3. Microscopic Study on Magnetism of Amorphous Materials

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ABSTRACT

Amorphous materials have attracted our attension because they show various interesting properties characteristic of the systems with structural randomness. The macroscopic properties have been investigated extensively, but the microscopic ones are still far from well understood. In this work we investigate the microscopic properties of two types of amorphous magnets: alloy and oxide. The microscopic magentic properties of these materials are considered to be strongly related to the local atomic arrangements and structural relaxation phenomena.

The amorphous $(Co_{0.94}Fe_{0.06})_{74.5}Si_{13.5}B_{12}$ alloy (long ribbon form) is one of the promising magnetic materials for practical application: this alloy is characterized by high permeability, low coercive force and nearly zero magnetostriction constant. The as-prepared sample has been known to show the uniaxial anisotropy along the ribbon's long direction as a macroscopic property, but the local axis of anisotropy has not been examined yet. We applied Mössbauer spectroscopy to this amorphous alloy and investigated the directional distribution of local magnetization axes in the specimen. This kind of information is hard to obtain by macroscopic techniques. In addition, Mössbauer spectroscopy has the advantage that the sample can be studied in the demagnetized state.

The directions of local magnetization axes are found to be laid in the ribbon plane and to be distributed around the ribbon's long direction. If we assume the Gaussian distribution around the ribbon's long direction, the standard deviation is estimated to be about 45°. Such a large distribution of local magnetization axes can not be expected in crystalline solids with uniaxial magnetic anisotropies. This is essentially characteristic of the amorphous materials with structural randomness.

From the thermodynamic viewpoint, the amorphous materials are the nonequilibrium systems. This characteristic causes the instability of atomic arrangements and various properties. We investigated the effects of heat treatments both on the local magnetic anisotropy and the atomic arrangement.

The annealing at 753K ($>T_C$ = 668K) only for 5 min, which is called as the stress-release annealing, removes the preferred orientations of magnetization axes in the ribbon plane: the magnetization axes are distributed almost at random in the ribbon plane. The spectrum still

shows the typical shape of the amorphous alloy, but a small increase of the hyperfine field H_{hf}(<2%) is observed in the annealed sample. This result indicates that the stress-release annealing causes a certain rearrangement of the constitutive atoms, and the circumstances around the magnetic ions are altered.

When we annealed the sample (753K,5min) additionally at 423K in a magnetic field, the magnetization axes rotate from random orientations toward the direction along the magnetic field, and almost all of the magnetization axes are aligned to the magnetic field after the annealing for 10h: the uniaxial magnetic anisotropy is induced. The axes of the magnetic anisotropy thus aligned exhibit a tendency to scatter again to a random orientation when the sample is annealed even at rather low temperatures around 453K.

Both of the hyperfine field and quadrupole splitting do not change in the course of the annealings. These results suggest that the small displacement of constituents play an important role in the mechanism of induction and removal of the local magnetic anisotropies.

We investigated the crystallization process by annealing the specimen at 799K ($=T_x$) or at 873K. The first stage of crystallization was examined by Mössbauer spectroscopy, X-ray diffraction and electron microscopy. The results obtained by each technique are almost consistent with each other, but the small differences are found between them. We consider that the different parts of the results are not contradictory but complementary to each other: the different techniques sometimes give the different profiles of the subject. The details are discussed in the article.

Amorphous magnetic oxides stimulate the interest of many experimentalists, but they have not been examined extensively because of the difficulties in preparations of the glasses containing high concentration of magnetic ions. In order to investigate the magnetic properties of amorphous oxides in comparison with those of amorphous alloys, we applied the Mössbauer spectroscopy to the amorphous oxides Fe_2O_3-BaO-B_2O_3, which is one of a few systems ever known as homogenious magnetic amorphous oxides. Though a large quadrupole splitting is observed in a paramagnetic spectrum, the magnetically split spectrum at low temperature is symmetric around their center of gravity. The symmetric features of the magnetic spectra are reproduced by the following model calculation: (1) The wide distribution of the asymmetric parameters of the electric field gradients (EFG). (2) A random orientations of the principal axes of EFG tensors relative to the direction of the hyperfine field H_{hf}. First hypothesis comes from the consideration that the local asymmetries of ligand field around the ferric ions may be distributed more or less randomly. The hypothesis is very important

to reproduce the symmetric spectrum. This model is considered to be reasonable for the structurally disordered system. The knowldge of the local asymmetries of ligand field is expected to provide the information concerning with the angular distribution of the atomic arrangement, which can be scarcely obtained by other techniques.

The temperature dependence of hyperfine field of the amorphous oxide Fe_2O_3-BaO-B_2O_3 was examined accurately. The hyperfine field decreases slower than the corresponding Brillouin function with increasing temperature. This result is quite different from that of most of the amorphous alloys. The reason for the difference remains still unsettled.

4. Semi-Classical Theory of Atomic Collision Based on the Dynamical Representation and Its Application to $(Li-Na)^+$ System

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ABSTRACT

In the theoretical treatment of atom-atom or ion-atom collision processes the adiabatic state representation is generally the best one unless collision energies are very high. In this representation the electronic transitions can be interpreted in terms of non-adiabatic coupling terms. There are two kinds of non-adiabatic couplings, i.e., radial coupling and rotational coupling. The non-adiabatic radial coupling which governs a transition between the adiabatic molecular states of the same symmetry has been investigated successfully. The transition occurs locally at avoided crossing of potential energy curves. The Landau-Zener-Stueckelbelg theory, and its extentions and modifications can be successfully applied to the problem. Rotational coupling presents another important non-adiabatic coupling which governs a transition between the adiabatic states of different symmetry. Because of the difficulty in the analytical structure of this coupling, any good analytical theory to deal with the rotationally induced non-adiabatic transitions has not been yet developed.

Recently the semiclassical theory of rotationally induced non-adiabatic transitions is proposed based on a "dynamical state" representation. In this new representation all transitions can be considered to occur locally at the avoided crossings of the new dynamical effective potential curves. Because of this localized behavior, we can deal with a many-state