula departs from bus stop "T4" and when coming from Harjattula, it stops at the bus stop "T3".

Taxi

Tel. +358 2 10041

Taxi from city center to Harjattula cost about 40 euros, from airport to Harjattula about 50 euros. After 8 p.m. there is a small additional charge.

Note! In case you have not yet registered for social events but wish to take part, please contact the Congress Office for possible vacancies.

City Reception

on Thursday, 18 August at 18:30-20:00
Bus transportation from Harjattula at 17:45. Return transportation at 20:00.

All CC11 participants are warmly welcome to join the City Reception on Thursday evening at the Turku City Hall. The reception is hosted by the City of Turku. The City Hall in located in the city centre of Turku, in the corner of river Aurajoki and Aurakatu street, a stone's throw from the market square. Address: Aurakatu 2.

Light buffet dinner will be served. Please note that the reception is free of charge, but pre-registration is required.

Day trip in the Archipelago

on Sunday, 21 August, at 11:30-21:00

The day starts at 11:30 with a boat trip from Harjattula through the beautiful archipelago to the charming small town of Naantali. Lunch will be served on board. In Naantali the participants will have a chance to visit the old town famous for its ornate villas. The trip continues by boat from Naantali to the Tammiluoto Country Winery, located by the sea, on Lemlax island in Parainen. Originally an orchard, Tammiluoto began producing wine in 1996. Over the years it has evolved into an attraction, which draws thousands of visitors annually, both travellers and event guests. Possibility to buy the products of the state. Dinner will be served on the winery. Return to Harjattula at about 21:00.

Tickets 50 eur including lunch and dinner.

The History of Turku Castle

on Saturday, 20 August, at 15:30

Bus transportation from Harjattula at 14:45. The tours will be guided in English and in Russian.

The Turku Castle has stood in guard over the river Aurajoki since the 1280's. During the centuries the fortification gradually changed into a grand greystone palace. In the Middle Ages the castle was often visited by monarchs and became an important administrative centre. In the 16th century, Duke John established a luxurious renaissance court in the castle. During this guided tour you will hear about the history of the Turku Castle, its construction and defending, the splendor of the court and everyday life. After the guided tour you will have free time in the city center. Bus transportation back to Harjattula is arranged at 18.30 from the Market Square in front of the Orthodox church, address Yliopistonkatu 19. If you want to leave earlier or stay longer, you can take the local bus number 15 from Market Square back to Harjattula. After the guided tour you will have free time in the city center. Bus transportation back to Harjattula is arranged at 18:30 from the Market Square in front of the Orthodox church, address Yliopistonkatu 19. If you want to leave earlier or stay longer, you can take the local bus number 15 from Market Square back to Harjattula.

The guided tour is free of charge, but pre-registration is recommended.

Excursion for Accompanying persons:

Luostarinmäki Handicrafts Museum

on Friday, 19 August, at 11:30

Transportation from Harjattula at 11:00. The tour will be guided in English.

In 1827 the Great Fire of Turku caused enormous destruction, but Luostarinmäki was spared. Today Luostarinmäki is a Handicraft Museum that provides a unique setting to see the craftsmen of the pre-industrial era.

The guided tour is free of charge for Accompanying persons, but pre-registration is recommended.

10:00–10:15 Opening

10:15–11:00 Morning session 1

10:15 METALLIC HYDROGEN (I01)
Silvera Isaac, Harvard University, USA

11:00–11:30 Coffee break

11:30–12:40 Morning session 2

11:30 ELASTIC PROPERTIES OF HELIUM AND HYDROGEN UNDER PRESSURE (I02)
Freiman Yuri, B. Verkin Institute for Low Temperature Physics and Engineering, NAS of Ukraine, Ukraine

12:10 THE MODIFIED DEBYE-GRUNEIZEN MODEL FOR HIGHLY COMPRESSED DIAMOND (I03)
Yakub Eugene, Odessa National Economic University, Ukraine

12:40–14:00 Lunch

14:00–15:40 Afternoon session 1

14:00 HIGH-PRESSURE SYNTHESIS OF SUPERHYDRIDES (I04)
Goncharov Alexander F., Geophysical Laboratory, Carnegie Institution of Washington, USA

14:40 NEW HIGH PRESSURE LAYERED PHASES OF CS2 AND SiS2 (I05)
Martoňák Roman, Comenius University in Bratislava, Slovakia

15:10 MELTING LINE PARAMETERS AND THERMODYNAMIC PROPERTIES OF METHANE AT HIGH PRESSURES (C01)
Yakub Lydia, V.S.Martynovsky Institute of Refrigeration, Cryotechnology and Energetics, Odessa, Ukraine

15:30–16:00 Coffee break

16:00–16:40 Afternoon session 2

Short presentations of posters
4 min/poster, max 3 slides
Posters P01-P09

18:30 Reception of the City of Turku

Departure from Harjattula at 17:45

09:00–10:30 Morning session 3

09:00 HIGH TEMPERATURE SUPERCONDUCTIVITY IN HYDROGEN-RICH MATERIALS (I06)
Eremets Mikhail, Max Planck Institute for Chemistry, Mainz, Germany

09:45 HIGH PRESSURE NEUTRON DIFFRACTION STUDIES ON SOLID OXYGEN (I07)
Klotz Stefan, IMPMC, Université P&M Curie, France

10:30–11:00 Coffee break

11:00–12:30 Morning session 4

11:00 QUANTUM GRAVITATIONAL SPECTROSCOPY (I08)
Nesvizhevsky Valery, Institut Max von Laue - Paul Langevin, France

11:45 MAGNETIC REESONANCE STUDY OF ATOMIC HYDROGEN AND TRITIUM STABILIZED IN SOLID TRITIUM MATRICES BELOW 1 K (C02)
Sheludiakov Sergei, University of Turku, Finland

12:30–14:00 Lunch

14:00–15:50 Afternoon session 3

14:00 SUPERSIZED MOLECULES OF HELIUM AND MOLECULES IN SUPERFLUID HELIUM (I09)
Toennies Peter, Max Planck Institute, University of Göttingen, Germany

14:40 X-RAY COHERENT DIFFRACTIVE IMAGING OF QUANTUM VORTICES IN HELIUM DROPLETS (I10)
Vilesov Andrey, Univ Of Southern CA, USA

15:20 THEORETICAL MODELLING OF SUPERFLUID 4HE VISCOUS RESPONSE ON THE NANOMETER SCALE (I11)
Eloranta Jussi, California State University, Northridge, USA

15:50–16:20 Coffee break

16:20–17:00 Afternoon session 4

Short presentations of posters.
4 min/poster, max 3 slides
Posters P10-P18

17:10–18:30 Poster session

09:00–10:40 Morning session 5

09:00 NON-ISOTHERMAL KINETICS OF CHEMICAL AND PHYSICAL PROCESSES IN SUPERFLUID HELIUM (I12)
Gordon Eugene, IPCP RAS, Chernogolovka, Russia

09:40 THE CREATION OF LONG-LIVED MULTIELECTRON BUBBLES IN SUPERFUID HELIUM (C03)
Silvera Isaac, Harvard University, USA

10:10 METAL NANOWIRES AND MESOSCOPIC NETWORKS AT A FREE SURFACE OF SUPERFLUID HELIUM (C04)
Moroshkin Petr, RIKEN, Japan

10:40–11:10 Coffee break

11:10-12:10 Morning session 6

11:10 EXPERIMENTAL OBSERVATION OF THE DECAY INSTABILITY OF GRAVITY-CAPILLARY WAVE ON THE SURFACE OF LIQUID HYDROGEN (C05)
Brazhnikov Max, Insitute of Solid State Physics RAS, Russia

11:40 THERMAL TRANSPORT IN HIGHLY ANISOTROPIC ORIENTATIONAL GLASS-FORMERS (C06)
Szewczyk Daria, Institute of Low Temperatures and Structure Research PAS, Polska

12:00 PURIFICATION AND EXTRACTION OF RARE GASES BY FREEZE OUT METHOD (C07)
Chyhrin Artem, Cryoin Engineering, Ukraine

12:20–14:00 Lunch

15:30 Guided tour at Turku Castle

Transportation from Harjattula at 14:45

Free afternoon

19:00 Sauna

11:00-21:00 Archipelago tour

09:00–11:50 Morning session 7

09:00 SUPERSOLID STATES: WHERE DO WE FIND THEM? (I13)
Prokof'ev Nikolay, University of Massachusetts, Amherst, USA

09:40 DEFECT MOTION IN A QUANTUM SOLID WITH SPIN: HCP 3HE (I14)
Beamish John, University of Alberta, Canada

10:20 MAGNETIC RESONANCE STUDY OF ATOMIC HYDROGEN ISOTOPES STABILIZED IN SOLID HYDROGEN MATRICES BELOW 1K (C08)
Ahokas Janne, University of Turku, Finland

10:50–11:20 Coffee break

11:20–12:30 Morning session 8

11:20 CRYSTALLIZATION WAVES IN 3HE (I15)
Todoshchenko Igor, Low Temperature Laboratory, Aalto University, Finland

12:00 RADIATION EFFECTS IN SOLID NITROGEN (C09)
Savchenko Elena, B. Verkin Institute for Low Temperature Physics & Engineering NASU, Ukraine

12:30–14:00 Lunch

14:00–15:10 Afternoon session 5

14:00 CRYOEMISSION OF NITROUS OXIDE AND ETHANOL. DYNAMIC AND ENERGY CHARACTERISTICS (I16)
Drobyshev Andrey, Kazakh National University, Kazakhstan

14:40 PHASE TRANSITIONS IN SOLID ETHANOL (C10)
Efimov Victor, Institute of Solid State Physics RAS, Russia

15:10–15:40 Coffee break

15:40–17:00 Afternoon session 6

15:40 CAPTURING GASES IN CARBON HONEYCOMB (I17)
Krainyukova Nina, B. Verkin Institute for Low Temperature Physics and Engineering NASU, Ukraine

16:20 INFLUENCE OF DEFECTS ON VIBRATIONAL CHARACTERISTICS OF LINEAR CHAINS OF INERT GASES ATOMS ADSORBED ON BUNDELES OF CARBON NANOTUBES (C11)
Manzhelii Elena, B. Verkin Institute for Low Temperature Physics and Engineering, Ukraine

16:40 HEAT CAPACITY OF 1D MOLECULAR CHAINS (C12)
Barabashko Maksym, B.Verkin Institute for Low Temperature Physics and Engineering of NASU, Ukraine

17:10–18:30 Poster session

09:00–10:50 Morning session 9

09:00 CLUSTER APPROACH IN CRYOCRYSTALS (I18)
Strzhemechny Mikhail, Verkin Institute for Low Temperature Physics and Engineering, Ukraine

09:40 THERMALLY INDUCED LUMINESCENCE OF NITROGEN NANOCLUSTERS CONTAINING STABILIZED NITROGEN ATOMS (I19)
Khmelenko Vladimir, Texas A&M University, USA

10:20 SPECTROSCOPIC OBSERVATION OF NITROGEN ANIONS N– IN CRYOCRYSTALS (C13)
Boltnev Roman, Joint Institute for High Temperatures, RAS, Russia

10:50–11:20 Coffee break

11:20–12:30 Morning session 10

11:20 NANOCLUSTER IMPURITY-HELIUM GEL - A NEW CLASS OF SOFT MATTER (I20)
Mezhov-Deglin Leonid, Institute of Solid State Physics RAS, Russia

12:00 PHOTOISOMERIZATION OF AZOBENZENES ISOLATED IN CRYOGENIC MATRICES (C14)
Duarte Luís, University of Helsinki, Finland

12:20–14:00 Lunch

14:00–15:20 Afternoon session 7

14:00 SOME FUNDAMENTAL REACTIONS IN CRYOGENIC MATRICES (I21)
Khriachtchev Leonid, University of Helsinki, Finland

14:40 CALORIMETRIC MEASUREMENTS BETWEEN 1.5 K AND 300 K IN MOLECULAR GLASSES AND DISORDERED CRYSTALS (I22)
Ramos Miguel, Universidad Autonoma de Madrid, Spain

15:20–15:50 Coffee break

15:50–17:20 Afternoon session 8

15:50 ADHESION, PLASTICITY AND OTHER PECULIAR PROPERTIES OF SOLID METHANE (I23)
Kirichek Oleg, ISIS Facility, STFC, UK

16:30 THERMAL CONDUCTIVITY OF METHANE - SIO2 CRYOCRYSTAL NANOCOMPOSITES (C15)
Stachowiak Piotr, Institute for Low Temperatures and Structure Research, Polish Academy of Sciences, Wroclaw, Poland

17:00 THERMAL CONDUCTIVITY OF CRYOCRYSTALS FROM METHANE TO TETRACHLOROMETANE: REGULARITIES AND SINGULARITIES (C16)
Krivchikov Alexander, 1B. Verkin Institute for Low Temperature Physics and Engineering of NAS Ukraine, Ukraine

17:30–18:30 Poster session

09:00–10:40 Morning session 11
09:00 STICK-SLIP MOTION OF THE WIGNER SOLID OVER LIQUID HELIUM SURFACE (I24)
Kono Kimitoshi, RIKEN, Japan

09:40 SUPPRESSION OF BRAGG-CHERENKOV SCATTERING OF WIGNER CRYSTAL ON LIQUID HELIUM IN A PERODIC POTENTIAL (C17)
Lin Jui-Yin, Okinawa Institute of Science and Technology Graduate University, Japan

10:10 DYNAMIC NUCLEAR POLARIZATION AND CONTROL OF 29SI NUCLEAR SPINS IN DOPED SI (C18)
Järvinen Jarno, University of Turku, Finland

10:40–11:10 Coffee break

11:10–11:30 Closing

P01 LUMINESCENCE OF IMPURITY-HELIUM CONDENSATES SUBMERGED IN SUPERFLUID HELIUM
Boltnev Roman, Joint Institute for High Temperatures, RAS, Russia

P02 WIGNER CRYSTAL PHASE OF AN ULTRA-COLD TWO-DIMENSIONAL FERMI SYSTEM WITH LONG RANGE DIPOLE-DIPOLE INTERACTION
Ciftja Orion, Prairie View A&M University, USA

P03 NEW THEORETICAL APPROACH AND EXPERIMENTAL FINDINGS IN STUDYING MATRIX-ISOLATED CH3 ROTATOR
Dmitriev Yurij, Ioffe Institute, Russia

P04 THE REFRACTIVE INDEX OF CRYODEPOSITES OF ETHANOL, METHANE AND NITROUS OXIDE IN THE VICINITY OF THE PHASE TRANSFORMATION TEMPERATURE
Drobyshev Andrey, Kazakh national university, Kazakhstan

P05 THE EFFECT OF TEMPERATURE DEPOSITION AND CONCENTRATION ON THE VIBRATIONAL SPECTRA OF THE WATER-METHANE CRYOFILMS
Drobyshev Andrey, Kazakh national university, Kazakhstan

P06 HEAT TRANSMISSION IN SUPERFLUID HELIUM
Efimov Victor, Institute of Solid State Physics RAS, Russia

P07 HIGH TEMPERATURE ANOMALIES OF THE CRYSTALLINE METHANE. INTERPRETATION OF EXPERIMENTAL DATA
Kirichek Oleg, ISIS Facility, STFC, UK

P08 HOPPING PRECESSION OF MOLECULES IN CRYSTALLINE CARBON DIOXIDE FILMS
Krainyukova Nina, B. Verkin Institute for Low Temperature Physics and Engineering NASU, Ukraine

P09 ARGON NANOCLUSTERS WITH FIVEFOLD SYMMETRY IN SUPERSONIC GAS JETS AND SUPERFLUID HELIUM
Krainyukova Nina, B. Verkin Institute for Low Temperature Physics and Engineering NASU, Ukraine

P10 CRYOCRYSTALS AS SUBSTRATES FOR SURFACE STATE ELECTRONS
Leiderer Paul, University of Konstanz, Germany
P11 INFLUENCE OF HELIUM ATOMS ADSORBTION ON THE EMISSION PROPERTIES OF CARBON NANOTUBES
Levchenko Alexandr, Institute of Solid State Physics RAS, Russia

P12 INSTABILITY OF THE WATER SURFACE IN AN EXTERNAL ELECTRIC FIELD
Levchenko Alexandr, Institute of Solid State Physics RAS, Russia

P13 STRUCTURE OF SOLID &#945 – NITROGEN DOPED METHANE
Mysko-Krutik Nataliya, B.Verkin Institute for Low Temperature Physics and Engineering, Ukraine

P14 EFFECTS IN HEAT TRANSFER CAUSED BY THE PRESENCE OF DIFERENT TYPES OF NANOPARTICLES INSIDE CRYOCRYSTALS
Nikonkov Ruslan, Institute of Low Temperature and Structure Research PAS, Poland

P15 VISUALIZATION OF THE SURFACE PATTERNS IN HE-II
Pelmenev Alexander, L.D. Landau Institute of Theoretical Physics RAS, Russia

P16 SURFACE INSTABILITY OF SUPERFLUID He-II INDUCED BY A STEADY HEAT FLOW WITHIN THE LIQUID
Remizov Igor, ISSP RAS, Russia

P17 EXPERIMENTAL SAMPLE CELL FOR MOLECULAR BEAM DEPOSITION AND MAGNETIC RESONANCE STUDIES OF MATRIX ISOLATED RADICALS AT TEMPERATURES BELOW 1 K
Sheludiakov Sergei, University of Turku, Finland

P18 THERMAL CONDUCTIVITY OF MEAT DURING FREEZING. EXPERIMENTAL INVESTIGATION AND COMPUTER SIMULATION
Shinbayeva Ainura, Kazakh national university, Kazakhstan

I01 METALLIC HYDROGEN

Isaac F. Silvera
Lyman Laboratory of Physics, Harvard University, Cambridge MA 02138, USA
silvera@physics.harvard.edu

We have observed metallic hydrogen as a first-order phase transition at megabar pressures and at high temperatures [1]. In 1935 Wigner and Huntington [2] predicted that solid molecular hydrogen would transform to solid atomic metallic hydrogen (MH) as a first-order dissociative phase transition if pressurized to a sufficient density in the T=0 K limit. Thus began decades of theoretical predictions and experimental efforts along this low temperature pathway. A high temperature pathway for general atomic systems was studied by Norman and Starostin [3]. In this case, high-density molecular hydrogen is heated above the melting line and with further heating liquid molecular hydrogen is predicted to undergo a dissociative first-order phase transition (with a critical point) to liquid atomic hydrogen. This is the phase of MH that we have observed. Hydrogen is pressurized in diamond anvil cell (DAC) to the megabar region and heated to temperatures ~1000-2000 K. Hydrogen is difficult to maintain under these conditions with static heating, as it diffuses into the gasket and diamonds and the diamonds fail. We have developed pulsed laser heating techniques so that hydrogen is heated for a few hundred nanoseconds, sufficient time for phase equilibrium, but insufficient for serious diffusion. Heating curves and optical properties are measured. A heating curve is a plot of temperature vs laser heating power and should result in a monotonically rising curve unless a phase transition occurs. Above the melting temperature we observe a plateau that is associated with the latent heat for a first-order phase transition. For temperatures above the plateau we observe metallic behavior in the measured transmittance and reflectance of the heated sample in agreement with theoretical predictions, confirming the observation of MH.

In order to "qualify" for the Cryocrystal Conference we have also studied hydrogen and its isotopes at low temperature using near infrared spectroscopy. In solid HD we observe two remarkable new quantum phase transitions in which the HD dissociates but reforms as molecular hydrogen and deuterium (along with HD) in the 2-3 megabar regime [4]. Recently we have pressurized hydrogen to 4.2 megabar, the highest pressures ever reported for hydrogen and its isotopes [5]. We observe a quantum phase transition at 3.55 megabar at liquid helium temperatures, but at the highest pressures achieved solid hydrogen is still not metallic.

The NSF, grant DMR-1308641, the DOE Stockpile Stewardship Academic Alliance Program, grant DE-NA0001990, and NASA Earth and Space Science Fellowship Program, Award NNX14AP17H supported this research.

[1] M. Zaghoo, A. Salamat, and I. F. Silvera, Phys. Rev. B 93, 155128 (2016)
[2] E. Wigner and H. B. Huntington, J. Chem. Phys. 3, 764 (1935)
[3] G. E. Norman and A. N. Starostin, Teplofiz. Vys. Temp. 8, 413 (1970)
[4] R. Dias, O. Noked, and I. F. Silvera, PRL. 116, 145501 (2016)
[5] R. Dias, O. Noked, and I. F. Silvera, arXiv:1603.02162v1 (2016)

I02 ELASTIC PROPERTIES OF HELIUM AND HYDROGEN UNDER PRESSURE

Yu.A. Freiman, Alexei Grechnev
Verkin Institute for Low Temperature Physics and Engineering, Ukraine
yuri.afreiman@gmail.com

The elastic moduli, sound velocities, Poisson's ratio, and elastic anisotropy coefficients of hcp solid helium have been calculated using density functional theory in generalized gradient approximation (up to 30 terapascals (TPa), and pair triple semiempirical potentials (up to 100 GPa). Zero-point vibrations (ZPV) have been treated in the Debye approximation assuming 4He isotope (we excluded the quantum-crystal region at very low pressures from consideration). Both methods give a reasonable agreement with the available experimental data [1]. Our calculations [2] predict significant elastic anisotropy of helium at low pressures. Under terapascal pressures helium becomes more elastically isotropic. Our calculations confirm the previously measured decrease of the Poisson's ratio with increasing pressure. This is not a quantum effect, as the same sign of the pressure effect was obtained when we disregarded zero-point vibrations. At TPa pressures, Poisson's ratio (PR) reaches the value of 0.31 at the theoretical metallization point (P=17.48 GPa). For $P = 0$, we predict a PR of 0.38, in excellent agreement with the low P – low T experimental data.

