Non-Equilibrium Materials Prof. **Akihisa Inoue** (1990.5~)

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【Research Activities】

In this fiscal term, we have succeeded in fabricating small pressure sensors with ultrahigh sensitivity, and the smallest geared motor in the world both of which are made of metallic glasses. In addition, we have found new non-equilibrium materials in Co-based alloy system with higher mechanical strength than that we found in the last term. Furthermore, we also have found Fe-based alloy system with high strength, high saturation magnetization and excellent hard magnetic properties. The metallic glass sensors produced in this term enable us to use them under higher pressure atmosphere, which is as twice high as that of stainless sensors, and have a more than four times higher sensitivity than that of the stainless sensor. There are two types of the sensors: high pressure type made of Ni-based alloy, and high sensitivity type made of Zr-based alloy, and by adopting strain-gage-vaporization techniques well-developed for the metallic glasses, we are proceeding the researches aiming at the industrialization of these sensors by the fiscal term of 2007. In addition, we have also succeeded in fabricating the smallest geared motor in which the micro scale gears are built-in. The geared motor is made of metallic glass with a diameter of 1.5 mm, and has a gear-reduction ratio of 40:1. The geared motor of metallic glass has a longer endure life time than that of steel by the factor of thirty or more, which enable us to produce the gear motor with miniturelization and high-load properties. We have started to conduct the researches with the aim of using this geared motor as drive source in advanced medical equipment such as an endoscope or a catheter, so as to achieve the aim until the fiscal year of 2006. We have developed another new non-equilibrium material in Co-based alloy with ultra-high strength more than 5000 MPa. The $Co_{43}Fe_{20}Ta_{5.5}B_{31.5}$ alloy exhibits the supercooled liquid region of 72 K before crystallization, and can be produced as a bulk metallic glass with a maximum diameter of 2 mm. Furthermore, the alloy has a high strength of 5185 MPa, high Young's modulus of 268 GPa, and its high strength exceeding 5000 MPa remains in the temperature ranges up to 698 K. We have found good soft magnetic materials in Fe-based alloys with high saturation magnetization of 1.5 T, low coercive force as small as 3 A/m, and high permeability of the order of 17,000 at 1 KHz. We have also developed another Fe-based alloy with hard magnetic properties in Fe-Pt-B system by controlling the morphology and make it as a nano-composite material. The composite exhibits good hard magnetic properties: remanence of 0.79-0.82, saturation magnetization of 0.93-1.05 T, coercive force of 375-487 kA/m, and maximum energy product of 118-127 kJ/m^3.

1. NISHIYAMA N., AMIYA K., INOUE A.
Bulk Metallic Glasses for Industrial Products

Mater. Trans., 45 (2004), 11245-1250.

2. INOUE A., SHEN B.L., KOSHIBA H., KATO H., YAVARI A.R.
Ultra-High Strength above 5000 MPa and Soft Magnetic Properties of Co-Fe-Ta-B Bulk Glassy Alloys
Acta Mater., 52(2004), 1631-1637.

3. INOUE A., SHEN B.L., CHANG C.T.
Super-High Strength of over 4000 MPa for Fe-based Bulk Glassy Alloys in [(Fe1-xCox)0.75B0.2Si0.05]96Nb4 System
Acta Mater., 52(2004), 4093-4099.

4. INOUE A., SHEN B.L.
New Fe-Based Bulk Glassy Alloys with High Saturated Magnetic Flux Density of 1.4-1.5T
Mater. Sci. Eng., A375-377(2004), 302-306.

5. ZHANG W., LOUZGUINE D.V., INOUE A.
Synthesis and Magnetic Properies of Fe-Pt-B Nanocomposite Permanent Magnets with Low Concentrations
Appl. Phys. Lett., 85(2004), 4998-5000.

【Plan】

The research scheme of this fiscal term can be mainly classified into following four topics. (1) Development of new non-equilibrium alloys: Using the empirical criteria for the achievement of stabilization of supercooled liquid, we are planning to search for alloy systems with much higher stability than the previous ones. Then, we will try to fabricate metallic glasses in a single-phase and nano-crystalline- and nano-quasicrystalline phases dispersive states as well. Then, we try to find out the clues for obtaining new bulk metallic glasses with ultra-high strength and high ductility which have never obtained to date for any kinds of materials. Then, we will investigate fundamental data on novel atomic configurations, alloy systems and compositons for the formation of solid solutions with nanometer grains size, and their atomic configurations, structure, morphology, composition segregations in a nano-scale, mechanical properties, corrosion behavior, magnetic and electronic properties. These fundamental data are used for the evaluation of the alloys for basic studies and industrial utilities. The target alloy systems are ferrous alloy systems consisting of Fe-, Co-, Ni-, Mg-, Ti-, Al- and Cu-based alloys, which all described above are of great high social needs. (2) Computational predictions: By conducting the thermodynamic analyses of the empirical criteria which are practically used for the development of non-equilibrium alloys, and describing them with thermodynamic functions, we are going to establish the computational techniques for the prediction of stabilization of the supercooled liquid and the formation of non-equilibrium phases. (3) Progress of industrialization of the non-equilibrium alloys: By developing the suitable process and optimizing the compositions of the alloys, we will evaluate the possibility for the industrialization of the alloys, and we will have been developed in this term. On the basis of the fundamental findings exemplified as structure, morphology and fundamental properties of the materials of several kinds of non-equilibrium materials, we will investigate the industrial properties. Furthermore, we will develop new fabrication- and work-process by utilizing the phase transformations in a supercooled liquid range and characteristics of the nano-equilibrium phases. I ascertain the utility of the new non-equilibrium alloys as industrial materials.