Phase Diagram of $^4$He Adsorbed in 1D 2.4 nm Nanopores of FSM

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Superfluidity of $^4$He adsorbed in one-dimensional (1D) nano-channels of FSM has been observed by the torsional oscillator experiment\textsuperscript{1}. The superfluid properties depend on the pore diameter as well as the coverage (the amount adsorbed). Here, we studied the state of $^4$He adsorbed in 2.4 nm diameter 1D pores as a function of the coverage by measuring the pressure for adsorption and heat capacity. In the 2.4 nm pores, uniform $^4$He layers are formed up to about 1.7 atomic layers. At the lower coverages than about 1.1 layers, the $^4$He atoms are localized below a temperature $T_L$ which lowers with increasing the coverage. The heat capacity isotherms have maxima $n_B$ about 1.4 layers. The decrease of heat capacities above $n_B$ indicates Bose quantum fluid layers on inert layers, where qualitatively different low-temperature heat capacities between $^4$He and $^3$He isotopes were adsorbed in other pore diameter FSM. The $^4$He superfluid is observed above about 1.5 layers. Since the inert-layer thickness is estimated to be about 0.55 nm, the tubes (or column) of the $^4$He fluid about 1.3 nm in diameter shows the superfluidity. The fluid tubes are likely to be in a 1D state at low temperatures where the thermal phonon wavelength is longer than the tube diameter.