In order to find the Poisson's ratio in hcp phase I of hydrogen theoretically, we have calculated elastic constants using pair and three-body semi-empirical potentials in the framework of the approach developed earlier for helium [2]. No rotational degrees of freedom were included in this approach. Aggregate values, such as bulk and shear moduli and the Poisson's ratio, were obtained within Voigt-Reuss-Hill averaging scheme. For five elastic constants there is a reasonable qualitative agreement with the experimental results [3] although theory gives somewhat larger elastic anisotropy than the experiment. The theoretical PR ratio obtained without ZPV increases monotonously with pressure which badly contradicts the experiment. The inclusion of ZPV improves the situation to some extent, as the theory can qualitatively account for the minimum at about 45 GPa and the growth in the region above 45 GPa, however, the sharp decrease of PR for pressures below 45 GPa is not accounted for. The main reason for this discrepancy is neglect of the rotational degrees of freedom of hydrogen molecules [4].

It is interesting to contrast the present theoretical results for hydrogen to our previous ones for helium. While the 2- and 3-body potentials for hydrogen and helium have the same functional form and even rather close values of parameters, the resulting behavior of Poisson's ratio is drastically different. The classical PR (ignoring ZPV) increases with pressure monotonously for H_2, but decreases for He. For helium, ZPV does not affect PR in any significant way, and there is a reasonably good agreement between theory and experiment. For H_2 (as an H_2 molecule has half the mass of a ^{4}He atom) ZPV are much more important and drastically affect the PR for P<50 GPa. The classical behavior (the positive sign of d(PR)/dP) is seen above 45 GPa, while the negative region of d(PR)/dP) below 45 GPa is likely a quantum effect. We can conclude that in contrast to helium, ZPV are highly important for the elastic properties of hydrogen.

[1] C.-s. Zha, H.-k. Mao, and R.J. Hemley, Phys. Rev. B 70, 174107 (2004).
[2] A. Grechnev, S.M. Tretyak, Yu.A. Freiman et al., Phys. Rev. B 92, 024102 (2015).
[3] C.-s. Zha, T.S. Duffy, H.-k. Mao, and R.J. Hemley, Phys. Rev. B 48, 9246 (1993).
[4] Yu.A. Freiman, A. Grechnev, S.M. Tretyak et al., Low Temp. Phys. 41, 445 (2015).

I03 THE MODIFIED DEBYE-GRÜNEISEN MODEL FOR HIGHLY COMPRESSED DIAMOND

Eugene Yakub
Odessa National Economic University, Ukraine
yakub@oneu.edu.ua

Thermodynamic properties of diamond predicted in *ab initio* DFPT calculations [1] demonstrate unusual high-pressure behavior. Thermal expansion coefficient increases with temperature and decreases with increasing pressure. At P>700 GPa and room temperature it becomes negative. On the contrary, the bulk modulus increases with increasing pressure and decreases with the temperature. Analysis of *ab initio* data [1] reveals that high-pressure behavior of diamond at low and high temperatures is essentially different and low-temperature properties of diamond cannot be reproduced correctly on the basis of usual Debye-Grüneisen model even when longitudinal and transverse phonon modes are described by their own Debye temperatures and thermal Grüneisen parameters [2].

A new modification of the Debye-Grüneisen model is proposed. It takes into account non-equidistance of the anharmonic oscillators' energy levels. The low-temperature version of this model explicitly considers anharmonic displacement of only lowest energy levels of both longitudinal and transverse phonons. As it is demonstrated in the paper, the equation of state based on this version of the modified Debye-Grüneisen model reproduces all predicted low-temperature thermodynamic properties of diamond [1] at pressures up to 1 TPa, including the region of its negative thermal expansion.

[1] J. Xie, S. P. Chen, J. S. Tse, S. de Gironcoli and S. Baroni, Phys.Rev., 60, 9444 (1999).
[2] L. A. Girifalco, Statistical Mechanics of Solids, Oxford University Press, 2000, 544 P.

I04 HIGH-PRESSURE SYNTHESIS OF SUPERHYDRIDES

Alexander F. Goncharov
Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C. 20015, USA
agoncharov@carnegiescience.edu

Hydrogen-rich alloys are proposed to facilitate realization of metallic hydrogen at high pressures due to a chemical precompression undergone by hydrogen in such compounds [1]. However, the effect of structure and chemical composition on the formation and properties of such materials remain purely understood. In this work, I will present synthesis and properties of hydrogen–rich alloys (superhydrides) which become thermodynamically stable at high pressures. I will review a number of our recent studies of structure, optical and vibrational properties of hydride with various compositions (of noble gases, chalcogens, simple molecules, and metals). These materials revealed a wide range of metastability holding a promise for synthesis of materials with unique physical and chemical properties for a variety of applications [2-4]. This investigation has a direct relevance for planetary interiors as the compounds synthesized in this study can exist as alternative planetary ices or mantle/core minerals. I thank S. Lobanov, M. Somayazulu, A. R. Oganov, V. V. Struzhkin, D.-Y. Kim, E. Stavrou, N. Holtgrewe, Cheng Ji, S. Jiang, X.-J. Chen, V. Prakapenka, Z. Konopkova for contributing greatly to this work.

1. N. W. Ashcroft, Phys. Rev. Lett. 92, 187002 (2004).
2. A. F. Goncharov, et al., J. Chem. Phys.142, 214308 (2015).
3. A. F. Goncharov, et al., Phys. Rev. B 93, 174105 (2016).
4. V. V. Struzhkin et al., Nat. Commun., in press; cond-mat., arXiv:1412.1542

I05 NEW HIGH PRESSURE LAYERED PHASES OF CS2 AND SiS2

Roman Martoňák[1], S. Shahab Naghavi[2,4], Dušan Plašienka[1], Yanier Crespo[5], and Erio Tosatti[2,3,5]
1Department of Experimental Physics, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Bratislava, Slovakia, 2International School for Advanced Studies, Trieste, Italy, 3CNR-IOM Democritos National Simulation Center, Trieste, Italy, 4Department of Materials Science and Engineering, Northwestern University, Evanston, Illinois, USA, 5International Centre for Theoretical Physics, Trieste, Italy
martonak@fmph.uniba.sk

CS_2 and SiS_2 belong to the important family of IV–VI AB_2 compounds made of light elements which includes archetypal systems such as CO_2 and SiO_2. In solid CS_2 a series of structural transitions was observed at high pressure upon compression of the Cmca molecular crystal, eventually resulting in a disordered tetrahedral structure [1] which did not allow an accurate structural determination. We applied an ab initio evolutionary search [2] and found a new layered tetrahedral $P2_1/c$ structure, of especially high stability, and characterized by pairs of edge-sharing tetrahedra [3]. Unlike tetrahedrally coordinated CO_2 phases, this structure undergoes a semiconductor-metal transition at the relatively low pressure of 30-50 GPa [3], a transition which is in agreement with experiment [1]. This layered structure appears to be a likely candidate for the phase found experimentally above 30 GPa in Ref. [1]. With that in mind we suggest that by applying high pressure at low temperature one could perhaps prepare this phase with higher crystallinity thus allowing for better structural comparisons with our prediction, and to this end we calculated the Raman and IR spectra of the new phase. Wondering moreover whether similar phases could appear in different compounds of the same family, we extended our interest to SiS_2. Strikingly, the very same $P2_1/c$ layered structure which we predicted for CS_2 turned out to be recently observed (and named HP1) in SiS_2 [4], a finding which points to a new link in the high-pressure crystal chemistry of this family of compounds. Actually, the high-pressure phase diagram of SiS_2 is currently known only up to cca 6 GPa, featuring several tetrahedrally coordinated phases (NP, HP1, HP2, HP3), but nothing seems to be known about the structural and electronic evolution of SiS_2 at higher pressures. By means of ab initio calculations combined with evolutionary structure searching [5] we now predict three new low-enthalpy phases of SiS_2 with space groups $P\text{-}3m1$, $P6_3mc$ and $R\text{-}3m$ [6]. In all three phases, the Si coordination has switched from 4 to 6 and, interestingly, all these new structures are layered, consisting of sheets formed by edge-sharing octahedra (SiS_6 units). The most stable *P-3m1* phase (with a single SiS_2 layer per unit cell) is isostructural to CdI_2, where all sheets are directly above each other. It becomes stable above 6 GPa and at low pressures is semiconducting with an indirect band gap. The gap closes with increasing pressure leading to metallization around 30 GPa. New high pressure measurements will be called for to address these predictions. Facile sliding of these high pressure layered structures should also be of interest.

[1] R. P. Dias, C.-S. Yoo, M. Kim, J. S. Tse, Phys. Rev. B 84, 144104 (2011)
[2] A. Oganov , C. Glass, J. Chem. Phys. 124, 244704 (2006).
[3] S. S. Naghavi, Y. Crespo, R. Martoňák, E. Tosatti, Phys. Rev. B 91, 224108 (2015)
[4] J. Evers, P. Mayer, et al., Inorg. Chem. 54, 1240 (2015).
[5] D. Lonie, E. Zurek, Comput. Phys. Commun. 182, 372 (2011)
[6] D. Plašienka, R. Martoňák, E. Tosatti, in preparation.

C01 MELTING LINE PARAMETERS AND THERMODYNAMIC PROPERTIES OF METHANE AT HIGH PRESSURES

L.N. Yakub, E.S.Bodiul
V.S. Martynovsky Institute of Refrigeration, Cryotechnology and Energetics,
Odessa National Academy of Food Technologies, Ukraine
unive@icn.od.ua

Location of the methane fcc-phase melting line was predicted using two theoretical equations of state: for the solid and liquid phases. Equations of state for both phases were constructed in the framework of perturbation theory, in which the crystal (or liquid), build of spherical molecules, appears as a reference system, and the octupole - octupole interaction of methane molecules is a perturbation.

Helmholtz free energy of the reference system crystal was evaluated using canonical equation of state [1], based on the generalization of the Mayer's group expansion on solids, proposed in [2], and the equation of state for the liquid phase was based on the thermodynamic perturbation theory, developed for molecular liquids [3].

Orthobaric volumes and caloric properties of coexisting phases are calculated and compared with the limited experimental data available. The contributions of the octupole - octupole interaction to different thermodynamic properties of solid and liquid methane are estimated and discussed.

[1] L. Yakub, Int. Journ. Thermophys. 35, 1957 (2014).
[2] L. Yakub and E. Yakub. Journ. Chem. Phys. 136, 144508 (2012).
[3] M. S. Ananth, K.E.Gubbins and C.G. Gray. Molec. Phys., 28, 1005 (1974).

I06 HIGH TEMPERATURE SUPERCONDUCTIVITY IN HYDROGEN-RICH MATERIALS

Mikhail Eremets, Alexander Drozdov
Max Planck Institute of Chemistry, Mainz, Germany
m.eremets@mpic.de

Superconductivity with Tc>200 K has been found in hydrogen sulfide at high pressures [1]. The superconductivity has been proved by observation of zero resistance, Meissner effect, and isotope effect. X-ray diffraction studies [2] confirm predicted cubic structure of the superconductive phases. Fig. 1 summarizes the pressure dependence of superconducting temperature for hydrogen sulfide and its isotope deuterium sulfide. Apparently this pressure dependence reflects two phases with different pressure dependences. The determined cubic structure of these high Tc phases is in a good agreement with the R3m and *Im3m* structure predicted for $(H_2S)_2H_2$ [3]. We will present also recent results on further study of the superconductivity by different methods and compare the experimental results with available numerous theoretical calculations.

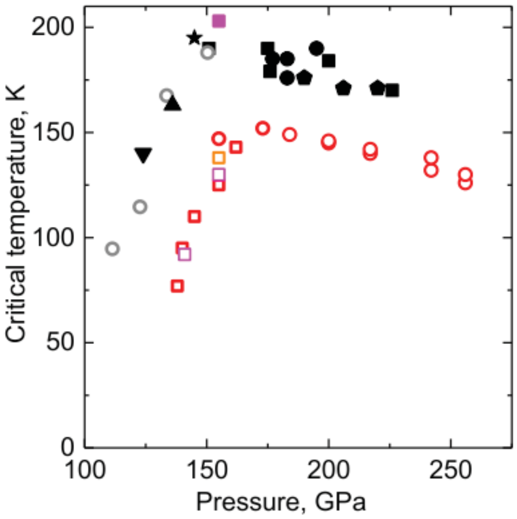


Figure 1: The pressure dependence of the critical temperature of superconductive transition for hydrogen sulfide (black points) and deuterium sulfide (red points) derived from electrical measurements. Magenta points are obtained from the magnetic susceptibility measurements in SQUID.

[1] Drozdov A.P., et al. Conventional superconductivity at 203 K at high pressures. Nature. 525: p. 73-77 (2015).
[2] Einaga M., et al. Crystal Structure of 200 K-Superconducting Phase of Sulfur Hydride. Nature Physics, (2016).
[3] Duan D., et al. Pressure-induced metallization of dense (H2S)2H2 with high-Tc superconductivity. Sci. Reports 4, p. 6968 (2014).

I07 HIGH PRESSURE NEUTRON DIFFRACTION STUDIES ON SOLID OXYGEN

Stefan Klotz[1], Th. Strässle[2], Th. Hansen[3], M. Bartkowiak[2], V. Pomjakushin[2]
1IMPMC, Université P&M Curie, 4 Place Jussieu, 75252 Paris, France, 2Paul Scherrer Institut, 5232 Villigen PSI, Switzerland, 3Institut Laue Langevin, Avenue des Martyrs, 38042 Grenoble, France
e-mail: Stefan.Klotz@impmc.upmc.fr

Oxygen is the only elemental molecule which carries a magnetic moment. In this contribution we will present neutron diffraction data on solid oxygen under high pressure up to 8 GPa which address the crystal and magnetic structure of α–, β– and δ-O_2 which are stable in this pressure range, between 0 and 300 K [1-3]. In particular I will show unpublished data on the magnetic phases found in δ-O_2, the pressure dependence of the short-range order in β–O_2, as well as the highly unusual thermal expansion of these phase at ambient pressure, all determined by neutron diffraction. The question on possible magnetic ordering/correlations in ε-O_2 will be addressed.

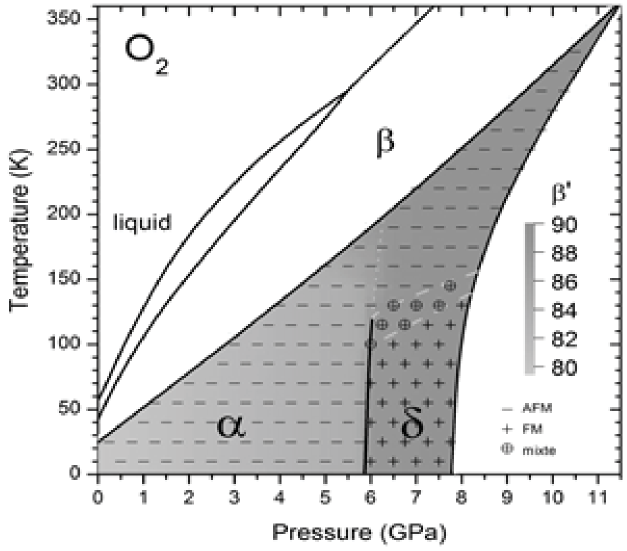


Figure: Phase diagram of oxygen, showing type of magnetic inter-layer coupling (+,-, ⊕) in α– and δ-O_2, as well as distortion angle β' [3].

[1] S. Klotz, Th. Strässle, A. Cornelius, J. Philippe, Th. Hansen, Phys. Rev. Lett. 104, 115501 (2010).
[2] S. Klotz, Th. Strässle, Th. Hansen, Notizario Neutroni e Luce Sincrotrone 17, 10 (2012).
[3] S. Klotz et al., unpublished

I08 QUANTUM GRAVITATIONAL SPECTROSCOPY

Valery Nesvizhevsky [1*], GRANIT and GBAR collaborations
1Institut Max von Laue – Paul Langevin, 71 avenue des Martyrs, Grenoble, France
nesvizhevsky@ill.eu

Quantum gravitational spectroscopy with ultracold systems is an emerging field based on recent major experimental and theoretical advances. Gravitational spectroscopy profits from exceptional sensitivity due to the extreme weakness of gravitation compared to other fundamental interactions; thus, it provides an access to the precision frontier in particle physics and other domains. Quantum gravitational spectroscopy is its ultimate limit addressing the most fragile and sensitive quantum states of ultracold particles and systems. Ultracold particles – neutrons, atoms, and antiatoms – with sufficiently high phase-space density are the condition for providing observable phenomena with gravitational quantum states. Some of such studies, like those with ultracold neutrons, have become reality [12]; others with ultracold atoms and antiatoms are in preparation.

GRANIT is a projects pushing forward the precision and sensitivity of quantum gravitational spectroscopy with ultracold neutrons [1]. Quantum states of antihydrogen atoms in GBAR are the key for pushing the precision of measurements of gravitational properties of antimatter [2]. These domains were recently discussed at GRANIT workshop and presented in a Special Issue [3]. They are analyzed in textbook [4]. Here we present status, recent advances in the field and closest prospects [5-11].

References
[1] D. Roulier, F. Vezzu, S. Baessler et al., Status of the GRANIT facility, Adv. High En. Phys. 730437 (2015).
[2] P. Perez, D. Banerijee, F. Biraben et al., The GBAR antimatter gravity experiment, Hyper. Inter. 233, 21 (2015).
[3] I. Antoniadis, S. Baessler, V.V. Nesvizhevsky, and G. Pignol, Quantum gravitational spectroscopy, Adv. High En. Phys. 467409 (2015).
[4] V.V. Nesvizhevsky, and A.Yu. Voronin, Surprising Quantum Bounces (Imperial College Press, London, UK, 2015).
[5] S. Baessler, V.V. Nesvizhevsky, G. Pignol et al., Frequency shifts in gravitational resonance spectroscopy, Phys. Rev. D 91, 042006 (2015).
[6] G. Pignol, S. Baessler, V.V. Nesvizhevsky et al., Gravitational resonance spectroscopy with an oscillating magnetic field gradient in the GRANIT flow-through arrangement, Adv. High En. Phys. 628125 (2015).
[7] M. Escobar, F. Lamy, A.E. Meyerovich et al., Rough mirror as a quantum state selector: analysis and design, Adv. High En. Phys. 764182 (2015).
[8] G. Dufour, A. Gerardin, R. Guerout et al., Quantum reflection of antihydrogen from the Casimir potential above matter slabs, Phys. Rev. A 87, 012901 (2013).
[9] G. Dufour, A. Gerardin, A. Lambrecht et al., Quantum reflection of antihydrogen from nanoporous media, Phys. Rev. A 87, 022506 (2013).
[10] G. Dufour, P. Debu, A. Lambrecht et al., Shaping the distribution of vertical velocities of antihydrogen in GBAR, Europ. Phys. J. C 74, 2731 (2014).
[11] A.Yu. Voronin, V.V. Nesvizhevsky, O.D. Dalkarov et al., Resonance spectroscopy of gravitational states of antihydrogen, Hyper. Inter. 228, 133 (2014).
[12] V.V. Nesvizhevsky, H.G. Boerner, A.K. Petukhov et al., Quantum states of neutrons in the Earth's gravitational field, Nature 415, 297 (2002).

C02 MAGNETIC RESONANCE STUDY OF ATOMIC HYDROGEN AND TRITIUM STABILIZED IN SOLID TRITIUM MATRICES BELOW 1K

S.Sheludiakov[1], J.Ahokas[1], J.Järvinen[1], O.Vainio[1], L.Lehtonen[1], D.Zvezdov[1,2], S.Vasiliev[1], D.M.Lee[3] and V.V.Khmelenko[3],
1 Department of Physics and Astronomy, University of Turku, 20014 Turku, Finland, 2 Institute of Physics, Kazan Federal University, 18 Kremlyovskaya St., Kazan, Russia, 3 Department of Physics and Astronomy, Texas A&M University, College Station, TX, 77843, USA
seshel@utu.fi

Solid hydrogen isotopes are the simplest and the most interesting among the quantum solids. Light atomic impurities stabilized in matrices of solid hydrogens are delocalized and able to diffuse through the lattice. It might be expected that accumulating unpaired hydrogen atoms in such matrices to high concentrations may lead to a number of fascinating phenomena related to quantum degeneracy or emergence of a strong exchange interaction between electron clouds of atoms with a possibility of impurity-driven conductivity. It turned out that adding a certain amount of β-radioactive tritium to the gas mixture before deposition provides the way of obtaining the highest atomic concentrations compared to other methods. The main purpose of this work was to examine the opportunity of reaching the maximum possible concentrations of T and H atoms in T_2 and T_2:H_2 matrices where a large fraction of T atoms can be converted into H during the course of the isotopic exchange reactions $T+H_2=HT+H$ and $T+HT=T_2+H$.

