Magneto-optical Kerr effect in magnetoplasmonic crystals

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Abstract

Strong modification of transversal magneto-optical Kerr effect (TKE) is experimentally observed in 1D and 2D magnetoplasmonic crystals due to resonant excitation of surface plasmon-polaritons. In one-dimensional structures the SPP excitation leads to appearance of Fano-type resonant features in the TKE spectrum.

1. Introduction

Periodically patterned surface provides an opportunity to excite surface plasmon-polaritons (SPP) at the surface of subwavelength gratings called plasmonic crystals. Plasmonic crystals are generally fabricated from noble metals, for example, from gold or silver. Magnetoplasmonic crystals represent a special class of plasmonic crystals which are fabricated from magnetic metals, for example, from nickel, cobalt or from composite of magnetic and noble metals. Such structures possess magneto-optical activity and surface plasmon resonances simultaneously. In recent years many papers about effects in magnetoplasmonic systems have appeared. [1,2,3] In this work, transversal magneto-optical Kerr effect (TKE) in 1D and 2D magnetoplasmonic crystals are studied.

2. Transversal Magneto-Optical Effect in 1D magnetoplasmonic crystals

Samples of 1D magnetoplasmonic crystals are formed by periodical nickel grooves made at the nickel surface. Nickel films with the thickness of h=100 nm were thermally deposited onto a polymeric substrate having 1D spatial profile. The period of the structure is 320 nm and the depth of the grooves is ~50 nm. The AFM image and its spatial Fourier transform are shown in Fig.1(c,d). Surface plasmon-polaritons can be excited on such periodically patterned metal surface due to phase matching conditions between the wave-vector of the incident light, SPP wave-vector and vector of reciprocal lattice. A graphical representation of the SPP phase-matching is shown in Fig. 1(a,b). SPP excitation is observed as Wood's anomaly dip in reflection spectra for the p-polarized light, corresponding to energy flux redistribution between the reflected light and SPP. Magneto-optical Kerr effect measurements were performed in transversal configuration for the p-polarized light using saturating ac-magnetic field with the maximal strength of 0.5 kOe. The spectral dependences of TKE for different angles of incidence are shown in Fig.2. The SPP excitation leads to appearance of Fano-type resonant features in the TKE spectrum. Spectral dependence of TKE is shifted to the negative TKE values under increasing of the angle of incidence and asymmetric Fano-type resonance is red-shifted following to the Wood's anomaly shift. The shape of TKE spectrum in the vicinity of Wood's anomaly is also changed with the angle of incidence increase.

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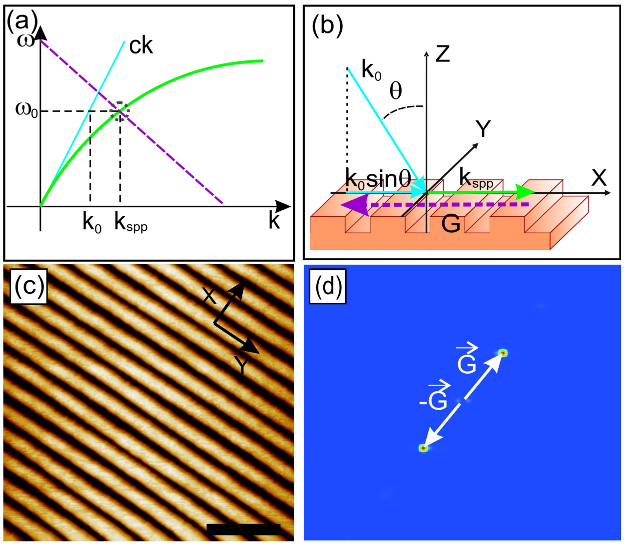

Fig. 1: (a) Graphical representation of the SPP phase-matching as the crossing of dispersion laws of interacting waves. (b) Schematic of the 1D magnetoplasmonic crystal and configuration of the phase-matching for the SPP excitation. (c) The AFM image of the 1D magnetoplasmonic crystals. Black bar is equal to 1 μm. (d) Fourier transform of the AFM image in the reciprocal space visualizing the reciprocal vector **G**.

