Magnetism of alkali metal clusters in pressure-doped zeolites

(圧入法によるゼオライト中のアルカリ金属クラスターの磁性)

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Magnetic orderings were observed in alkali-metal clusters stabilized in the nanoporous crystals of aluminosilicate zeolites, although bulk alkali-metals are nonmagnetic. Zeolite is crystalline and has regularly arrayed nanospaces with the well-defined size and alkali-metal clusters are formed in those nanospaces by adsorbing guest alkali metal atoms into zeolite. Mutual interaction between arrayed clusters can lead to macroscopic phenomena, such as magnetic ordering. Magnetic properties of alkali-metal clusters in zeolites were found to vary with changing the loading density of guest alkali metal, namely the average number of guest alkali metal atoms per cluster. The loading density of guest alkali metal, n, can be widely controlled by gas phase adsorption of alkali metals. However, n has the maximum limit at ambient pressure. In this study, we have developed the novel technique of pressure-doping in order to increase n more than the maximum value at ambient pressure. Magnetic properties of various alkali metal clusters in pressure-doped zeolites were investigated.

At doping pressure of 700 – 1000 MPa, new ferromagnetic phase was observed in K clusters in pressure-doped zeolite Low Silica X (LSX) with the FAU-type structure. Curie temperature and Weiss temperature have the maximum value of 13 K and 9.3 K at 910 MPa, respectively. The positive value of T_W clearly indicates the existence of ferromagnetic interaction, probably between supercage clusters. This is very different from other ferromagnetisms found in alkali-metal clusters in zeolites, where the antiferromagnetic interaction plays an important role in the magnetic ordering. Furthermore, an itinerant electron ferromagnetism is anticipated for this ferromagnetism because the metallic state was confirmed at ambient pressure. The estimated loading density n of guest K under pressure reaches around 1 and 2 atoms per supercage at the doping pressures of 700 and 1000 MPa, respectively. The possible electronic models of the new ferromagnetic phase are discussed.

The pressure-doping technique was also applied to K and Rb clusters in zeolite A and Na-K clusters in zeolite LSX. The magnetic properties of those alkali-metal clusters are reported in this thesis.