We create high concentrations of T and H atoms by storing 50-500nm pure normal T2 and T_2:H_2 mixture films at temperatures down to 70mK where unpaired atoms are generated by electrons released in disintegration of tritium. The main investigation tools are a 128GHz ESR spectrometer and a quartz-crystal microbalance (QM). The ESR resonator has an open design of a Fabry-Perot type and the QM's top electrode also works as its bottom mirror [1].

We report on reaching the average concentration of tritium atoms in pure T_2 films approaching $2x10^{20}cm^{-3}$. A record-high concentration of atomic hydrogen, $1x10^{20}cm^{-3}$, was achieved by storing a T_2:40%H_2 mixture film where a fraction of T atoms became converted into H due to the isotopic exchange reaction $T+H_2=TH+H$. The maximum concentrations of H and T atoms were limited by their recombination which was enforced by tritium disintegration. Depending on the storage conditions recombination also appeared in an explosive manner: both being stimulated and spontaneously and led to a partial sublimation of tritium films. The threshold concentrations of H and T atoms for explosive recombination were found to be dependent both on the film thickness and storage temperature.

[1] Sheludiakov et al. Rev.Sci.Instrum. 85, 053902 (2014)

I09 SUPERSIZED MOLECULES OF HELIUM AND MOLECULES IN SUPERFLUID HELIUM

J. Peter Toennies
Max Plank-Institute for Dynamics and Self-Organization, Am Fassber 17, 37077 Göttingen, Germany, jtoenni@gwdg.de

The cryocrystals community is certainly well familiar with the wonderous properties of bulk superfluid helium. In my talk I would like to call attention to the equally fascinating properties of small molecules of helium. These have been produced in low temperature molecular beams and isolated by Matter-Wave diffraction. Their remarkable size also results from the unique inertness, small mass and Boson character of helium atoms.

The unusually sharp velocity distributions of $\Delta v/v \sim 10^{-2}$ of highly expanded He beams at ultralow gas temperatures of 10^{-3} K were the first evidence that the helium gas was unique. The effect was explained by the enormous size of the T→0 K cross section of 1590 nm^2. Later the weakly bound dimer could be isolated in the beam of atoms by Matter-Wave diffraction from a transmission nanograting. It was found to be a halo molecule with an average bond distance of 5.2 nm (H2: 0.075 nm) making it the largest naturally occurring gas phase diatomic molecule.[1] Since 1970 there has been a long search for an extremely weakly bound system with an increasing number of bound states as the interaction gets weaker predicted by Vitali Efimov. By combining Matter-Wave diffraction with laser Coloumb explosive dissociation it has recently been detected and found to have an average bond distance of greater than 10.0 nm.[2]

Since about 1990 the spectroscopy of molecules embedded in 10^{-3} – 10^{-4} atom (0.37 K) droplets have revealed unexpected sharp rotational and electronic line spectra with surprisingly small line shifts and negligible broadening. Several experiments and theories have suggested that these remarkable features are due to the superfluidity of the droplets.[3] Only recently, however, has the first evidence for a Landau critical velocity in droplets with 10^3 – 10^7 atoms been published and provides the first solid evidence for superfluidity as known in the bulk.[4]

Another recent experiment in which the embedded molecules have been impulsively excited into a recurring quantum state have revealed an unexpected quenching not found for the free molecules, despite the free rotations observed in the spectra.[5] This experiment still challenges interpretation.

At the end of my talk I will briefly review several new experiments on large biomolecules made possible by encapsulating them in ultra-cold droplets.

[1] J. P. Toennies, Mol. Phys. 111, 1879 (2013); [2] M. Kunitzki et al., Science 348, 551 (2015); [3] J. P. Toennies and A. F. Vilesov, Angew. Chem. Int. Edit. 43, 2622 (2004); [4] N. B. Brauer et al., Phys. Rev. Lett. 111, 153002 (2013); [5] D. Pentlehner et al. Phys. Rev. Lett. 110, 093002 (2013)

I10 X-RAY COHERENT DIFFRACTIVE IMAGING OF QUANTUM VORTICES IN HELIUM DROPLETS

Andrey Vilesov
University of Southern California, USA
vilesov@usc.edu

Helium nanodroplets have long been considered ideal model systems to explore quantum hydrodynamics in self-contained, isolated superfluids. However, the dynamic properties of individual droplets, such as vorticity, remained beyond the reach of experimentalists. Here, we investigate the rotation of single, superfluid 4He droplets (D=200-2000 nm) via single-shot femtosecond X-ray coherent diffractive imaging [1]. As indicated by large centrifugal deformations, the droplets' angular velocities span a range from vanishing to those close to the disintegration limit. The shapes of rotating viscous and superfluid droplets are compared. The formation of quantum vortex lattices inside the droplets is confirmed by observing characteristic Bragg patterns from Xe clusters trapped in the vortex cores. The vortex densities are up to five orders of magnitude larger than observed in bulk liquid He, accessing a previously unattainable regime of quantum rotation. The images of the vortex filaments in the droplets were obtained from the diffraction images via phase retrieval techniques [2]. Excessive doping by Xe changes equilibrium arrangement of vortices in the droplet and leads to stabilization of widely spaced configurations [3]. Evidence for non-stationary vortex dynamics comes from observations of asymmetric formations of vortices in some droplets. This collaborative work was performed at Linac Coherent Light Source, the free electron laser within SLAC National Accelerator Laboratory.

[1] L. F. Gomez et al., Science 345, 906 (2014).
[2] R. M. P. Tanyag et al., Structural Dynamics 2, 051102 (2015).
[3] C. Jones et al., Phys. Rev. B. 93, 180510(R) (2016).

I11 THEORETICAL MODELING OF SUPERFLUID 4HE VISCOUS RESPONSE ON THE NANOMETER SCALE

Jussi Eloranta[1]
[1]*Department of Chemistry and Biochemistry, California State University, Northridge, CA, USA*
Jussi.Eloranta@csun.edu

The Orsay-Trento bosonic density functional theory (OT-DFT) model [1] is extended to include dissipation due to viscous response of finite temperature superfluid 4He on the nanometer scale. The viscous functional is derived from the Navier-Stokes equation by using the Madelung transformation and accounts for the possible liquid inhomogeneities that occur, for example, at gas-liquid interfaces (interfacial viscosity). The model was calibrated against the experimentally known electron bubble (diam. approx. 4 nm) mobilities along the saturated vapor pressure line between 1.2 and 2.1 K [2] where the liquid viscous response is dominated by thermal rotons. The temperature dependence of mobility for several different artificially created bubble sizes were calculated and the results are discussed in the context of the roton scattering and Stokes limited mobility models [3]. The calculated mobilities as a function of the bubble size can be compared with the experimentally observed “exotic ion” data [4], providing estimates for the corresponding bubble sizes in the liquid. Possible sources of such ions are briefly discussed. Finally, the OT-DFT model is also shown to reproduce the experimentally observed mobilities for snowball structures formed around Ca+ and Sr+ [5].

[1] F. Dalfovo, A. Lastri, L. Pricaupenko, S. Stringari, and J. Treiner, Phys. Rev. B, 52, 1193 (1995).
[2] R. J. Donnelly and C. F. Barenghi, J. Phys. Chem. Ref. Data, 27, 1217 (1998).
[3] A. F. Borghesani, Ions and electrons in liquid helium, Oxford Science Publications, Oxford (2007).
[4] W. Wei, Z. Xie, L. N. Cooper, G. M. Seidel, and H. J. Maris, J. Low Temp. Phys., 178, 78 (2015).
[5] W. I. Glaberson and W. W. Johnson, J. Low Temp. Phys., 20, 313 (1973).

I12 NON-ISOTHERMAL KINETICS OF PHYSICO-CHEMICAL PROCESSES IN SUPERFLUID HELIUM

Eugene B. Gordon
Institute of Problems of Chemical Physics, Russia
Gordon.eb@gmail.com

Superfluid helium (He II) was considered (and is commonly considered) as the simplest matrix for carrying out chemical reactions. As a quantum liquid it should represent a smooth homogeneous media where guest particles may freely diffuse to each other at any temperature. At every collision they have to immediately stick together. Because ultra-high thermal conductivity of He II all processes was thought to proceed isothermally there. In particular, the particles should stick together forming a loose structure.

However it was clearly shown [1] that for the quest particles suspended in He II the last is far from being homogeneous. The quasi-1D quantized vortices ever existed in the superfluid tried to capture any impurity into their core, so that the whole process of condensation occurs predominantly within the vortices, giving long thin nanowires as the products [2-4]. Our further studies have shown that (fortunately for applications), these physico-chemical processes are in no way isothermal. The theoretical basis for this conclusion is the fact that intensive heat flow nucleates turbulence, locking the laminar flow of the normal component that responsible for enormously high thermal conductivity of He II. For the objects larger than one micron this threshold heat flow is about 3 W/cm2 [5]. Such a value is still unknown in nanoscale, but it is worth noting that to prevent melting at the fusion of two cold metallic 1 nm balls, the huge rate of heat removal (> 105 W/cm2) is required [6].

Experimentally, the allegation that the coagulation of the metal nanoparticles in He II leads to a molten product, then acquiring due to the surface tension a spherical shape, were based on the following: (i) the metal atom close-packing in nanowires, (ii) "large" compared to the vortex core thickness of wires, and (iii) the presence among the products of balls with the ideal shape and atomically smooth surface [7]. Recent analysis shows that experimental diameters of nanowires for all investigated metals perfectly fit the predictions of the model, which describes the coagulation through melting [8].

However, direct evidence of melting during the coagulation represents the results of our recent experiments on the detection of thermal radiation accompanying metal condensation in the He II. Experiments with W, Mo, Pt and In ablation displayed a direct correlation between the radiation intensity and the melting temperature of metals under study. The process of metal condensation and the extremely interesting process of molten nanoparticles cooling in He II were investigated as well.

[1] E. B. Gordon, R. Nishida, R. Nomura and Y. Okuda, JETP Lett., 85, 581 (2007)
[2] E. B. Gordon and Y. Okuda, Low Temp. Phys., 35, 209 (2009).
[3] E. B. Gordon, A. V. Karabulin, et al, Low Temp. Phys., 36, 590 (2010).
[4] P. Moroshkin, V. Lebedev, et al, EPL, , 90, 34002 (2010).
[5] S.W. Van Sciver, Cryogenics, 19, 385 (1979).
[6] E. B. Gordon, A. V. Karabulin, et al, J. Exp. Theor. Phys., , 112, 1061 (2011).
[7] E.B. Gordon, A.V. Karabulin, et al, High Energy Chemistry, , 48(3), 206 (2014).
[8] E.B. Gordon, JLTP, submitted (2016)

C03 THE CREATION OF LONG-LIVED MULTIELECTRON BUBBLES IN SUPERFLUID HELIUM

Jieping Fang[1], Jacques Tempere[1,2], and Isaac F. Silvera[1],
1 Lyman Laboratory of Physics, Harvard University, Cambridge MA 02138, USA
2 TQC, Departement Fysica, Universiteit Antwerpen, Universiteitsplein 1, B2610 Antwerpen, Belgium
silvera@physics.harvard.edu

Multielectron bubbles (MEBs) in liquid helium were first observed in the late 1970s by Volodin, Khaikin, and Edel'man[1] and analyzed by Shikin[2]. Their equilibrium properties have never been explored experimentally due to their short lifetimes. In comparison to magnetically trapped neutral atoms, an MEB is a quantum gas of charged fermions, electrons, confined in a bubble. In liquid helium it is a spherical cavity containing electrons in a nanometer thin layer on the inner helium surface to form a two-dimensional electron gas (2DEG) on a three-dimensional surface. MEBs have been predicted to have a number of exciting low-temperature properties including Wigner crystallization, quantum melting, superconductivity, electron localization by new mechanisms (ripplo-polaron lattice), unusual quantum Hall states, etc., reviewed elsewhere[3]. MEBs in liquid helium are predicted to have dynamic instabilities for zero or positive pressures, and stability for negative pressures. We report the production of long-lived MEBs in a novel cell filled with superfluid helium at static negative pressures. MEBs were extracted from the vapor sheath of a heated filament loop embedded in the superfluid helium and were observed by high-speed photography as they rose in the helium under buoyant forces. These MEBs can be captured in an electromagnetic trap by straightforward means for study.

Partial support for this research was provided by a grant from Alby and Kim Silvera. JT received support from the Fund for Scientific Research – Flanders, FWO projects G.0115.12N, G.0119.12N, G.0122.12N, G.0429.15N and by the Scientific Research Network of the Research Foundation-Flanders, WO.033.09N.

[1] A. P. Volodin, M. S. Khaikin, and V. S. Edel'man, JETP Lett. 26, 543 (1978).
[2] V. B. Shikin, JETP Lett. 27, 39 (1978).
[3] J. Tempere, I. F. Silvera, and J. T. Devreese, Surface Science Reports 62, 159 (2007).

C04 METAL NANOWIRES AND MESOSCOPIC NETWORKS AT A FREE SURFACE OF SUPERFLUID HELIUM

P. Moroshkin[1], K. Kono[1,2,3], P. Leiderer[4]
1 RIKEN CEMS, Japan, 2 NCTU, Taiwan, 3K FU, Russia, 4 University of Konstanz, Germany
Petr.moroshkin@riken.jp

Laser ablation of various metals in bulk superfluid He leads to the formation of metallic nanowires and large networks [1]. Similar aggregates have been also found in doped He microdroplets [2]. The current interest to this phenomenon is driven by two considerations: the properties of these nanowires may differ strongly from those of the nanowires obtained by more conventional methods; it is expected that the study of the nanowire formation may provide new insights into the physics of quantum fluids.

We report the results of a new experimental study of nanowires and mesoscopic networks formed at the free surface of superfluid He at T = 1.4 K, in the presence of a vertical static electric field. The dopants (Cu, Ba) are introduced into superfluid He from the gas phase. The surface of the superfluid acts as a trap for metallic particles of various sizes and thus greatly enhances their coalescence into one-dimensional and two-dimensional structures. The resulting filaments and networks are observed in situ and collected for a subsequent scanning electron microscope (SEM) study at a room temperature. Sub-micron metallic particles are visualized by using laser light scattering and their motion is monitored in real time by a fast video camera. Typical image of a large Ba network floating at the liquid He surface is shown in Fig. 1 (a) and a SEM image of a part of a similar Cu network is shown in Fig.1 (b). The SEM analysis confirms that the mesoscopic networks and filaments are composed of a very large number of nanowires with a characteristic diameter of 10 nm and extremely large aspect ratios.

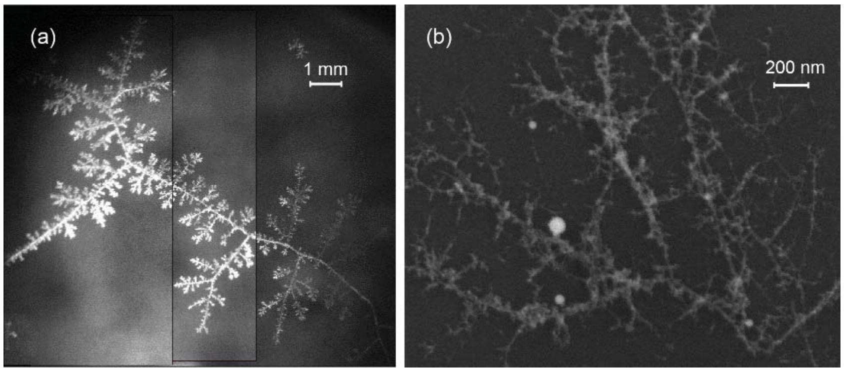


Fig1. a) photograph of a Ba network floating at the free surface of superfluid He; b) SEM image of a part of a Cu network formed at the free surface of superfluid He and collected after the experiment.

Although the nanowire nucleation cannot be captured by our methods, our observations demonstrate that the networks are formed by connecting individual particles and filaments trapped at the helium surface. The coalescence process is strongly influenced by the electric charges generated by the laser ablation above the liquid and driven towards the liquid surface by the static electric field. We observe a shuttle-like motion of metallic particles of various sizes carrying electric charge between the free surface of the liquid and the electrode at the bottom of the sample cell. We suggest that these particles serve as building blocks for the mesoscopic filaments and networks.

[1] P. Moroshkin et al., Europhys. Lett., 90, 34002 (2011).
[2] L. F. Gomez, E. Loginov, A. F. Vilesov, Phys. Rev. Lett., 108, 155302 (2012).

C05 EXPERIMETAL OBSERVATION OF THE DECAY INSTABILITY OF GRAVITY-CAPILLARY WAVE ON THE SURFACE OF LIQUID HYDROGEN

M. Yu. Brazhnikov, A. A. Levchenko, L. P. Mezhov-Deglin, I. A. Remizov
Institute of Solid State Physics RAS, Russia
makc@issp.ac.ru

The decay instability of monochromatic wave, i.e. instability of wave in respect to decay on two other waves, is a general property of nonlinear systems in which three-wave interaction processes are allowed [1]. The decay of the wave on two other waves along with the inverse process of nonlinear interaction of two waves generating the third wave are responsible for the redistribution of energy among waves in a turbulent regime. Here we report the results of experimental studies of the decay instability of gravity-capillary waves on the charged surface of liquid hydrogen.

Hydrogen was condensed into a rectangular container placed on the bottom plate of a flat capacitor. Alternating voltage applied between the plates of capacitor was used to excite resonant modes of the surface oscillation of liquid hydrogen in the container in a frequency range of 14 – 30 Hz. Waves were detected by measuring the intensity of the laser beam reflected from the oscillating surface. Due to nonlinearity the wave on the driving frequency produces a direct cascade consisting of high-order harmonics. For some of the resonant modes besides direct cascade a pair of incommensurable subharmonics appear in the spectrum of the surface oscillations when the driving amplitude is high enough. In the beginning of the growth the amplitudes of the subharmonics rise exponentially with time. Using the experimentally obtained values for increment of decay instability and decrement of viscous damping of the gravity-capillary waves on the surface of liquid hydrogen we have estimated the coefficient of nonlinear interaction for three-wave process.

[1] V. E. Zakharov, V. S. L'vov, G. Falkovich, Kolmogorov Spectra of Turbulence I, Springer-Verlag, Berlin (1992).

C06 THERMAL TRANSPORT IN HIGHLY ANISOTROPIC ORIENTATIONAL GLASS-FORMERS

Daria Szewczyk[1], Andrzej Jeżowski[1], Josep Ll. Tamarit[2], Alexander I. Krivchikov[3]
1Institute of Low Temperature and Structure Research PAS, Poland, 2ETSEIB Universitat Politecnica de Catalunya, Spain, 3B. Verkin Institute for Low Temperature and Engineering NAS of Ukraine, Ukraine
d.szewczyk@int.pan.wroc.pl

In contrast to structural glasses, which display both positional and orientational disorder, in orientational glasses the disorder involves exclusively the orientational degrees of freedom of the molecules, while the molecular centers of mass form an ordered lattice. The objects of our studies are glass-forming systems with even less degrees of freedom, namely the orientationally disordered (OD) phases of a dipolar benzene derivatives, pentachloronitrobenzene ($C_6Cl_5NO_2$) and 1-chloro 4-nitrobenzene ($C_6H_4ClNO_2$) .

We investigate thermal conductivity as well as heat capacity of PCNB and 1Cl4NB as a function of temperature and thermal annealing in the vicinity of the transition points. The literature reported glass transition for those molecular crystals are marked at 187 K and 245 K respectively [1,2].

The results of thermal conductivity of PCNB exhibit a temperature dependency characteristic for amorphous materials. One can no detect any disturbances around the expected phase transition point. After long annealing at higher temperatures the thermal conductivity values have risen about 10%, but the character of the sample remained the same. Also it was possible to observe a slight drop of κ above 175K, following a further increase. The 1Cl4NB samples exhibited a much stronger phenomena. First probe was to check the thermal conductivity on heating. The character like previously was amorphous type, but at about 225 K a sharp jump in κ occurred. It was followed by a sudden drop of conductivity value at 245 K, which is marked as a glass transition. Afterwards sample was annealed and an another measurement took place. Second curve display an entirely distinct character, namely the temperature dependency of κ resembles a dielectric crystal with a maximum at 15 K, exceeding 3.3 $Wm^{-1}K^{-1}$.

Heat capacities of the ordered and disordered crystalline phases of PCNB and 1Cl4NB were measured with Physical Property Measurement System between 1.8 K and 250 K. For PCNB heat capacity was measured on heating, a bulge was observed at 176K, lower than previously reported. To confirm the anomaly as a glass transition sample was kept the "bulge point", at 170K for 13h. It resulted in substantial narrowing and sharpening of the meniscus. Implied by the research of K. Saito et al. [3] on 1Cl4NB we have carried out two separate measurements. First, after fast cooling, heat capacity values were determined on heating up to 250K, then was subjected to annealing at 260K for 72h. The heat capacity of the disordered state exceeds over five times that of the ordered phase at lowest investigated temperatures and maintains a higher value for the whole temperature range. There is no hump for the disordered phase, when presented in Cp/T3.Only a subtle change in the 230K region is observed, which may be influenced by the upcoming glass transition.

The detailed analysis of the influence of the type of disorder on thermal transport will be carried out in terms of phonon scattering mechanisms.