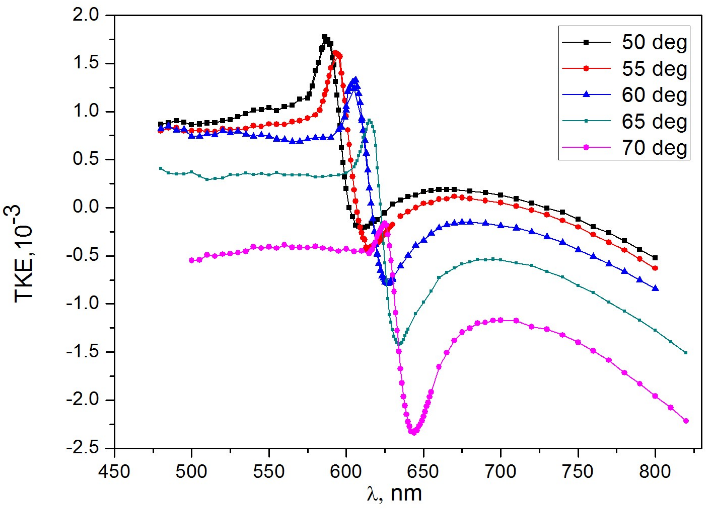

Fig.2:The spectral dependences of transversal Kerr effect in 1D nickel magnetoplasmonic crystals for different angles of incidence.

3. Transversal Magneto-Optical Kerr Effect in 2D magnetoplasmonic crystals

The second group of the samples represents itself 2D slabs of Ni inverse opals with the 560 nm - period. The form and geometrical parameters of such structures are usually characterized by normalized thickness, which is the ratio of the nickel layer thickness to the diameter of microspheres in the opal slab. Optical properties of metal inverse opal slabs have strong dependence from the normalized thickness because not only delocalized surface plasmons but also localized plasmons can be excited in such structures. In this work, Ni inverse opal slabs with normalized thickness in the range from 0.2 to 1.1 are studied. The SEM image of nickel inverse opal slab with normalized thickness of 0.6 is shown in Fig.3. Due to hexagonal packing, opal slab has six reciprocal vectors and, consequently, only two configurations with the azimuthal angles of $\psi=0^0$ and $\psi=30^0$ are important. As well as in 1D structures, SPP can be excited in 2D structures in narrow spectral range where phase matching conditions are fulfilled. This was observed as dips in reflection spectra for the *p*-polarized light. The TKE spectra of Ni inverse opal slabs measured at the angle of incidence $\theta=60^0$ for two azimuthal angles of $\psi=0^0$ and $\psi=30^0$ are shown in Fig.4. The peak positions in the TKE spectra are in the vicinity of dips in reflection spectra and correspond to phase matching conditions of SPP excitation for these azimuthal configurations. The TKE enhancement of about 2-4 times is observed.

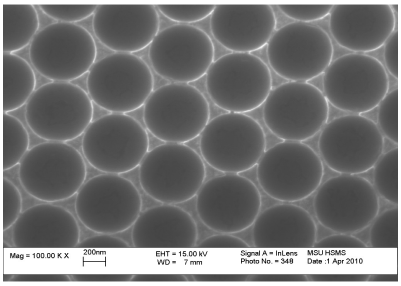

Fig.3: The SEM image of nickel inverse opal slab with the period of *d*=560 nm.

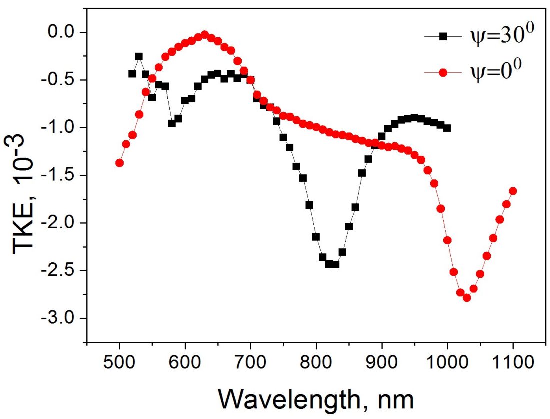

Fig.4: The spectral dependences of transversal Kerr effect in 2D nickel inverse opal slabs for two azimuthal angles, angle of incidence $\theta=60^0$.

4. Conclusions

The SPP excitation at the Wood's anomaly is experimentally observed in 1D nickel magnetoplasmonic crystals and 2D nickel inverse opal slabs. The strong resonant modification of magneto-optical transversal Kerr effect is experimentally observed in the vicinity of Wood's anomaly, corresponding to phase-matching conditions for SPP excitation.

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