[1] Z.C. Tan, Y. Nakazawa, K. Saito, M. Sorai, Bull.Chem. Soc. Jpn., 74, 1221 (2001)
[2] Y. Tozuka, Y.Yamamura, K. Saito, M. Sorai, J. of Chem. Phys, 112, 2356 (2000)
[3] K. Saito, H. Kobayashi,Y. Miyazaki, M. Sorai, Sol. Sta. Comm., 118, 611 (2001)

C07 PURIFICATION AND EXTRACTION OF RARE GASES BY FREEZE OUT METHOD

Bondarenko V. L.[1], Symonenko Iu. M.[2], Chigrin A. A.[3]
1Bauman Moscow State Technical University, Russia, 2Institute of Refrigeration, Cryotechnology and Ecoenergetics n.a. V.S. Martynovsky, Ukraine, 3Cryoin Ingineering, LTD, Ukraine
artemon_2006@mail.ru

In the coming decade there is expected a steady growth in the global consumption of rare gases. Plants with relatively low productivity join a list of suppliers of krypton-xenon concentrate. Under these conditions, operation of large plants for the enrichment of Kr and Xe mixture is not always justified.

We have developed alternative methods of krypton and xenon enrichment from a poor mixture directly in the places of its extraction. We have created a cryogenic freezer Xe, which allows using a product with xenon content of less than 0.02% as initial feedstock. We get xenon with no less than 99.5% purity at the outlet of the unit.

Freezeout (desublimation) is used in the technologies of rare gases extraction, along with adsorption and condensation methods for separating mixtures. Similar to the adsorption, this method is cyclical and requires energy for periodic cooling of the unit up to operating temperatures TC. TC level is selected in such a way as to provide selective absorption of a valuable product (or impurities). Separation of an individual component occurs when the partial pressure of this component in the mixture is above the phase transition pressure of the substance.

By way of example, let us consider the use of a freezer for extracting xenon from the low-potential flows. Such mixtures are obtained in air separation plants equipped with krypton columns. Kr-Xe concentrate has more than 98% oxygen. Other components include: nitrogen ≈ 1.5%; methane 0.2 ... 0.3%; krypton <0.2% xenon and <0.02%. A major obstacle to the processing of the mixture is the threat of liquefaction of oxygen. For this reason, when using N_2 as a refrigerant (Tc = 78 K), the operating pressure maintained in the freezer is at the level of $P_{\Sigma} \leq 22$ kPa.

At these operating parameters the first four mixture components (O_2, N_2, CH_4 and Kr) remain in a gaseous state. They leave the apparatus, practically, without changing their concentration. Only xenon at 85 K reaches the crystallization conditions. In the process of transition to the solid state, the partial pressure of Xe in the mixture and the equilibrium temperature are reduced. At the output at Tc = 78 K, not more than 16% of the initial content of xenon remains in the mixture. Thus, for the accepted conditions, for the degree of extraction of xenon is about 84%.

In addition to the named example, freezing out process, as an alternative to adsorption, finds application in the separation of neon helium mixture and helium purification. For obtaining 99.995% purity helium at $P_{\Sigma} = 0.2$ MPa, temperature TC = 13K is required. In many plants for processing gas concentrations, freezers are used for absorption of high-boiling impurities. Nitrogen vapors with temperature Tc = 100 ... 150K are used as a refrigerant. This method allows almost complete removal of moisture and CO2 from the mixture, which can adversely affect the performance of low-temperature separators.

During the testing of freezer prototypes, we studied the effect of frost on the temperature and the concentration of the effluent flow. To reduce thermal resistance between the refrigerant and the mixture, we used an effective finning of the channel on the gas stream side.

I13 SUPERSOLID STATES: WHERE DO WE FIND THEM?

Nikolay Prokof'ev
University of Massachusetts, Amherst, USA

I will review current theoretical understanding of how supersolid states can be formed and what conditions at the level of microscopic and macroscopic behavior they have to satisfy. I will start with the case of density waves in classical-field theories (first used by E. Gross), numerical simulations of the GPE equation, and supersolid droplet crystals observed by path-integral Monte Carlo for soft-core potentials. These results will we projected on current experiments with Rydberg atoms. An interesting exact prediction is that supersolid "bubble" phases have to exist in two-dimensional dipole systems in the vicinity of the liquid-solid phase transition line, but are very hard to observe. Next, I will discuss numerous theoretical evidence that perfect 4He crystals are not supersolid, and how crystal defects may bring back the superfluid response. Finally, I will mention crucial differences between the continuous space systems and atoms subject to the external periodic potential with respect to forming stable supersolid phases.

I14 DEFECT MOTION IN A QUANTUM SOLID WITH SPIN: HCP 3HE

John Beamish and Zhi Gang Cheng
University of Alberta, Canada

Tunneling can delocalize point defects in quantum solids, allowing vacancies and impurities to propagate freely, even at zero temperature. In isotopically pure hcp ^{4}He crystals, dislocation lines also move without dissipation at low temperatures. This greatly reduces the elastic shear modulus, an effect referred to as "giant plasticity". In crystals of the lighter isotope, ^{3}He, zero point motion is even larger but the atoms also have spin. Above a few mK, solid ^{3}He is paramagnetic and the spin interactions create a random potential which should prevent the ballistic propagation of point defects seen in solid ^{4}He. Gliding dislocations rearrange spins on a much larger scale, which should also affect their motion. We have made a detailed study of high purity hcp ^{3}He crystals using low frequency measurements of the elastic shear modulus and dissipation. Our experiments confirm that dislocations are mobile and reduce solid ^{3}He's shear modulus above 100 mK but are pinned by isotopic (^{4}He) impurities at low temperatures. In contrast to solid ^{4}He, hcp ^{3}He's shear modulus is essentially independent of frequency and does not show dissipation either from impurities moving with the dislocations or from scattering of thermal phonons. Instead, a large, non-activated dissipation appears at the lowest frequencies and the high temperature dissipation is roughly independent of frequency. These features indicate that ^{4}He impurities are not very mobile in hcp ^{3}He, and that a new dislocation damping mechanism associated with ^{3}He spins is important at low frequencies.

C08 MAGNETIC RESONANCE STUDY OF ATOMIC HYDROGEN ISOTOPES STABILIZED IN SOLID HYDROGEN MATRICES BELOW 1K

J. Ahokas[1], S. Sheludiakov[1], J. Järvinen[1], O. Vainio[1], L. Lehtonen[1], D. Zvezdov[1,2], S. Vasiliev[1], D.M. Lee[3] and V.V. Khmelenko[3]
1Department of Physics and Astronomy, University of Turku, 20014, Turku, Finland, 2Institute of Physics, Kazan Federal University, 18 Kremlyovskaya St., Kazan 42008, Russia, 3Department of Physics and Astronomy, Texas A&M University, College Station, TX, 77843, USA
jmiaho@utu.fi

Solid hydrogen isotopes represent a special class of so-called quantum crystals which are characterized by weak intermolecular interactions and large zero-point energy. Hydrogen and deuterium atoms stabilized in such solid matrices become delocalized in the lattice sites and diffuse in a series of exchange tunneling reactions: $H+H_2=H_2+H$ and $D+D_2=D_2+D$. Similar exchange reactions $D+H_2=HD+H$ and $D+HD=D_2+H$, involving both hydrogen isotopes may take place in D_2:H_2 (HD) mixtures and result in a spectacular conversion of atomic deuterium into hydrogen atoms, while T-to-H conversion can be expected in T_2-H_2 mixtures. Impurity atoms are not stable and recombine into molecules if encounter each other in neighboring lattice sites.

In our experiments thin films of molecular hydrogen (50-500nm) were deposited on a quartz crystal microbalance (QM) below 1K. The QM electrode works also as a flat mirror of 130 GHz ESR spectrometer enabling direct studies of the samples. High concentrations of atomic impurities in the range 1019 -1020 cm-3 were created by electron impact dissociation of the molecules. The electrons resulted from an rf discharge running close to the sample [1] or from the β-decay of tritium which was mixed to the sample gas before deposition. So far the highest densities have been reached in the T_2 samples, approaching $2*10^{20}$ cm^{-3} for T in T_2 and $1*10^{20}$ cm^{-3} for H in T_2:H_2 mixture.

For the first time we studied the isotopic exchange reactions in a temperature range 0.1-1.5K which appear to be the lowest temperature where chemical reactions have been observed in a solid phase so far. We measured the reaction rate of $D+HD=D_2+H$ in HD and D_2:0.23% HD matrices and found, that the rate of the reaction is nearly independent of temperature within this range. Our results suggest that atoms remain mobile in the temperature range, even though both H and D recombination is strongly inhibited at temperatures below 1K.

We observed that Dynamic Nuclear Polarization (DNP) of H atoms in D_2:H_2 (HD) mixtures can be created by both the Overhauser and Solid effects efficiently. In addition to that, nuclear spins of hydrogen atoms can be polarized by saturating the center of the ESR spectrum resembling Overhauser effect in metals, the effect which is absent for H atoms in pure H_2 samples [2]. We suggested that a large number of H radical pairs formed during the course of the isotopic exchange reactions, coupled by strong exchange interaction. The radical pairs may possess an allowed transition at the center of the ESR spectrum while D atoms help to create a strong enough oscillating field at the position of ESR pumping.

[1] S. Sheludiakov et al., Rev. Sci. Instrum, 85, 053902 (2014).
[2] S. Sheludiakov et al., arxiv.org/abs/1509.05588 (2015).
[3] S. Sheludiakov et al., Phys.Rev.Lett.,113, 265303 (2014).

I15 CRYSTALLIZATION WAVES IN ^{3}HE

I. Todoshchenko, A. Savin, M. Haataja, and P. J. Hakonen
Low Temperature Laboratory, Department of Applied Physics,
Aalto University, 00076 AALTO, Finland
todo@boojum.hut.fi

An interface between two media is a topologically stable system where the 3D symmetry is broken. This allows for the existence of exotic particles, for instance Majorana

fermion (a particle which is its own anti-particle) or anyon (particle which is neither boson nor fermion). It is also possible that the Universe is in fact an interface between media of larger dimensionality, which makes the investigation of surface excitations very interesting and intriguing.

Among various kinds of surfaces, most interesting are surfaces of (or between) different phases of helium which manifests superfluidity of at least three different types and has solid phases where point defects are delocalized. The most effective way to explore the excitations living on helium surfaces is to study surface waves. In addition to usual capillary waves, helium also supports phase waves, like a melting-freezing wave on the surface between solid and liquid phases.

Crystallization waves in ^{4}He have been predicted by Andreev and Parshin [1] and discovered by Keshishev et al. [2] at temperatures below 0.5 K. By measuring the spectrum of crystallization waves at crystal surfaces of different orientations, Rolley et al. have observed a singularity in the surface tension in the direction perpendicular to the basal facet [3,4]. This beautiful observation has fully confirmed the important theoretical concept of the elementary step on a crystal facet.

In ^{3}He crystallization wave is even more interesting object to study because it propagates on the surface of fermionic superfluid which may support exotic states discussed above. In addition, spin currents contribute to the inertia of this wave along with usual mass flow, and in high enough magnetic field the whole mass of the wave is of a magnetic origin. However, crystallization waves in ^{3}He are overdamped and could be observed only at temperatures below 0.5 mK. This sub mK temperature requirement sets strong limitations for the excitation of the waves because the capacitors utilized to drive the waves produce significant heat to the helium sample.

In our experiment we used a quartz tuning fork placed in the liquid close to the crystal surface. The change of the position of the solid-liquid interface resulted in the change of the mass of the liquid involved in the oscillations of the fork and, in turn, to the shift of the resonance frequency of the fork. Due to the high quality factor of the fork resonance we were able to detect the change of the surface position with the accuracy of one nanometer, which allowed us to apply relatively small drive to the capacitor. We were thus able to observe the first evidence of the crystallization waves on the surface between superfluid and solid phases of 3He at record-low temperature of 0.4 mK. The response of the crystal surface to the drive has been found to be faster than our time resolution of 5 ms.

[1] A. F. Andreev and A. Ya. Parshin, Sov. Phys. JETP 48, 763 (1978).
[2] K. O. Keshishev et al., JETP Lett. 30, 56 (1980).
[3] E. Rolley, S. Balibar, and F. Graner, Phys Rev. E 49, 1500 (1994).
[4] E. Rolley et al., J. Low Temp. Phys 99, 851 (1995).

C09 RADIATION EFFECTS IN SOLID NITROGEN

E. Savchenko[1], I. Khyzhniy[1], S. Uyutnov[1], M. Bludov[1], A. Barabashov[1], G. Gumenchuk[2] and V. Bondybey[2]
1Institute for Low Temperature Physics & Engineering NASU, Ukraine,
2Lehrstuhl für Physikalische Chemie II TUM, Germany
elena.savchenko@gmail.com

Radiation effects in model molecular cryocrystal – solid N_2, attract much attention in diverse fields such as material and surface sciences, physics and chemistry of interstellar and solar systems, particle physics. The intense current interest to nitrogen solids is also associated with the potential use of polynitrogen compounds as environment-friendly high energy density materials (HEDM). Radiation-induced processes in solid nitrogen and nitrogen-containing condensates were discussed principally in terms of neutral species reactions. The role of the charge states in the relaxation of excitations is just beginning to be studied. Only recently the hole self-trapping – formation of N_4^+, [1] and creation of N_3^+ [2] in electron-bombarded solid N_2 were found. Generation of negatively charged nitrogen species N_3^- [3] and N^- [4] was reported in the most recent studies.

Here we present new trends in the study of radiation effects in nitrogen solids with a focus on relaxation channels involving charge states. An electron beam of variable energy was used to excite N_2 solids and discriminate radiation-induced processes in the bulk and at the surface. Relaxation dynamics was monitored by cathodoluminescence (CL) and nonstationary luminescence (NsL), along with optical and current activation spectroscopy. Correlated in real time measurements of thermally stimulated luminescence (TSL) and exoelectron emission (TSEE) as well as optically stimulated luminescence (OSL) and exoelectron emission (OSEE) were performed. Desorption of excited atoms and molecules was monitored spectroscopically.

The dose behaviour of optical emissions observed over a wide spectral range indicates accumulation of radiation-induced defects. The entire complex of the experimental methods used enables us to detect both neutral and charged centers of both signs. An accumulation of N_3^+, N_3^-, N_4^+ and trapped electrons (up to 10^{16} cm^{-3}) as well as N and N_3 radicals is detected. The dissociative recombination (DR) reactions of N_4^+ and N_3^+ in solid N_2 are traced spectroscopically verifying the final products of the neutralization reactions. It is shown that the DR reactions underlie processes of defect formation and desorption. The experiments performed with a variable voltage applied to an electrode for TSEE current detection demonstrate significant accumulation of uncompensated negative charge. The part played by pre-existing and radiation-induced defects in charge stabilization and energy storage is discussed. Optical and thermal stability of the charge centers has been ascertained.

[1] E.V. Savchenko, I.V. Khyzhniy, S.A. Uyutnov, A.P. Barabashov, G.B. Gumenchuk, M.K. Beyer, A.N. Ponomaryov, and V.E. Bondybey, J. Phys. Chem. A 119, 2475 (2015).
[2] Y-J. Wu, H-F. Chen, S-J. Chuang, T-P. Huang, Astrophys. J. 768, 83 (2013).
[3] E. Savchenko, I. Khyzhniy, S. Uyutnov, M. Bludov, G. Gumenchuk and V. Bondybey, Radiat. Meas. 90C, 1 (2016).
[4] R.E. Boltnev, I.B. Bykhalo, I.N. Krushinskaya, A.A. Pelmenev, S. Mao, A. Meraki, P.T. McColgan, D.M. Lee and V.V. Khmelenko, PCCP, 18, 16013 (2016).

I16 CRYOEMISSION OF NITROUS OXIDE AND ETHANOL. DYNAMIC AND ENERGY CHARACTERISTICS.

A. Drobyshev[1], Yu. Strzhemechny[2], A. Aldiyarov[1], E. Korshikov[1], V. Kurnosov[1], D. Sokolov[1]
1Kazakh National University, Kazakhstan, 2Texas Christian University, United States of America
Andrei.drobyshev@kaznu.kz

Previously [1] we have found that cryodeposition of nitrous oxide at temperatures below 120 K is accompanied by the emission of light in the visible spectrum. It has been determined that the observed radiation is a single light flash duration of about 5×10^{-5} seconds. New experimental data which have appeared in recent years [2, 3] and the more advanced information technologies allow more detailed study of this phenomenon and expand the range of test substances. This paper discusses the results of an experimental study of the dynamic and energy characteristics of cryoemission of nitrous oxide and ethanol.

The measurements were performed in the range of temperatures and pressures condensations 10-20 K and 10^{-5}-10^{-4} Torr, respectively. It was found that the time to reach the maximum amplitude of the flash emission of nitrous oxide is significantly less than that of ethanol, namely, $t=0{,}015\times10^{-3}$ and $t=0{,}3\times10^{-3}$ seconds, respectively. The emission energy spectra of test substances were measured, which are the narrow emission peaks of different amplitudes and are located in the energy range from 4 eV to 1.2 eV.

[1] D. Garypogly, A. Drobyshev, Fiz. Nizk. Temp. 16, 936 (1990)
[2] R. Balog, P. Cicman, N. C. Jones, D. Field, Phys. Rev. Lett. 102, 073003 (2009).
[3] D. Field, O. Plekan, A. Cassidy et al, Intern. Rev. Phys. Chem. 32, 345 (2013).

C10 PHASE TRANSITIONS IN SOLID ETHANOL

Victor Efimov, Alexander Isotov, Oksana Rybchenko
Institute of Solid State Physics RAS, Chernogolovka, Moscow distr., Russia
victor_efimov@yahoo.co.uk

The influence of size factor on the mechanisms and dynamics of phase transformations is one of the most interesting problems in physics of nanoobjects. In this sense, ethanol samples give very wide area for study of the influence of size of the samples on crystallization processes and phase transitions at heating. Ethanol easy formats an amorphous structure at quick cooling of the liquid below 156 K down to liquid nitrogen temperatures ("bulk sample"). The similar amorphous structure was formed through impurity-helium gel technique after evaporating of liquid helium and decay of the ethanol cluster ("gel sample") [1]. In this case the size of the samples was the order of the tens nm, what is in good correspondence with results of small angle neutron scattering [2]. Subsequent heating of the samples from absolutized ethanol above 100 K leads to crystallization amorphous into cubic phase (CP), the rate of which depends on size of the samples ('bulk" or 'gel" samples) and the temperature of the annealing. After heating above 110 K CP phase began transform into monoclinic phase. The same, the rate of phase transition was defined by the sample properties and annealing conditions.

The crystallization of amorphous sample from ethanol with remanent concentration of water (~4%) never came through "cubic plastic deformed" phase. The rate of crystallization amorphous into monoclinic phase of these samples was impeded, too.

In the report we discuss the nature of crystallization process of amorphous ethanol into PC phase and congruence the rate of the transition with JMAK (W.A.Johnson, R.F.Mehl, M. Avrami, A.N.Kolmogorov) theory [3]. We consider phase transition into monoclinic phase, energy characteristic of the process as well as the peculiarity of phase transition cubic phase into monoclinic one.

[1] V.Efimov, L.Mezhov-Deglin, Patent N 2399581, "Method of preparation of nanoparticles from gases and vapor of fluids" (2010)
[2] V. B. Efimov, L. P. Mezhov-Deglin, C. D. Dewhurst, A. V. Lokhov, and V. V. Nesvizhevsky, "Neutron Scattering on Impurity Nanoclusters in Gel Samples," Advances in High Energy Physics, vol. 2015, Article ID 808212, 4 pages
[3] https://en.wikipedia.org/wiki/Avrami_equation

I17 CAPTURING GASES IN CARBON HONEYCOMB

Nina V. Krainyukova[1]
1B. Verkin Institute for Low Temperature Physics and Engineering NASU, 61103 Kharkiv, Ukraine
krainyukova@ilt.kharkov.ua

In our recent paper [1] we reported observation of an exceptionally stable honeycomb carbon allotrope obtained by deposition of vacuum sublimated graphite. The structures are built exclusively from *sp*2-bonded carbon atoms, and may be considered as three-dimensional graphene. In their both periodic and random forms such structures demonstrate high levels of physical absorption of various gases (Fig. 1) unattainable in other carbon forms such as fullerites or nanotubes [2]. The absorption extent depends on the honeycomb sizes $a = (2.5 + 1.5n)\times \mathrm{rNN}$; here $\mathrm{rNN} = 1.44$ Å is the nearest neighbor distance in a carbon layer and n is an integer.

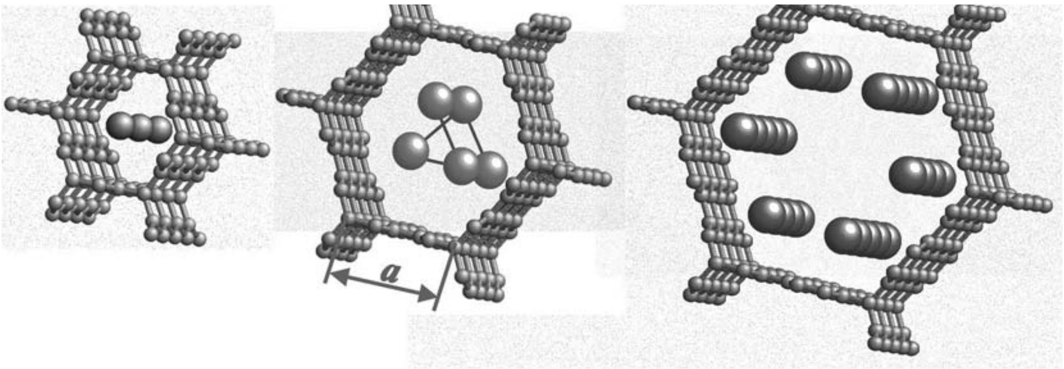


Fig. 1. The most plausible arrangements of absorbed Ar, Kr and Xe (from left to right) atoms in the growing carbon honeycomb cells.

In this work we show that the formation of honeycomb structures is highly sensitive to the carbon evaporation temperature and deposition rates. Both parameters are controlled by electric current flowing through thin carbon rods (~ 1.5 mm in diameter). We analyze the produced carbon films by means of transmission high-energy electron diffraction. Two distinctly different regimes were found. At lower electric currents (below ~ 40 A) only surface sublimation occurs that results in almost pure honeycomb structures. At higher currents the surface-to-bulk rod melting becomes visible. In the latter case a large contribution of glassy carbon is identified in the films obtained.

The experimental diffraction patterns from honeycomb structures filled with absorbed gases are consistent with the proposed models.

[1] N. V. Krainyukova, E. N. Zubarev, Phys. Rev. Lett., 116, 055501 (2016).
[2] N. V. Krainyukova, Low Temp. Phys., 35, 294 (2009).

C11 INFLUENCE OF DEFECTS ON VIBRATIONAL CHARACTERISTICS OF LINEAR CHAINS OF INERT GASES ATOMS ADSORBED ON BUNDELES OF CARBON NANOTUBES

E.V. Manzhelii
B. Verkin Institute for Low Temperature Physics and Engineering, 47 Lenin Ave., 61103 Kharkov, Ukraine
emanzhelii@ilt.kharkov.ua

One-dimensional (1 D) models due to their simplicity often give possibility to obtain analytical expressions for physical values which can be used for a qualitative description of 3 D models. Note that the non-degeneracy of the quasi-one-dimensional system spectrum significantly simplifies the investigation of defect-induced perturbations of the spectrum. The main obstacle in the investigation of 1 D periodic systems is their instability. In fact, even at T=0 the mean-square displacements of atoms diverge [1]. This difficulty does not occur if the spectrum of 1 D system starts with a frequency different from zero. In practice, it is enough to place a chain in an external field (e.g., on a substrate).

Of great interest are the chains of inert gases adsorbed in the grooves between the nanotubes in bundles of closed nanotubes saturated by gases in the case of low concentration of the saturating gas. The 1 D nature of the objects formed by inert gases in bundles of nanotubes is confirmed by the neutron diffraction [2] and specific heat [3] studies of nanotube bundles. In [4], it was shown that starting from a certain frequency the vibrations of atoms in the chain in a groove between two nanotubes are either quasi-localized or have 1 D character. This frequency is determined by the contribution of the interaction between the atoms of the chain and the atoms of the nanotube to the self-interaction matrix. The spectral characteristics of the atoms of the chain are well described by simple analytical expressions. Basing on the results obtained in [5], it can be assumed that the distance between the atoms of the chain adsorbed in the groove is slightly less than the equilibrium distance between the atoms of the inert gas. Therefore the constant for noncentral interatomic interaction, which determines the transverse vibrations of the chain, is negative. These results in the specific dispersion relation for the oscillations polarized across the chain. The stability of the chain is determined exclusively by its interaction with the substrate.

The chain with a modified local interatomic interaction is considered. The defect appears because of the removal of single atoms from the compressed chain [5]. The analytical results for the changes in the phonon spectra and vibrational characteristics of the chain are obtained. In particular, the conditions of formation and the characteristics of the discrete frequency levels lower than the starting frequency of the continuous spectrum and the change of the low temperature heat capacity are found.

[1] L.D Landau, JETP, 7, 627 (1937).
[2] S.O.Diallo, B. Fåk, M.A. Adams, O.E. Vilses et al., EPL, 88, 56005 (2009).
[3] M.I.Bagatskii, V.G. Manzhelii, V.V. Sumarokov, M.S. Barabashko, Low Temp. Phys., 39, 618. (2013).
[4] E.V. Manzhelii, S.B. Feodosyev, I.A. Gospodarev, E.S. Syrkin and K.A. Minakova, Low Temp. Phys., 41, 577 (2015).
[5] M.I. Bagatskii, M.S. Barabashko, and V.V. Sumarokov, JETP Letters, 99, 461 (2014).

C12 HEAT CAPACITY OF 1D MOLECULAR CHAINS

Maksym S. Barabashko[1], Mikhail I. Bagatskii[1], Vladimir V. Sumarokov[1,2], Andrzej Jeżowski[2], and Piotr Stachowiak[2]

1B.Verkin Institute for Low Temperature Physics and Engineering of NASU, 47 Nauka Ave., 61103, Kharkov, Ukraine, 2W. Trzebiatowski Institute of Low Temperature and Structure Research of PAS, 2 Okólna Str., 50-422 Wrocław, Poland

e-mail: msbarabashko@gmail.com

Unique structure of bundles of closed-cap single – walled carbon nanotubes (c-SWNT) makes possible to form low-dimensional adsorbate nanosystems. In this study the heat capacity of 1D chains of molecular adsorbates with different noncentral intermolecular interaction is reported.

Measurements on the heat capacity of 1D chains of nitrogen CN2(T) and methane CCH4(T) molecules (adsorbed in the outer grooves of bundles of closed-cap single – walled carbon nanotubes) have been made using an adiabatic minicalorimeter in the temperature ranges 2 - 40 K and 2 - 60 K, respectively.

Experimental $C_{N2}(T)$ is in good agreement with the theoretical calculation of the phonon heat apacity at constant volume for 1D chains of Kr below 9 K. The temperature dependence of the heat capacity of 1D chains of nitrogen molecules is close to linear below 3 K. The frequency of the longitudinal phonon mode at the edge of the Brillouin zone for 1D chains of N2 have been estimated ($h\omega_L \approx$ [illegible]meV). The contribution of the translational vibrations of N2 molecules to the heat capacity of 1D chains is dominant below 8K whereas the contribution of the librations to the $C_{N2}(T)$ is essential above 15 K.

Experimental heat capacity of 1D chains of methane stands out above theoretical phonon heat capacity over all temperature range of study. The rotational heat capacity of methane molecules is separated. Character of the temperature dependence of CCH4(T) below 12 K indicates on the presence of Schottky anomaly caused by the tunneling between the lowest energy levels of rotational spectra of A, T, and E   nuclear spin modifications of the methane molecules. Special feature observed in the vicinity of 14 K is, apparently, due to orientational phase transition, in which the nature of the rotational motion of the molecules varies from libration to hindered rotation. The value of the rotational heat capacity is close to the case of free rotation of the methane molecules in the temperature range of 30 - 40 K. The sharp increase of $C_{CH4}(T)$ above 40 K is due to the processes of decay of 1D chains of CH_4.

Acknowledgments

Some of us are grateful for the financial support of the National Science Center, Poland, of the Harmonia project "Thermal properties of simple van der Waals crystals based nanostructure materials" (grant UMO-2013/08/M/ST3/00934).

I18 CLUSTER APPROACH IN CRYOCRYSTALS

M.A. Strzhemechny, V.V. Danchuk
B.Verkin Institute for Low Temperature Physics and Engineering, NASU, Kharkov, Ukraine
e-mail: strzhemechny@ilt.kharkov.ua

Diluted cryoalloys, that is cryocrystals containing low fractions of impurities (broadly understood), had played the decisive role in understanding the phenomenon of quantum diffusion of "extraneous species" (impurities, excited molecular rotational states, vacancies, etc.). A concise summary of quantum diffusion results is provided.

Thermodynamic properties of diluted cryoalloys also can be quite consistently explained within the so called cluster approach using a single characteristic parameter, namely the excess volume per impurity particle ω, which is easily derived from structure data for diluted solid mixtures. This approach has been successfully employed for a few binary cryoalloys [1, 2], which included a molecular component like N_2 or CO_2.

In rare gas mixed crystals the cluster approach requires a special attention. Previously [3, 4], it was accepted that the volume v(x) of a RG alloy as a function of the impurity fraction x is expected to be close to a linear relation

$$v(x) = v_0 + \omega x \qquad (1)$$

This seemingly self-evident consideration turns out to be at least questionable at fractions below 2-3 mol.% [5].

Our reasoning shows that a very important factor for an isolated rare gas impurity is the attractive nature of the long-range interactions of the host atoms. Our calculations for a spherical krypton crystallite up to ten surrounding spheres with a single argon atom at its center show that the excess volume (negative, for this specific case) is roughly twice as little compared to what could follow from Eq. (1).

[1] M.A. Strzhemechny, A.A. Solodovnik, S.I. Kovalenko, Fiz. Nizk. Temp. 24, 889 (1998) [Low Temp. Phys. 24, 669 (1998)].
[2] V.V. Danchuk, A.A. Solodovnik, M.A. Strzhemechny, Fiz. Nizk. Temp. 36, 321 (2010) [Low Temp. Phys. 36, 254 (2010)].
[3] I. Prigogine, The Molecular Theory of Solutions, North-Holland, Amsterdam (1957).
[4] A.E. Curzon, A.J. Mascall, J. Phys. C 2, 220 (1969).
[5] A.A Solodovnik, N.S. Misko-Krutik, V.V. Danchuk, M.A. Strzhemechny, abstract submitted to 11th Cryocrystals Conference.

I19 THERMALLY INDUCED LUMINESCENCE OF NITROGEN NANOCLUSTERS CONTAINING STABILIZED NITROGEN ATOMS

V.V. Khmelenko[1], A. Meraki[1], P.T. McColgan[1], R.E. Boltnev[2,] D.M. Lee[1]
1Texas A&M University, Department of Physics and Astronomy, College Station, Texas, USA , 2Branch of Talroze Institute for Energy Problems of Chemical Physics, Russian Academy of Sciences, Chernogolovka, Moscow Region, 142432, Russia
khmel@physics.tamu.edu

We studied ensembles of molecular nitrogen nanoclusters containing high concentration of stabilized nitrogen atoms immersed in liquid helium. These nanoclusters were prepared by injection of nitrogen-helium gas mixtures passed through a zone of radiofrequency discharge into bulk superfluid helium (HeII) at T=1.5 K. Nanoclusters form porous structures filled by liquid helium. Stabilized nitrogen atoms reside mostly on the surfaces of nanoclusters.

We studied electron spin resonance (ESR) spectra of nitrogen atoms stabilized in the nanoclusters and thermoluminescence of the samples initiated by warming in the temperature range 1.2 - 4.4 K. The concentrations of stabilized nitrogen atoms determined from ESR spectra were of order $5 \cdot 10^{18}$ cm^{-3} and did not decrease substantially in the process of warming of the samples immersed in liquid helium. Optical spectra were obtained in the spectral range 240 -1000 nm. The α-group of nitrogen atoms, the β-group of oxygen atoms and the Vegard-Kaplan bands of N2 molecules were the most intensive features in the spectra. The typical temperature dependence of the thermoluminescence intensity has two maxima, one in HeII at T~1.9 K, and another in normal helium (HeI) at T~3.2 K. If the temperature was kept constant for the samples immersed in HeII, the intensity of thermoluminescence decayed following a hyperbolic law. Based on these experimental observations we suggested that luminescence of the samples immersed in HeII was initiated by quantum vortices, created in the process of applying heat flux to the system during warming process. The maximum of the thermoluminescence intensity corresponds to the maximum efficiency of formation of vortices at T~1.9 K, where the friction force between superfluid and normal components of liquid helium in counter flows also has a maximum. Hyperbolic decay of the thermoluminescence of the samples with characteristic times ~1000 s might be explained by decay of vortex density usually observed in HeII when the heat flux was terminated. Therefore, we obtained experimental evidence for quantum vortex induced recombination of nitrogen atoms leading to the appearance of excited nitrogen molecules. These molecules were responsible for blue emission (Vegard-Kaplan bands) and the α-group and β-groups due to energy transfer within nanoclusters to stabilized nitrogen and oxygen atoms. Thermoluminescence observed in HeI occurred due to the process of nanocluster association resulting in thermal explosions of a small fraction of nanoclusters.

We also studied dynamics of thermoluminescence during destruction of the nitrogen-helium samples when removed from liquid helium. At the end of destruction, bands of NO and O2 molecules were observed.

C13 SPECTROSCOPIC OBSERVATION OF NITROGEN ANIONS N– IN CRYOCRYSTALS

R. E. Boltnev[1,2], I. B. Bykhalo[1], I. N. Krushinskaya[1,2], A. A. Pelmenev[1], S. Mao[3], A. Meraki[3], P. T. McColgan[3], D. M. Lee[3], and V. V. Khmelenko[3]

1Branch of Talroze Institute for Energy Problems of Chemical Physics, Russian Academy of Sciences, Russia, 2Joint Institute for High Temperatures, Russian Academy of Sciences, Russia, 3Institute for Quantum Science and Engineering, Department of Physics and Astronomy, Texas A&M University, USA

boltnev@gmail.com

Our recent experimental results [1] and new ones show that observation of the so-called ⌧–line is always accompanied by the detection of exoelectrons and optical emission of N(^{2}D) atoms. Analysis of our results and old experiments [2-4] on thermoluminescence of cryocrystals and nanoclusters of N_2, Ne, Ar, and Kr, containing stabilized nitrogen atoms, gives evidence that the γ–line corresponds to the bound-bound transition, ^{1}D → ^{3}P, of nitrogen anions N– formed in solids by the association of delocalized electrons and metastable nitrogen atoms N(^{2}D). The fine structure of the γ–line emitted by the anions N– trapped in molecular nitrogen nanoclusters has been experimentally observed and investigated for the first time.

The study was supported by NSF Grant No. DMR 1209255 and by the Program "Matter at High Energy Densities" of the Presidium of the Russian Academy of Sciences.

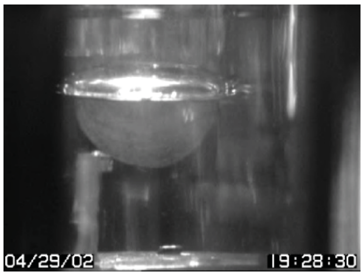
[1] R. E. Boltnev, I. B. Bykhalo, I. N. Krushinskaya, A. A. Pelmenev, V. V. Khmelenko, D. M. Lee, I. V. Khyzhniy, S. A. Uyutnov, E. V. Savchenko, A. N. Ponomaryov, G. B. Gumenchuk and V. E. Bondybey, Low Temp. Phys., 39, 580 (2013).
[2] M. Peyron and H. P. Broida, J. Chem. Phys., 30, 139 (1959).
[3] E. M. Horl, J. Molec. Spectrosc., 3, 425 (1959).
[4] R. Tian and J. Michl, Faraday Discuss. Chem. Soc., 86, 113 (1988).

I20 NANOCLUSTER IMPURITY-HELIUM GEL - A NEW CLASS OF SOFT MATTER

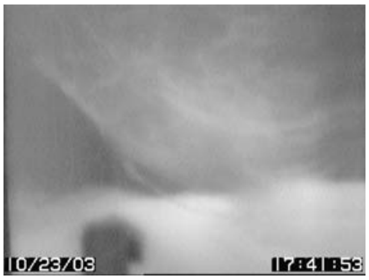
L.P. Mezhov-Deglin[1], V.B. Efimov[1], and V.V. Nesvizhevsky[2]
1 Institute of Solid State Physics RAS, Russia; 2 Institute Max von Laue – Paul Langevin, France
mezhov@issp.ac.ru

Nanocluster impurity-helium condensates or impurity gels in liquid helium should be assigned to a new class of materials: quantum soft matter. Dispersion system (backbone) of the gel is formed by agglomerates of impurity nanoclusters surrounded by a layer of solidified helium (van-der-Waals complexes); liquid helium filling the pores between nanolusters serves as the dispersion medium of the gel (quantum liquid in restricted geometry). Method for preparation jelly like samples by injection of the ^{4}He gas jet with 1-3% of impurity molecules or atoms in bulk of superfluid He-II through its surface was developed in 1974. Developed later on method condensation of a gas mixture flow at the free surface of superfluid He-II cooled below1.8 K permitted one to prepare impurity gel samples from the vapors of water or other liquids or gases at room temperatures (for references see the review [1]). Examples of the visible observations the initial stage of preparation the watergel, deuterogel and deuterated methane gel samples are shown below: a front of soft layer of impurity condensate, formed on the surface of He-II inside the lower part of the glass filling tube of ~ 1.5 cm inner diameter, slides down from the tube end into the experimental cell filled with He-II [2]. Superfluid He-II acts as an ideal cooling agent and the same time it penetrates into multiple pores of the nanoclusters condensate.

H_2O



D_2



CD_4

It should be mentioned that the first version of the method where the gas stream with a molecular gas impurity was coming through a discharge tube preliminary opened a possibility for preparation of gel samples with a high content of free radicals in molecular matrices in He-II.

Irreversible decay of gels on heating the water, etc. gel samples above liquid He temperatures in He gas atmosphere at P=1 atm is accompanied by appearance of the icy powder - amorphous impurity matter at the bottom of experimental cell. This powder can exist on heating it up to liquid nitrogen temperatures. Thus, it opens a new way for preparation and further investigations of the amorphous ices. Amorphous ice is so widespread in interstellar space that it could be the most common form of water in the universe. Left over from the age when the solar system was born, it is scattered across vast distances, often as particles no bigger than grains of dust. It's also been spotted in comets and icy moons.

[1]. L.P. Mezhov-Deglin, Impurity nanocluster structures in liquid helium, Phys. Usp. 48 (10), 1061 (2005).

[2]. V.B. Efimov, L.P.Mezhov-Deglin, A.V. Lokhov, V. Nesvizhevsky, C.D. Dewhurst, Neutron Scattering on Impurity Nanoclusters in Gel Samples. Advances in High Energy Physics, Volume 2015 (2015), Article ID 808212, 4 pages.

C14 PHOTOISOMERIZATION OF AZOBENZENES ISOLATED IN CRYOGENIC MATRICES

Luís Duarte[1], Leonid Khriachtchev[1], Rui Fausto[2] and Igor Reva[2]
1Department of Chemistry, University of Helsinki, P.O. Box 55, FI-00014 Helsinki, Finland.
2Department of Chemistry, University of Coimbra, P-3004-535 Coimbra, Portugal.
luis.duarte@helsinki.fi

2,2' -Dihydroxyazobenzene (DAB), 2,2' -azotoluene (AT) and azobenzene (AB) were isolated in argon and xenon matrices and their molecular structures and photochemical transformations were characterized by infrared spectroscopy and theoretical calculations [1]. All these compounds can adopt the E and Z isomeric forms around the central CNNC moiety, which can be enriched by several conformational and tautomeric modifications for DAB and AT. A number of DAB and AT isomeric forms were identified for the first time. For DAB, the *E* azo-enol isomer with two intramolecular six-membered quasi-rings formed via OH···N hydrogen bonds was found after deposition. Irradiation with UV light generated a different *E* azo-enol form with two intramolecular H-bonded five-membered quasi-rings. Phototransformation was shown to be reversible and the forms could be interconverted by irradiation at different wavelengths. The isomerization between these two forms constitutes a direct experimental observation of an *E* → *E* isomerization in azobenzene-type molecules. Further irradiation generated a form(s) bearing both OH and NH groups. For AT, two *E* isomers with the CH3 groups forming five-membered and five/six-membered quasi-rings with the azo group were observed in the as-deposited matrices. Irradiation of AT with UV light generated a *Z* form that can be converted back to the *E* form at different irradiation wavelengths. *E*-AB was deposited in a xenon matrix and both *E* → *Z* and *Z* → *E* phototransformations were observed (contrary to what was previously reported in an argon matrix where only the *Z* → *E* conversion occurred) [2]. AB photoisomerization becomes more pronounced at elevated temperatures, thus indicating that the matrix effects responsible for hindering the AB photoisomerization are essentially due to steric restrictions. The different photoisomerization channels observed for these compounds are discussed in terms of a small-amplitude pedal motion.

[1] L. Duarte, L. Khriachtchev, R. Fausto, I. Reva, Phys. Chem. Chem. Phys., DOI: 10.1039/C6CP02583H (2016).
[2] L. Duarte, R. Fausto, I. Reva, Phys. Chem. Chem. Phys., 16, 16919 (2014).

I21 SOME FUNDAMENTAL REACTIONS IN CRYOGENIC MATRICES

Leonid Khriachtchev
Department of Chemistry, University of Helsinki, P.O. Box 55, FI-00014, Finland
leonid.khriachtchev@helsinki.fi

Matrix-isolation infrared spectroscopy is a powerful tool to study fundamentals of chemical reactivity, including photochemistry [1–3]. New molecules and radicals, including conformational isomers, can be prepared and identified usually with the help of quantum chemical calculations. Tunneling of hydrogen often plays a role in reactions at low temperatures. Photodissociation and photoisomerization are also very important and active areas of research.

Photolysis of matrix-isolated molecules can produce new species due to in-cage reactions of photoproducts. For example, photolysis of formic acid (HCOOH) leads to the $H_2O\cdots CO$ and $H_2\cdots CO_2$ complexes. UV irradiation of the $H_2O_2\cdots SO_2$ and $H_2O_2\cdots CO$ complexes forms the $H_2O\cdots SO_3$ and $H_2O\cdots CO_2$ complexes, respectively. An exciting system is the $H_2O\cdots O$ complex, UV irradiation of which leads to H_2O_2. For some molecules (like S_2 and SO_2), the photoproducts are shortly separated after photolysis and slight annealing of the matrix leads to their local mobility and recombination accompanied by chemiluminescence.

Photolysis can produce fragments (atoms) that are well separated in the matrix. In particular, photodissociation of N_2O and HBr produces oxygen and hydrogen atoms, respectively. Upon annealing, these atoms can extensively move in the matrix and react with other species. Examples of such reactions are numerous and include $H + HCCH \rightarrow H_2CCH$, $H + HNCO \rightarrow H_2NCO$, $H + SO_2 \rightarrow HSO_2$, $H + CO\cdots H_2O \rightarrow HCO\cdots H_2O$, and $O + CO\cdots H_2O \rightarrow CO_2\cdots H_2O$. Reactions of oxygen and hydrogen atoms with formic acid are remarkable: the HCOOH + O reaction is conformational-dependent and the HCOOH + H reaction leads to the simplest geminal diol radical *trans–cis*-$HC(OH)_2$.

We also describe reactions leading to noble-gas hydrides with the general formula HNgY where H is a hydrogen atom, Ng is a noble-gas atom, and Y is an electronegative fragment [4]. The HNgY species are formed in the H + Ng + Y reaction of the neutral fragments. Examples of these species include HXeOBr, HKrCCH, and HArF. In addition to the closed-shell species, noble-gas radicals HXeO and HXeCC are known. These radicals can further react to produce HXeOXeH and HXeCCXeH, respectively. In addition to noble-gas hydrides HNgY, we have studied noble-gas molecules of a different type, YNgY' where Y' is another electronegative fragment [5].

[1] Y. Haas, U. Samuni, Prog. Reaction Kinetics 23, 211 (1998).
[2] Physics and Chemistry at Low Temperatures, edited by L. Khriachtchev, Pan Stanford, Singapore, 2011.
[3] L. Khriachtchev, J. Phys. Chem. A 119, 2735 (2015).
[4] L. Khriachtchev, M. Räsänen, R. B. Gerber, Acc. Chem. Res. 42, 183 (2009).
[5] T. Arppe, L. Khriachtchev, A. Lignell, A. V. Domanskaya, and M. Räsänen, Inorg. Chem. 51 4398 (2012).

I22 CALORIMETRIC MEASUREMENTS BETWEEN 1.5 K AND 300 K IN MOLECULAR GLASSES AND DISORDERED CRYSTALS

M. A. Ramos1,2, M. Moratalla1, J. Labarga1,3, C. Alvarez-Ney1, J. M. Castilla1
1Laboratorio de Bajas Temperaturas, Departamento de Física de la Materia Condensada,Universidad Autónoma de Madrid, Madrid, Spain
2 Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera (INC),Universidad Autónoma de Madrid, Madrid, Spain
3 ETSI Caminos, Canales y Puertos,Universidad Politécnica de Madrid, Madrid, Spain
miguel.ramos@uam.es

An overview of ongoing calorimetric measurements in a wide low-temperature range for several small-molecule glass-forming liquids and plastic crystals is presented. By combining a quasiadiabatic continuous method developed by us [1], employed at both liquid nitrogen and helium temperatures, with the well-known thermal relaxation method at lower temperatures, we have measured the specific heat C_p in the range 1.5-300 K for several small-molecule substances that are in liquid state at room temperature. This allows us: (i) to obtain their thermodynamic functions such as the entropy; (ii) to investigate the "anomalous" glassy thermal properties at low temperatures, either in structural glasses or in disordered crystals.

Specifically, we have studied toluene, one of the most fragile glass-forming liquids, both in its crystal and amorphous state, as well as several halomethanes $\mathrm{CCl_4{-}_nBr_n}$ (n = 0,1,2). In the case of toluene, the only available C_p data at low temperature in the literature were limited to 11.5 K for the crystal [2] and down to 5.7 K for the glass [3]. Toluene is not a good glass former and crystallizes easily. Thus, the authors of ref. [3] measured in fact toluene doped with about 10 mol % of benzene to supress crystallization. We have been able to obtain and measure a bulk glass of toluene by doping with only 2 mol % of ethanol.

We have also measured the specific heat of the halomethane system $\mathrm{CCl_4{-}_nBr_n}$ (n = 0,1,2), which exhibit plastic crystal phases below room temperature and go into normal crystalline phases at lower temperatures. For $n \neq 0$, some kind of substitutional disorder and corresponding molecular motion is expected, associated with the exchange of positions between Cl and Br atoms. Heat capacity measurements in $\mathrm{CCl_3Br}$ and $\mathrm{CCl_2Br_2}$ above 6 K [4] have evidenced a glass transition at about 90 K for both substances, probably due to a freezing of those molecular motions. More recently, thermal conductivity measurements at low temperature [5] have shown however absence of the characteristic glassy anomalous behavior for the $\mathrm{CCl_4{-}_nBr_n}$ system. Our low-temperature Cp measurements will be discussed in that context.

[1] E. Pérez-Enciso and M.A. Ramos, Termochim. Acta, 461, 50 (2007).
[2] D. W. Scott et al., J. Phys. Chem., 66, 911 (1962).
[3] O. Yamamuro et al., J. Phys. Chem. B, 102, 1605 (1998).
[4] T. Ohta, O. Yamamuro, T. Matsuo, J. Phys. Chem., 99, 2403 (1995).
[5] A.I. Krivchikov et al., J. Non-Cryst. Solids, 407, 141 (2015).

I23 ADHESION, PLASTICITY AND OTHER PECULIAR PROPERTIES OF SOLID METHANE

O. Kirichek
ISIS Facility, STFC, Rutherford Appleton Laboratory, United Kingdom
oleg.kirichek@stfc.ac.uk

Methane is one of the most abundant hydrocarbon compounds known. It occurs widely in our environment in solid, liquid and gaseous forms both terrestrially and extra-terrestrially. On Earth, methane is the major constituent of natural gas which is transported and stored in the liquid form, before being released as low pressure gas into the gas supply grid. Nowadays solid methane is broadly used as a moderator material in high intensity cold neutron sources. There is also significant presence of solid methane on several planetary bodies in the solar system [1]. All solid methane related areas of research mentioned above require detailed information about thermodynamic and mechanical properties of solid methane.

Hear we review some properties of crystalline solid methane in temperature range 10 – 90K. Adhesion and plasticity of polycrystalline solid methane have been studied in the temperature range 10 – 90K [2]. It was shown that adhesion is very strong in the 60K – 90K temperature range where the solid methane is soft and sticky. Closer to the melting point (at 90.6K) the solid methane behaves as extremely viscous non-Newtonian liquid. Below 60K solid methane loses its stickiness and ductility. Methane adhesion remains similar for very different materials.

We are also going to present some video observations which reveal unexpected and mostly inexplicable properties of solid methane which could be of some interest for designing new methane moderators for neutron sources and planetary physics particularly the study of the environment of Titan [3].

[1] May Chiao Nature Physics 12, 203 (2016).
[2] O. Kirichek, A. J. Church, M. G. Thomas et al. Cryogenics 52, 325 (2012).
[3] J. D. Hofgartner, J. I. Lunine Icarus 223, 628, (2013)

C15 THERMAL CONDUCTIVITY OF METHANE - SIO2 CRYOCRYSTAL NANOCOMPOSITES

R.V. Nikonkov1, A.I. Krivchikov[2], P. Stachowiak[1], A. Jeżowski[1]
1Institute for Low Temperatures and Structure Research, Polish Academy of Sciences, PN 1410, 50-950 Wroclaw, Poland
2B. Verkin Institute for Low Temperature Physics and Engineering of NAS Ukraine, 47 Lenin Ave., Kharkov 61103, Ukraine
E-mail: P.Stachowiak@int.pan.wroc.pl

Over recent decade a tremendous increase of interest into investigations of physical properties of nocomposite crystalline materials has been observed. Application motivated goals such a search for thermoelectric materials showing high value of the figure of merit, on one hand, and the scientific interest into new phenomena observed in crystals with nanoparticles embedded in their structures, on the other, gave boost to the investigations of transport properties of such systems. In the current contribution we report the results of the thermal conductivity investigations of methane crystal samples possessing in its structure nanopowders of SiO_2 of different linear dimensions, varying from 5 to 170nm. Using a simple thermal conductivity model we show how the nanoinclusions influence the thermal conductivity of the investigated crystal and change its crystalline structure during growth of the samples.

This work was supported by National Science Centre, Poland, within Harmonia project “Thermal properties of simple van der Waals crystals based nanostructure materials” (grant UMO-2013/08/M/ST3/00934).

C16 THERMAL CONDUCTIVITY OF CRYOCRYSTALS FROM METHANE TO TETRACHLOROMETANE: REGULARITIES AND SINGULARITIES

A. Krivchikov[1], O. Korolyuk[1], J. Tamarit[2] and P. Stachowiak[3]
1B. Verkin Institute for Low Temperature Physics and Engineering of NAS Ukraine, Ukraine,
2 Group of Characterization of Materials, Department of Physics, ETSEIB, Universitat Politucnica de Catalunya, Spain
3 Institute for Low Temperature and Structure Research, Polish Academy of Sciences, Poland
Krivchikov@ilt.kharkov.ua

The review is devoted to experimental studies of thermal conductivity of polycrystalline molecular solids at low temperatures: structural and orientational glasses, glass – like crystals and crystals with different degrees of orientational disorder. The thermal conductivity of CH_4, CD_4 and CBr_nCl_{4-n} (n=0,1,2) crystals which exhibit occupational site disorder has been measured for temperatures between 2 K and 150 K. Such temperature range comprises signatures of dynamical processes involving the site occupancy of the chlorine and bromine atoms for CBr_nCl_{4-n} compounds. New effects have been detected and studied in the thermal conductivity property for these well translationally ordered molecular crystals as the effects of site-occupation disorder on the low-temperature thermal conductivity of molecular crystals mediated by substitution of Br atoms by Cl atoms in the tetrachloromethane molecules, which results in a significant decrease of the thermal conductivity [1].

The literature data on the thermal conductivity of a number of orientationally disordered molecular crystals in the high temperature region were analyzed [2]. It was shown that the thermal conductivity can be described as a sum of two components: due to propagating phonons and localized “diffuse” modes. The thermal conductivity increases according to relation $\kappa(T) = A/T + B$, the B term being associated with the input of localized short-wave, or “diffuse” vibrational modes.

Also, we were able to notice a group of simple molecular polycrystals which show their thermal conductivity very close to each other in the low temperature region [3]. What is more, the similarity of the thermal conductivity of the polycrystals for many reasons resembles known and well-studied for over 30 years the universality observed for low-temperature thermal conductivity of amorphous solids. Here, utilizing already developed thermal conductivity models, we try to understand what phenomena could result in the similarity of the thermal conductivity of the polycrystals and therefore to explain the experimental finding.

[1] A. I. Krivchikov et al, Journal of Non-Crystalline Solids, 407, 141 (2015).
[2] Krivchikov, A. I., et al., Low Temperature Physics, 41, 551 (2015).
[3] Romanova, T., et al, Physica B: Condensed Matter, 459, (2015).

I24 STICK-SLIP MOTION OF THE WIGNER SOLID OVER LIQUID HELIUM SURFACE

Kimitoshi Kono1,2,3, David G. Rees1,2, Niyaz R. Beysengulov1,3, Yong-Han Lin2, Sheng-Shiuan Yeh2, and Shao-Pin Chiu2, Dmitrii Tayurskii1,3, and Juhn-Jong Lin1,2,4
1RIKEN CEMS, Wako 351-0198, Japan, 2Institute of Physics, NCTU, Hsinchu 300, Taiwan, 3Institute of Physics, KFU, Kazan, Russia, 4Department of Electrophysics, NCTU, Hsinchu 300, Taiwan
kkono@riken.jp

Surface state electrons (SSE) on liquid helium realize the clearest Wigner solid (WS) at low temperatures[1]. The WS is a lattice of electrons, which is dressed by a cloud of ripplons. The Bragg scattering of ripplons from the WS gives rise to a commensurate deformation of the He surface known as the dimple lattice (DL)[2]. The WS-DL system is analogous to polaron states in which electrons are dressed by a cloud of virtual phonons, or lattice deformation. Decoupling dynamics of the WS and polaron systems exhibit strong similarities.

In contrast with other systems, the coupling of the WS with the DL is of a dynamical nature, due to interference between ripplons emitted by the moving WS. When the velocity of the WS-DL system approaches the phase velocity of ripplons of wavevector equal to the WS periodicity, refered to as vBC, constructive interference resonantly deepens the DL. Accordingly, the resistive force increases by approaching vBC so as to regulate the WS velocity below vBC. However, when the driving force exceeds the resistive force, the WS eventually decouples from the DL. A stationary DL depth on the order of 10-12 m can grow more than one order of magnitude deeper at the decoupling point.

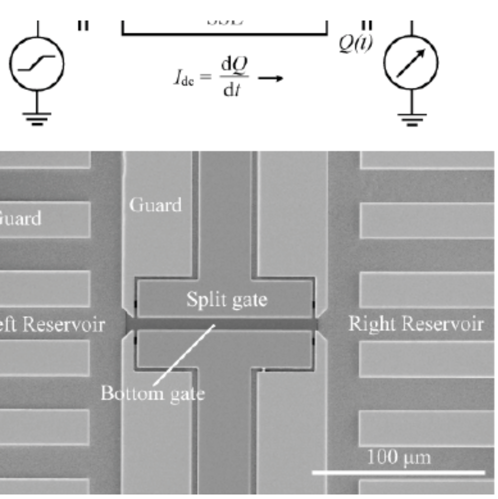


Fig. 1 (a) Schematic circuit diagram of the dc current measurement. The SSE in the CM form an electrical resistance R. (b) scanning electron micrograph of a micro channel device

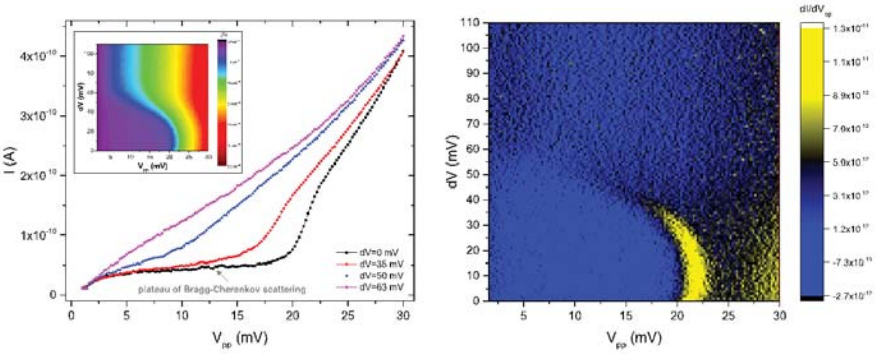
Recently, detailed dynamics of WS-DL systems can be studied by employing a micro-fabricated device, as shown in Fig. 1. By using capillary action, liquid He condensed in a channel of 1~2 micron deep and 10 micron wide can be used to support SSE on the channel. This device is called a “micro-channel device”. The resistance of WS on the channel is high enough to sustain a large electric filed along the channel so that the decoupling is finely controlled. By employing this device, we succeeded in even demonstrating a successive coupling and decoupling processes of WS-DL systems. Under such a condition, the WS transport shows a stick-slip current oscillation.

[1] C. C. Grimes and G. Adams, Phys. Rev. Lett. 42, 795 (1979).
[2] D. S. Fisher, B. I. Halperin, and P. M. Platzman, Phys. Rev. Lett. 42, 798 (1979).

C17 SUPPRESSION OF BRAGG-CHERENKOV SCATTERING OF WIGNER CRYSTAL ON LIQUID HELIUM IN A PERODIC POTENTIAL

Jui-Yin Lin, A. V. Smorodin, A. O. Badrutdinov and D. Konstantinov
Okinawa Institute of Science and Technology Graduate University, Okinawa, 904-0495, Japan
jui-yin.lin@oist.jp

Decoupling of two systems can be realized by mismatch of their characteristic frequencies. To study the nature of friction, the interfacial dynamic motions of two lattices with microscopic lattice constants are of great interest [1, 2]. Wigner Crystal (WC) on liquid helium nicely presents the interaction between a lattice structure and a soft surface with a strong coupling. The kinetic energy of WC is transferred via many-electron coherent emissions into vibrational excitations of ripplons on the surface of liquid helium. This mechanism is described as the Bragg-Cherenkov scattering. Here we report the observation on suppression of Bragg-Cherenkov scattering of WC in the presence of an external periodic potential. We also propose a simple model that explains the suppression by the destructions in WC-ripplon interference as a result of the density modulation of surface-state electrons by the external periodic potential.



Suppression of Bragg-Cherenkov scattering. The measured signals are the current of surface-state electrons in solid phase moving through a 5-μm wide and 101-μm long channel. An external periodic potential of 1-μm in period is applied along the channel with the amplitude dV. Left: I-Vpp curves measured at different values of the amplitude of periodic potential dV, as indicated. The current plateaus correspond to the BC scattering regime. Inset: Same data organized as a 2D-plot showing I vs Vpp and dV. Right: Differential conductance dI/dVpp versus Vpp and dV, derived from the data presented in the inset. The bright yellow line, corresponding to transition from the BC regime to sliding regime, is clearly observed at low dV and completely disappears at higher dV.

[1] E. Meyer, Science, 348(6239), 1089 (2015).
[2] D. G. Rees et al., Physical Review Letters, 116(20), 206801 (2016).

C18 DYNAMIC NUCLEAR POLARIZATION AND CONTROL OF 29SI NUCLEAR SPINS IN DOPED SI

J. Järvinen[1], J. Ahokas[1], S. Sheludyakov[1], O. Vainio[1], L. Lehtonen[1], L. Vlasenko[2], S. Vasiliev[1]
1Wihuri Physical Laboratory, Department of Physics and Astronomy, University of Turku, Turku, Finland
2OA. F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia
jaanja@utu.fi

We report on experiments of dynamic nuclear polarization (DNP) of donor and ^{29}Si nuclear spins in natural silicon. We demonstrate very high polarization of ^{29}Si nuclei which are strongly coupled to donor electrons. By utilizing the methods of DNP it is possible to select spin ensembles based on the strength of 29Si superhyperfine interaction with the donor electron. The ensembles can be further manipulated with NMR. The samples were studied in strong magnetic field of 4.6 T and temperatures below 1 K, in which conditions the donor electron spins are fully polarized.

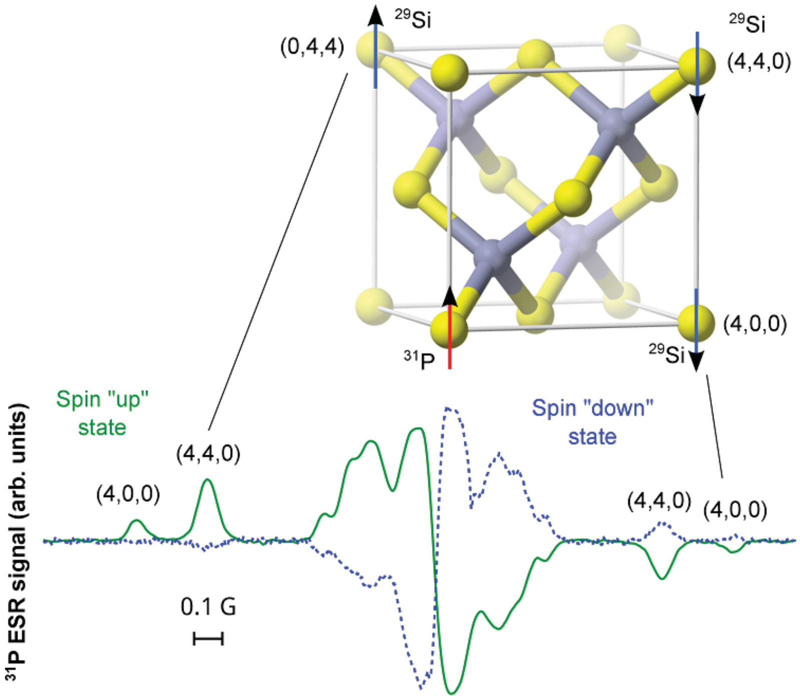


Fig. 1: Electron spin resonance signal of phosphorus donors in silicon. The peaks in the spectra correspond to orientation of the ^{29}Si nuclear spins in distinct lattice sites near the donors. The silicon nuclei can be polarized to an up or down state by exciting double electron-nuclear flip-flip of flip-flop transitions.

P01 LUMINESCENCE OF IMPURITY-HELIUM CONDENSATES SUBMERGED IN SUPERFLUID HELIUM

R. E. Boltnev[1], I. B. Bykhalo[2], I. N. Krushinskaya[1], A. A. Pelmenev[2]
1 Joint Institute for High Temperatures, Russian Academy of Sciences, Russia, 2Branch of Talroze Institute for Energy Problems of Chemical Physics, Russian Academy of Sciences, Russia
boltnev@gmail.com

The thermoluminescence spectra of impurity-helium condensates (IHC) submerged in superfluid helium have been studied for the first time [1]. Samples of IHC were formed by injection of helium gas jet (with the impurity content ~ 1 %) passed through a radiofrequency discharge into bulk superfluid helium [2]. Thermo- and photostimulated luminescence of impurity-helium condensates submerged in superfluid helium [3] is explained by neutralization reactions occurring in impurity nanoclusters. Optical spectra of excited products of neutralization reactions between nitrogen cations and thermo- or photoactivated electrons differ from the spectra observed at higher temperatures, when the luminescence due to nitrogen atom recombination dominates.

New results on current detection during the IHC destruction are presented [1]. Two different mechanisms of nanocluster charging are proposed to describe the phenomena observed during preparation and warm-up of IHC samples in bulk superfluid helium, and destruction of IHC samples out of liquid helium.

The work has been done under support of the Russian Science Foundation (grant#14-50-00124) in Joint Institute for High Temperatures, Russian Academy of Sciences.

[1] A.A. Pelmenev, I.N. Krushinskaya, I.B. Bykhalo, and R.E. Boltnev, Low Temp. Phys. 42, 224 (2016).
[2] E.B. Gordon, L.P. Mezhov-Deglin, and O.F. Pugachev, JETP Lett. 19, 63 (1974).
[3] R.E. Boltnev, E.B. Gordon, V.V. Khmelenko, I.N. Krushinskaya, M.V. Martynenko, A.A. Pelmenev, E.A. Popov, A.F. Shestakov, Chem. Phys. 189, 367 (1994).

P02 WIGNER CRYSTAL PHASE OF AN ULTRA-COLD TWO-DIMENSIONAL FERMI SYSTEM WITH LONG RANGE DIPOLE-DIPOLE INTERACTION

O. Ciftja
1Department of Physics, Prairie View A&M University, Prairie View, Texas 77446, USA
ogciftja@pvamu.edu

Ultra-cold two-dimensional (2D) Fermi systems provide fascinating opportunities to study subtle many-particle phenomena and phase transitions [1]. New states of matter range from Wigner crystal to quantum Hall effect phases in a strong magnetic field [2,3]. In such systems one can tune the properties of the interacting particles in a controllable way, for instance, rapid rotation mimics the role of a magnetic field, etc. While electrons interact with a Coulomb potential, in a typical experimental realization of an ultra-cold 2D Fermi system, the interaction between particles is dominated by the long range dipole-dipole interaction potential. In this work we focus our attention on the Wigner crystal phase of an ultra-cold 2D Fermi system of particles interacting with a long-range dipole-dipole interaction potential. We assume that the dipole moments are aligned parallel to each other and are perpendicular to the 2D system. The dipolar interaction potential in the 2D plane in this case is isotropic but not of Coulomb form. Since the classical Wigner crystal state is the starting point of many quantum models, it is very important to understand how the dipolar interaction affects the nature of the crystal's lattice lowest energy state. To this effect, we calculate the energy stability of various classical 2D Wigner crystal phases of fermions interacting with a long range dipole-dipole interaction potential and search for the lattice configuration with the lowest energy. The results obtained can be directly compared to experiments in the field of ultra-cold 2D atomic gases as well as studies of rotating 2D Fermi systems in a harmonic confinement potential [4].

[1] M. Baranov, L. Dobrek, K. Goral, L. Santos, and M. Lewenstein, Phys. Scr. 102, 74 (2002).
[2] M. O. Goerbig, P. Lederer, and C. M. Smith, Phys. Rev. B 69, 115327 (2004).
[3] O. Ciftja, Physica B 404, 1629 (2009).
[4] O. Ciftja, J. Phys. Chem. Sol. 75, 931 (2014).

P03 NEW THEORETICAL APPROACH AND EXPERIMENTAL FINDINGS IN STUDYING MATRIX-ISOLATED CH3 ROTATOR

Yu. A. Dmitriev[1], I. A. Zelenetckii[2], K. G. Styrov[2], N. P. Benetis[3]

1 Ioffe Institute, Russia, 2 Department of System Analysis and Control, Institute of Computer Science and Technology, Peter the Great St. Petersburg Polytechnic University, Russia, 3Department of Environmental Engineering and Antipollution Control, Technological Educational Institute of Western Macedonia (TEI), Greece

dmitrievyurij@gmail.com

Experimental data on the methyl radical, CH3, EPR spectrum anisotropy is a source of abundant and reliable information on the molecule rotational motion. Thanks to the quantum nature of the rotator, the adjacent rotational states are split by the large energy gap amounting to about 20 K, for the free radical, which makes observable the growing population of the higher levels at temperatures above the liquid helium, 4.2 K, temperature. At the lowest temperatures, the major contribution to the EPR spectrum comes from the ground, $J = 0$, and the first excited, $J = 1$, rotational states. Because of the coupling between the rotational and nuclear spin states obeying nuclear statistics, the ground state is an EPR quartet, while the first excited state is an EPR doublet. EPR spectra of CH3 radical trapped in solids yield anisotropic hyperfine (hf) interaction, g-, and linewidth tensors [1, 2]. Very recent calculations which base on a new theoretical approach [3] have shown that the quartet is described by axially symmetric hf- and g-tensors, while the doublet shows axial g-tensor and rhombic hf-interaction. A set of solid gas matrix-methyl isolations in CO2 through para-H2 affords tracking gradual reduction in the EPR anisotropy for trapped CH3 due to the tunneling and temperature-assisted tunneling rotation of the radical. Also reported here are simulations of experimental spectra in support of the suggested models of the radical reorientation dynamics.

One more issue addressed by this report, is the observation of non-rotating methyls first discussed by Kiljunen et al. [1]. These centers contribute four weak EPR doublets to the whole spectrum which grow stronger compared to the main multiplets as the spectrum recording temperature is decreased [3]. Based on the new theoretical finding [3], this report presents an explanation which attributes the doublets to the orthorhombic EPR transitions of the excited librational states of the radical.

The research was supported in part by the Russian Foundation for Basic Research (RFBR), research project 16-02-00127a.

[1] T. Kiljunen, E. Popov, H. Kunttu, J. Eloranta, J. Phys. Chem. A, 114, 4770 (2010).
[2] Yu. A. Dmitriev, V. D. Melnikov, K. G. Styrov, M. A. Tumanova, Physica B, 440, 104 (2014).
[3] N. P. Benetis, Yu. Dmitriev, F. Mocci, A. Laaksonen, J. Phys. Chem. A, 119, 9385 (2015).

P04 THE REFRACTIVE INDEX OF CRYODEPOSITES OF ETHANOL, METHANE AND NITROUS OXIDE IN THE VICINITY OF THE PHASE TRANSFORMATION TEMPERATURE

A. Drobyshev, A. Aldiyarov, D. Sokolov, A. Shinbayeva, N. Tokmoldin
Kazakh National University, Kazakhstan
Andrei.Drobyshev@kaznu.kz

Structural-phase transformations are often accompanied by changes in the number of degrees of freedom of molecules. This is most clearly evident in cases where the change in temperature, in particular, a decreasing leads to partial or complete freezing of the orientational ordering or the rotational subsystem of cryocrystals. These are the phase transitions in solid N2, CO, N2O, C2H5OH, etc. The effect of these processes on the optical properties of thin films, such as the refractive indices and the polarizability at the moment cannot be considered as fully clarified. Especially when it comes to the effect of the condensation temperature of thin films on these parameters [1-3].

This paper presents the results of an experimental study of the temperature dependence of the refractive index of ethanol, methane and nitrous oxide in the temperature range including the temperatures of the structural transformations of these substances. Measurements were carried out using a two-beam laser interferometer [4] in the temperature range of 14-130 K. It was found that in the vicinity of the temperatures of structural transformations, the temperature dependence of the refractive index shows a clear non-monotonic behavior.

[1]. M.A. Satorre, M. Domingo, C. Millan, R. Luna, R. Vilaplana, C. Santonja, Planetary and Space Science, 56, 1748 (2008)
[2]. Perry A. Gerakines and Reggie L. Hudson, Astrophysical Journal Letters, 805, 2, L20, (2015)
[3]. M. Domingo, R.Luna, M.A. Satorre, C. Santonja, C. Millán, Journal of Low Temperature Physics, 181, 1, 1-9 (2015
[4]. A.S. Drobyshev, D.N. Garipogly, Fizika Nizkikh Temperatur, 22(7), 814 (1996)

P05 THE EFFECT OF TEMPERATURE DEPOSITION AND CONCENTRATION ON THE VIBRATIONAL SPECTRA OF THE WATER-METHANE CRYOFILMS

A. Aldiyarov, A. Drobyshev, D. Sokolov
al-Farabi Kazakh National University, Kazakhstan
Abdurakhman.Aldiyarov@kaznu.kz

One of methods of physical modeling of formation of methane clathrates in the nature is a process of co-condensation of a mixture of water vapor and various methane concentrations on the cooled to low temperature substrates. This allows on the basis of obtained information, such as the IR spectra of formed films, their refractive indices, density, etc. to make certain conclusions about the methane clathrate formation processes, the impact on these process temperature, pressure, concentration and other parameters. Results of an experimental study of dependence of the vibrational spectra of water vapor and methane thin films at different temperatures of condensation and concentration are given in this work. Condensation temperature varied in the range 16-200 K at a pressure of gas phase.10-4 Torr. The film thickness was 5 micrometers. Based on analysis of the obtained data are being made the conclusions about the formation of methane clathrates, and temperature ranges of their existence.

P06 HEAT TRANSMISSION IN SUPERFLUID HELIUM

Victor Efimov[1], Luiza Kondaurova[2], Alexsey Tsoi[2]
1Institute of Solid State Physics RAS, Chernogolovka, Moscow distr., Russia;
2Institute of Thermophysics, SBRAS, Novosibirsk, Russia
victor_efimov@yahoo.co.uk

The heat transmission in superfluid helium has engineering as well as a scientific interest. On the one hand a refrigeration of superconductive solenoids as sources of magnetic field or as accumulators of energy and cooling of local overheating of solenoid wires is an engineering object. On the other hand the heat flux in superfluid helium increases density of quantum vortexes and guides a turbulent state, which impedes heat leak from the heat surface. So, the interesting scientific problem – remanent vorticity, formation of turbulent state of quantized vortexes, vortex density in stationary state and its decay – very close confluents with engineering poser.

Experiments indicated the film or bubble boiling as a last stage of body overheating in superfluid helium depends from deep under helium level and additional pressure on the heater surrounding and geometry of experiment.

In the report we review the experimental results of heat transmission in helium under overstress in simplest one-dimensional situation, discuss influence of thermodynamic processes on heat transport, significance of vortex system and quantum turbulence for heater overheating and compare these results with our calculation of time evolution of vortex density and increasing of superfluid-normal component friction at constant heat flux. The numerical calculation was done in frame of hydrodynamic of superfluid turbulence.

P07 HIGH TEMPERATURE ANOMALIES OF THE CRYSTALLINE METHANE. INTERPRETATION OF EXPERIMENTAL DATA

A.Yu. Zakharov[1], O. Kirichek[2], A.V. Leont'eva[3], A.I. Erenburg[4], A.Yu. Prokhorov[3],
1Novgorod State University, Russia, 2 Rutherford Appleton Laboratory, United Kingdom, 3Donetsk Institute for Physics & Engineering, Ukraine, 4 Ben-Gurion University of Negev, Israel.
oleg.kirichek@stfc.ac.uk

Today solid methane is broadly used as a moderator material in cold neutron sources. For efficient modelling, designing and operating of such moderators the detailed information about thermodynamic and mechanical properties of solid methane is required. Moreover there is significant presence of methane on several celestial bodies, so this information is also essential for understanding of variety of planetary surface properties. In this paper we review anomalous behaviour of some solid methane properties in temperature range 50 – 70K.

As it was shown in [1] the shear stresses corresponded to breaking point of the bond between solid methane and probe dramatically changes its temperature dependence around 60K. This result agrees well with behaviour of low frequency internal friction of crystalline methane which experiences anomalously large peak around 65K [2]. The effect even exceeds the peak observed at 20.48K phase transition. Such dramatic increasing of low frequency internal friction cannot be explained in framework of classic approach. It is necessary to emphasize, that similar in scale effects have not been observed in other cryo-crystals studied before by the same method.

Furthermore, systematic analysis of temperature dependences of thermodynamic, mechanical and physical properties of solid methane reviles anomalous behaviour previously observed in similar temperature range [3, 4]. Special place belongs to the paper by Tomita [5], where change in methane molecules rotation has been observed by NMR at temperatures above 60K. These results suggested transition to free-rotation regime.

In publication [3] a theoretical model of the transition from quantum to classical regimes of collective rotational excitations in solid methane has been suggested.

[1] O. Kirichek, A. J. Church, M. G. Thomas et al. Cryogenics, 52, 325 (2012).
[2] A.V.Leont'eva, G.A.Marinin, A.Yu.Prokhorov, B.Ya.Sukharevsky, Fiz.Niz.Temp, 20, 815 (1994).
[3] A.Yu.Zakharov, A.V.Leont'eva, A.Yu.Prokhorov, A.I.Erenburg, Fiz.Tv.Tela, 56, 1446 (2014).
[4] A.V. Leont'eva, A.Yu. Prokhorov, A.Yu. Zakharov, A. I. Erenburg, Journal of Experimental Physics, 2014, 127050 (2014).
[5] K. Tomita. Phys. Rev. 89, 429 (1953).

P08 HOPPING PRECESSION OF MOLECULES IN CRYSTALLINE CARBON DIOXIDE FILMS

Nina V. Krainyukova1, Bogdan Kuchta2
1B. Verkin Institute for Low Temperature Physics and Engineering NASU, 61103 Kharkiv, Ukraine,
2Université Aix-Marseille, CNRS, MADIREL, 13396 Marseille, France
krainyukova@ilt.kharkov.ua

It is well-established that the structure of solid CO_2 at ambient pressures is *Pa*3 with four molecules per its elementary cell preferably oriented along the four space cubic diagonals [1]. According to the currently accepted concept such molecules perform small librations with the average angle θ between molecule axes and cubic diagonals not exceeding 5-6 degrees at low temperatures (see Fig. 1). But several distinct experimental observations show that such a concept may be not completely true.

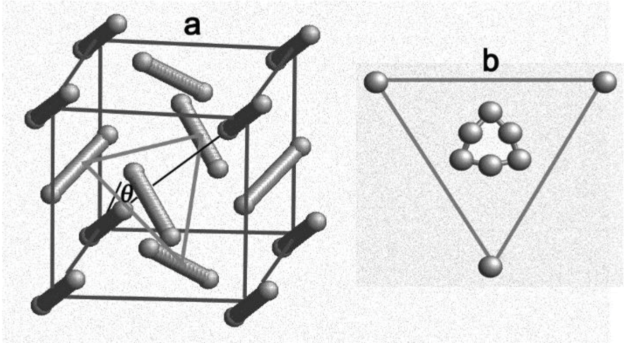


Fig. 1. The *Pa*3 structure (a) and the projection of the molecule tip trajectory on the basal plane (b)

In this work we report our results on the low-temperature transmission high-energy electron diffraction study on the solid carbon dioxide films in the temperature range 15-87 K that revealed the more complicated character of molecular motion than it was thought before.

Indeed we have found that some molecular orientations different from their alignment along space cubic diagonals fit much better to the experimental diffraction intensities. The precise analysis shows that molecule ends tend to be oriented towards the empty spaces between two molecules in the nearest basal planes (see Fig. 1b) instead to be preferably oriented along the space diagonals. We have found that the relevant maximal θ deviations in the selected directions could be as much as ~30 degrees at the lowest temperatures and decrease with increasing temperature. This results in the hopping precession of molecules instead of simple librations. To explain these observations we should apparently take into account interaction with more neighbors, not only the nearest. Such interactions can make molecules to deviate from cubic diagonals in a dynamical way.

[1] Physics of Cryocrystals, V.G. Manzhelii, Y.A. Freiman (Eds.), American Institute of Physics, (1997).

P09 ARGON NANOCLUSTERS WITH FIVEFOLD SYMMETRY IN SUPERSONIC GAS JETS AND SUPERFLUID HELIUM

N. V. Krainyukova[1], R. E. Boltnev[2], O. G. Danylchenko[1], V. V. Khmelenko[3], V. Kiryukhin[4], O. P. Konotop[1], D. M. Lee[3]
1B. Verkin Institute for Low Temperature Physics and Engineering NASU, 61103 Kharkiv, Ukraine,
2Branch of Institute of Energy Problems of Chemical Physics, Chernogolovka, Moscow Region 142432, Russia,
3Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77845, USA,
4Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA
krainyukova@ilt.kharkov.ua

The problem of size-dependent structural transformations between clusters with different symmetries including multiply-twinned particles (MTPs) has been of high scientific interest for a long time. Such MTPs as icosahedra and decahedra (Fig. 1) prevail as compared with single crystal nanoparticles due to their lower surface energies. The theory predicts that the most favorable at smallest sizes icosahedra lose their energetic prevalence in favor of decahedra at cluster sizes $N \sim 2000$ atoms. The upper limit for stable MTPs was estimated to be about $N \sim 10^5$ atoms, while above only the hcp clusters are the most favorable.

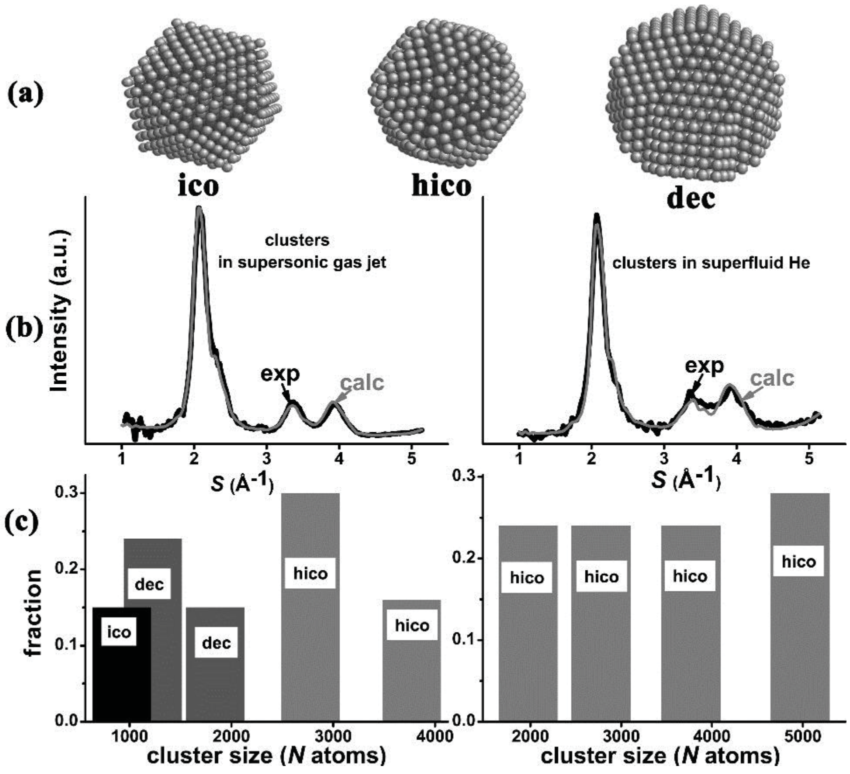


Fig. 1. Clusters with fivefold symmetry (a) revealed in our analysis of the diffraction data (b): icosahedra (ico), hexagonal icosahedra (hico) and decahedra (dec) with their relative fractions (c) in the studied samples.

We report the comparative study of argon nanoclusters formed in supersonic gas jets and immersed in superfluid helium by means of high-energy electron and x-ray diffraction methods respectively. Both techniques allow investigation of isolated clusters. We show that the theoretical predictions are in general close to reality but appearance of hexagonal icosahedra and shifts of size-dependent transformations could owe to the kinetic reasons as well as to the temperature related effects.

P10 CRYOCRYSTALS AS SUBSTRATES FOR SURFACE STATE ELECTRONS

Paul Leiderer[1,3], Kimitoshi Kono[2,3], David G. Rees[2,3]
1University of Konstanz, Germany, 2National Chiao Tung University, Taiwan, 3RIKEN CEMS, Japan
paul.leiderer@uni-konstanz.de

Surface State Electrons (SSE) on inert substrates have been studied for more than four decades, but still this system provides intriguing physical problems [1]. Most of the experiments carried out so far have been done on the surface of liquid helium, which appears as a nearly ideal substrate. However, the electron density is limited there to a value of ~$2\text{x}10^9$ cm^{-2} due to an electro-hydrodynamic (EHD) instability. This prevents one from studying SSE in the high-density regime, where the electron Wigner crystal is predicted to melt in a quantum phase transition towards a degenerate Fermi gas.

With solid substrates however, the EHD instability should in principle be avoided, allowing access to the high-density regime. Candidates, which, due to their small polarizability, provide external surface states for the electrons, are molecular hydrogen and neon. Indeed, experiments with SSE on these solids have been reported [2-5]. Whilst these investigations were made on bulk crystals, significant interest lies in manipulating electrons in confined geometries such as micron-sized channels [1]. In this case the substrate structure must be covered with a solid hydrogen or neon film. This can be achieved by preparing a film from the gas phase below the triple point temperature T_t by a quench-condensation process. However, this results in relatively rough solid films with low electron mobility [6]. Alternatively, a capillary-condensed liquid film in a channel can be solidified by slowly lowering the temperature below T_t.

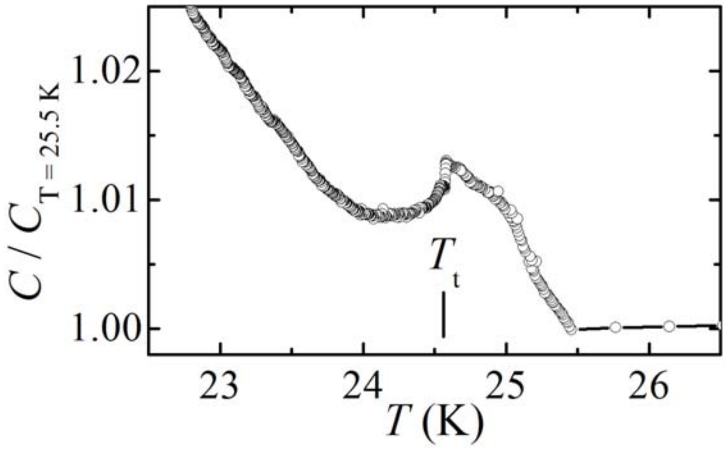


Figure 1. Normalized capacitance of the interdigitated channel device cooled in Neon gas. Above Tt liquid Neon capillary condenses into the channels. At Tt the capacitance decreases suggesting a deformation of the Neon surface on solidification.

Here we report efforts to follow the second route. An interdigitated capacitor was prepared on a PCB section, the copper electrodes of which formed an array of channels 300 µm wide, 30 µm deep and 15 mm long. The device was cooled slowly in Neon gas, taking care to maintain the pressure above the triple point value (433 mbar) when approaching T_t (24.56 K). Just above Tt the capacitance C of the device began to increase as liquid Neon condensed into the channels (Fig. 1). However, at T_t, a significant drop in C was observed. At still lower temperatures, C once again began to increase. Our results confirm the capillary condensation of the liquid Neon, and that the solid continues to thicken on the surface of the device below T_t. However, the marked drop in C at the triple point indicates that some deformation of the Neon film may occur due to strain exerted on the solid. The implications for the study of SSE on capillary condensed solids will be discussed.

[1] D. G. Rees et al., Phys. Rev Lett. 116, 206801 (2016).
[2] A. M. Troyanovskii et al., JETP Lett. 29, 385 (1979)
[3] K. Kajita, Surf. Sci. 142, 86 (1984)
[4] M. A. Paalanen and Y. Iye, Phys. Rev. Lett. 55, 1761 (1985)
[5] D. Cieslikowski et al., Phys. Rev. Lett. 58, 1751-1754 (1987)
[6] K. Kono et al., J. Low Temp. Phys. 82, 279-293 (1991)

P11 INFLUENCE OF HELIUM ATOMS ADSORBTION ON THE EMISSION PROPERTIES OF CARBON NANOTUBES

S.M.Umaev[1], A.A.Levchenko[1,2], S.V.Filatov[1,2]
1Institute of Solid State Physics RAS, Russia, 1L.D. Landau Institute of Theoretical Physics RAS, Russia
levch@issp.ac.ru

We have investigated field emission properties of charge sources based on carbon nanotubes prepared by arc discharge deposition of nanotubes onto a flat copper substrate [1,2]. The charge course was submerged into superfluid helium at temperature T=1.3 K. The collector fixed above the charge course at a distance of 3 mm was connected to an electrometer. The current of charges was measured by the electrometer when applying a high voltage to the charge source. In the originally prepared source the emission of charges (electrons) on the level of 10^{-12}A is observed at negative voltage above U=100V and increases exponentially with increasing voltage. If the source of charge is kept in liquid helium for 15 hours, the current-voltage characteristic changed significantly. The charges current on the same level of 10^{-12} A was registered at a voltage of U=200V. Extraction of gases from the source placed in vacuum chamber at room temperature for 24 hours leads to the complete recovery of emission properties. One can assume that the degradation of emission properties of the sources is associated with the adsorption of helium atoms by carbon nanotubes at low temperatures.

[1] D.N.Borisenko, P.M.Walmsley, A.I.Golov, N.N.Kolesnikov, Yu.V.Kotov, A.A. Levchenko, M. Fear, Instruments and experimental techniques, 57, 6, 755 (2014)
[2] D.N.Borisenko, P. M.Walmsley, A.I.Golov, N.N.Kolesnikov, Yu.V.Kotov, A.A. Levchenko, M.Fear, Low Temp. Phys. 41, 7, 567 (2015)

P12 INSTABILITY OF THE WATER SURFACE IN AN EXTERNAL ELECTIC FIELD

I.Chikina[1], D.Khramov[2], A.Levchenko[2], V.Shikin[2]
1 LIONS, NIMBE, CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191
Gif sur Yvette Cedex, France
2 ISSP RAS, Chernogolovka, Moscow District 142432, Russia

The influence of the dissociation degree for water molecules on the critical conditions of the development of instability of water-air boundary in an external electric field perpendicular to the boundary is discussed. It is shown that the occurring breakdown phenomena observed in [1] are characterized by two relaxation times: the time τ_{jet} of a charged liquid surface discharging and the time T_* of formation of the accumulation layer near the liquid-vapor boundary $(\tau_{jet} < T_*)$. Breakdowns can be periodical (see Fig.1) with a characteristic time T_*, depending on the properties of dilute charged solution and the value of external electric field $E_\perp$. The nature of the times τ_{jet} and T_* as well as methods for their measurement are discussed in details.

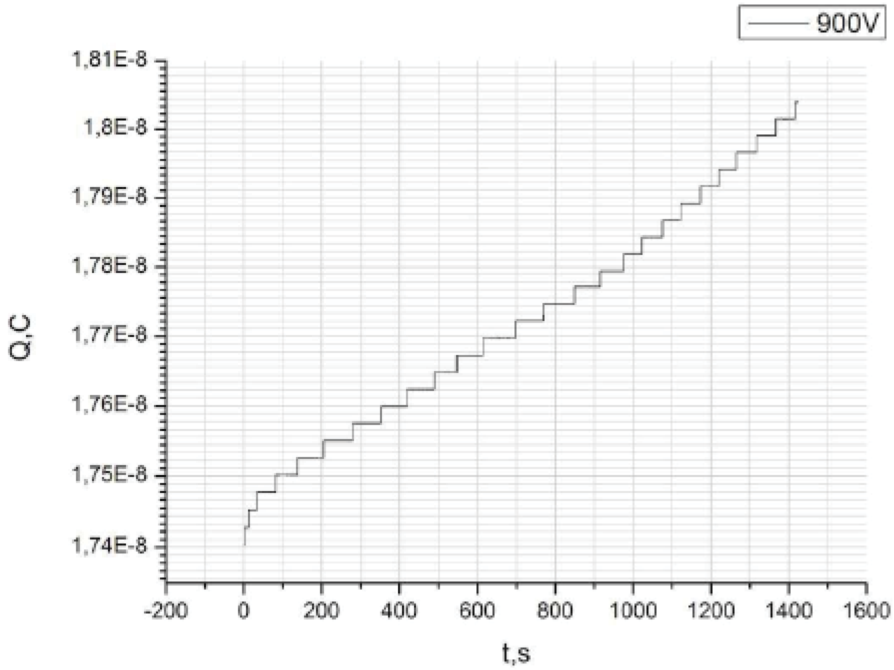


Fig.1. Time dependence of positive ions charge Q(t) coming through free liquid-vapor border of pure water measured in electrical field higher critical value.

1. A.Levchnko, A.Likhter, D.Khramov, V.Shikin. Proceedings of CC -2014, Almaty, Kazakhstan 2014

P13 STRUCTURE OF SOLID α – NITROGEN DOPED METHANE

N.S. Mysko-Krutik, A.A. Solodovnik
B.Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine,
Prospekt Nauky, 47, Kharkiv 61103, Ukraine
e-mail: misko@ilt.kharkov.ua

Solid nitrogen and methane are substances importance for solving problems of the solid state, such as molecular glasses, phase transitions, rotational states [1]; methane is known to occur in the planetary environments [2]. Solid N_2 are the formed by the linear and CH_4 - tetrahedral molecules. In the lattice CH_4 molecules demonstrate a tendency to approximate to spheres. Both crystals at low temperatures are orientationally ordered [3, 4]; close to melting both are in orientationally disordered states. The problem of external influence on the rotational states of methane-nitrogen alloys is of fundamental interest. The nitrogen – methane solid phase diagram has been determined using X-ray diffraction [5, 6]. There are subs rational discrepancies between results in those structure findings. One of our aims was to educate the reasons behind those discrepancy at low temperatures using a different experimental technique (THEED). One of advantages is the smaller size of typical crystallites a closer approach to thermodynamic equilibrium.

Our THEED studies were performed at two temperatures 5.5 and 20 K. CH_4 and N_2 mixtures were deposited on Al or carbon substrates. The methane molecular concentration x was varied from 0 to 40%. The deposition regime was chosen in order to obtain random distributions of impurities. The error in lattice parameter measurements was usually 0.1%.

Analysis for diffraction patterns allowed us to determine the region of existence of solid solutions. The lattice parameters as a function both x and T are analyzed using Prigogine's theory and the cluster approach [7]. The phase separation of the solutions was studied. The orientation order-disorder line was determined as a function of nitrogen content. The discussion of previous work and the various experimental methods is presented.

[1] The Physics of Cryocrystals, V. G. Manzhelii, Yu. A. Freiman, M. L. Klein, A. A. Maradudin (eds.), AIP Press, Woodbury (1997).
[2] New Horizons Update: Methane Detected; New Images of Pluto and Charon; Sunrise/Sunset Observations, Lillian Gipson (NASA), RIA NEWS, July 31, 2015.
[3] J. A. Venables, Phil. Mag., 21, 147 (1970).
[4] W. Press, S. Chem. Phys., 56, 2597 (1972).
[5] D. Connolley, T. Milbrodt, and R. Stoner, J. Chem. Phys., 73 (1980).
[6] A. I. Prokhvatilov, L. D. Yantsevich., Fiz.Nizk.Temp. 9, 185 (1983).
[7] V. V. Danchuk, A. A. Solodovnik, N. S. Mysko, Fiz.Nizk.Temp., 39, 586 (2013) [Low Temp. Phys. 39, 456 (2013)].

P14 EFFECTS IN HEAT TRANSFER CAUSED BY THE PRESENCE OF DIFERENT TYPES OF NANOPARTICLES INSIDE CRYOCRYSTALS

R.V. Nikonkov1, P. Stachowiak 1, A. Jeżowski 1

1 Institute of Low Temperature and Structure Research PAS, Okólna 2, 50-422 Wroclaw, Poland

R.Nikonkov@int.pan.wroc.pl

Transport properties of nanocomposites consisted of nanoparticles embedded in a cryocrystalline matrix are really interesting objects of investigation. By applying the thermal conductivity experimental technique to investigate such objects at low temperatures, one can get an answer to numerous questions regarding the influence of properties and parameters of such nanocomposites components on their total thermal conductivity. For such nanocomposites we used argon, nitrogen and carbon monoxide as the crystalline matrixes and nanopowders of silica and palladium as the includings. The key goal of the thermal transport investigation was to obtain and understand the basic information about the phonon interactions in materials of this kind. In our experiment we determined how the nanoparticles of different sizes effect the total thermal conductivity. We also specified the influence of the parameters of the crystalline matrix, such as the interaction strength between its constituents, the atomic (molecular) mass of constituents or the type of excited lattice thermal vibrations on the thermal conductivity. In order to see the most significant effects our measurements were carried out in the temperature range from 2 to 35K.

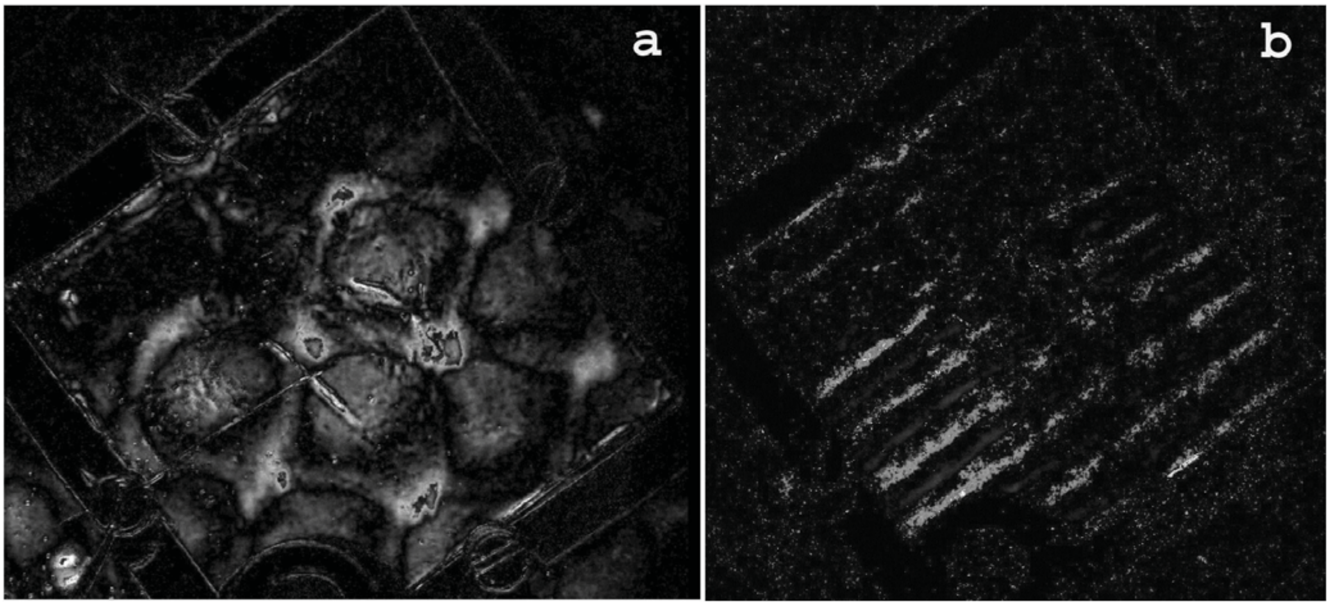
This work was supported by the National Science Centre (Poland) Grant No. UMO-2013/08/M/ST3/00934.

P15 VISUALIZATION OF THE SURFACE PATTERNS IN He-II

A.A Pelmenev[1, 2], A.A. Levchenko[1, 3], L.P. Mezhov-Deglin[1, 3]
1L.D. Landau Institute of Theoretical Physics RAS, Russia, 2Branch of Talroze Institute for Energy Problems of Chemical Physics RAS, Russia, 3Institute of Solid State Physics RAS, Russia
pelmenevaa@gmail.com

The low temperature insert into the commercial metal cryostat of inner diameter 200 mm and of the helium bath length 1260 mm for investigation of nonlinear phenomena on the free surface of superfluid He-II (for example, development of the Faraday instability on a vibrating liquid surface [1,2]) has been designed. Frequency of the vertical vibrations of an experimental cell filled with liquid helium can be changed in the range of 5 - 100 Hz while keeping it at a constant temperature down to 1.4 K. Amplitude of the cell vibrations can be varied in a broad range from 0.01 to 1 mm. We recorded the images of the liquid surface through a window positioned on the upper flange of the insert using a video camera with pixel array 1920 by 1080. In a series of preliminary measurements we have used glass cylindrical cells with an inner diameter up to 100 mm and 18 mm high, and also plexiglass square cells with the back side ~50 mm and up to 20 mm high.

An example of observations of the Faraday instability on the surface of He-II at high amplitudes of the cell vibrations is shown below: (a) - standing waves in the square cell of 4.8 cm length and 0.7 cm depth subjected to sinusoidal vertical vibration at 25 Hz; (b) – standing waves in the same cell at 40 Hz. The bath temperature is T = 1.5 K. The frequency of the standing waves is one half of the pumping frequency.



Later on for detailed visualization of the nonlinear processes on the He-II surface (development Faraday instabilities on the surface with a time at high pump amplitudes, or attenuation of the fluid rotation in the experimental cell) we used the small light particles (tracers), particularly ~60 μm hollow glass microspheres or ~1 mm beads of plastic foam with a density close to the He-II density, which were placed beforehand into the experimental cell.

The work was supported by the Russian Science Foundation, Grant No. 14-22-00259.

[1] W.S. Edwards and S. Fauve, J. Fluid Mech. Vol. 278, 123-148 (1994).
[2] Haruka Abe, Tetsuto Ueda, Michihiro Morikawa, Yu Saitoh, Ryuji Nomura, Yuichi Okuda. Phys. Rev. E 76, 046305 (2007).

P16 SURFACE INSTABILITY OF SUPERFLUID HE-II INDUCED BY A STEADY HEAT FLOW WITHIN THE LIQUID

I.A. Remizov, A.A. Levchenko, L.P. Mezhov-Deglin
Institute of Solid State Physics RAS, Russia
remizov@issp.ac.ru

Results of our recent investigations of the Kelvin-Helmholtz instability on the surface of superfluid He-II induced by a heat flow within the liquid are presented. Experiments were made in a rectangular optical cell filled with He-II in the temperature range from 1.3 to 2.0 K. Heat flux in bulk was generated by a film heater connected with an outer voltage source. The surface oscillations were monitored by recording the power variation of the reflected laser beam from the liquid surface.

Theory of K-H instability developed by S. Korshunov in the paper [1] predicts that the free He-II surface becomes unstable at a counterflow velocity above a certain threshold value. And we have estimated numerically the threshold heat fluxes Q_{thr} at different temperatures in He-II using the results of theoretical consideration [1]. From the comparison between the theory and experiment it follows, that the temperature dependence of the threshold heat flux Q_{thr} (T) predicted by the theory is consistent with the results of direct measurements, and at the same time, the experimental points are placed near an order of magnitude below the theoretical curve.

1. S.E. Korshunov, JETP Lett. 75, 423 (2002).

P17 EXPERIMENTAL SAMPLE CELL FOR MOLECULAR BEAM DEPOSITION AND MAGNETIC RESONANCE STUDIES OF MATRIX ISOLATED RADICALS AT TEMPERATURES BELOW 1K

S.Sheludiakov1, J.Ahokas1, J.Järvinen1, O.Vainio1, L.Lehtonen1, D.Zvezdov1,2, S.Vasiliev1, D.M.Lee3 and V.V.Khmelenko3,
1Department of Physics and Astronomy, University of Turku, 20014 Turku, Finland, 2Institute of Physics, Kazan Federal University, 18 Kremlyovskaya St., Kazan, Russia, 3Department of Physics and Astronomy, Texas A&M University, College Station, TX, 77843, USA
seshel@utu.fi

We present the design and performance of an experimental cell constructed for matrix isolation studies of atoms of all three hydrogen isotopes stabilized in different matrices of solid hydrogens. The sample cell allows sensitive weighing of the films by a quartz microbalance (QM) and their studies by magnetic resonance techniques in a strong magnetic field of 4.6T. We are able to regulate the deposition rate in the range from 0.01 to 10 molecular layers/s, and measure the thickness with a 0.2 monolayer resolution. The samples can be deposited directly from room temperature or from a specially built sublimation source. The upper QM electrode serves as a mirror for a 128GHz Fabry-Perot resonator connected to an electron spin resonance spectrometer. Unpaired atoms of hydrogen isotopes can be created inside the matrix by two different ways: running an rf discharge *in situ* in the sample cell or by adding a certain amount of β-radioactive tritium. The samples can be characterized by ESR and electron-nuclear double resonance which can be performed for all three hydrogen isotopes. From the magnetic resonance measurements we conclude that the films are smooth and provide homogeneous trapping conditions for embedded atoms. The current sample cell design also makes it possible to calibrate the ESR signal and estimate the average and local concentrations of atomic radicals in the films [1].

[1] Sheludiakov et al. Rev.Sci.Instrum. 85, 053902 (2014)

P18 THERMAL CONDUCTIVITY OF MEAT DURING FREEZING. EXPERIMENTAL INVESTIGATION AND COMPUTER SIMULATION.

A. Shinbayeva1, I. Arkharov2, A. Aldiyarov1, A. Drobyshev1, M. Zhubaniyazova3, V.Kurnosov1.
1al-Farabi Kazakh National University, Kazakhstan, 2Bauman Moscow State Technical University, Russia, 3K.Zhubanov Aktobe Regional State University, Kazakhstan
shinbayeva_a@hotmail.com

Cryogenic technologies of processing and storage of agricultural products are being increasingly used as an important factor in ensuring food safety. One of the directions of such technologies is a shock freezing of meat, which allows a much greater extent to ensure the preservation of the quality of frozen products in comparison with traditional technologies. An important parameter for reducing the energy consumption of the freezing process is the thermal conductivity of the meat. This paper presents results of an experimental investigations of the dependence of thermal conductivity of beef samples from temperature.The measurements were carried out using a specially designed measurement cell, allowing carry out measurements in the temperature range from 300 to 80 K.Computer simulation of the process of meat freezing based on the Stefan problem was carried out. Comparative analysis of obtained data is being carried out.

Author index