Basic magnetism, magnetic materials (permanent magnet, magnetostriction materials, magnetically heat generation materials) have been investigated. The outlines of previous studies are summarized in the followings.


Invar alloys are very small expansion coefficient materials, such as Fe-Ni alloys typically. The name, Invar, is sited from “Invariant” in English. Invar alloys are used in the many industrial fields, for instance, a bi-metal used for temperature regulation, a tank for natural liquid gas, shadow mask in a TV and so on.

Fe-based Invar alloys (Fe-Ni, Fe-Pd, Fe-Pt alloys) have face centered cubic lattice and the composition is on the boundary between body centered cubic (bcc) and face centered cubic (fcc) lattices in the periodic table. Furthermore, the magnetic moment of Invar alloys abruptly decrease with increasing Fe composition of alloy. Accordingly, it is emphasized that there are instabilities both in lattice and in ferromagnetism of Invar and many anomalous physical properties are observed for invar. The anomalies are called as “Invar problem”.

We proposed a model for Invar problem, in which two states for Fe in a fcc lattice are hypothesized. The two states are a high spin state having large magnetic moment and large atomic volume and a low spin state having small magnetic moment and small atomic volume. The model could explain Invar anomalies perfectly. The model is shown in Fig 1 (Ref.1). Then, we found a low temperature phase for Fe-Pd Invar alloys (Ref.2).
References


An epitaxially grown ultra thin film on a single crustal substrate could have a non-equilibrium crystal structure. We prepared single crystal artificial metallic super lattices by the molecular beam epitaxy (MBE) method. At first, magnetic moment of γFe was shown in Fig.2. Two magnetic states for γFe are explicitly shown. The experiment is the first attempt to prove the two states of γFe, high and low spin states. Next, ultra thin films of non-equilibrium fcc-Cr, bcc-Ni, and bcc-Cu were prepared and their magnetization was measured.

Furthermore, with super lattices of [Fe(100)/Au(100)], we clarified critical indexes of magnetic transformation for the two dimension ferromagnetic substance.

In addition, we found a surfactant effect of oxygen atom in epitaxial growth of γ-Fe/Cu(001)-O(2√2 × √2)R45 (Ref.6).

Fig.2 Ferromagnetic Moment per aγFe atom as a function of atomic volume of Fe. The lower horizontal axis is difference compared with atomic volume of Cu. When ΔV < 0, ferromagnetic moment per Fe becomes almost zero for paramagnetism or antiferromagnetism. When ΔV > 0, ferromagnetism appears and the value is about 2.5μB. The result means that γFehas two magnetic states, high and low spin states (Ref.4).
References

We performed development studies of half metal film materials for various spin electronics devices. As half metals with special electronic energy band structure, we studied the single crystal film of the perovskite type manganese oxide, spinel type oxide, cobalt-based Heusler alloys. By detail studies about establishment of the high quality ultra thin film manufacturing methods and magnetic and physical properties relating to crystal orientation or the interface consistency with a substrate, many important results for application of half metals to spin devices were obtained, Inverse tunneling magnetoresistance and very small dependency of magnetoresistance on bias voltage were found.

Fig.3 Tunnelling magnetoresistance effect for Co/STO/Sr2CrReO6/SrFeO3 at 4.2K. Using half metallic double perovskite Sr2CrReO6, the maximum value of 114 % in magnetoresistance effect was observed.
References
11.” Effect of crystallographic orientation of \( \text{Co}_2\text{MnGe} \) Heusler-alloy film on its surface roughness and ordered structure”, Y. Takeda, S. Yoshimura, M. Takano, H. Asano,


Magnetic materials for thermotherapy of the cancer (hyperthermia) of the cancer were studied as implant materials. It is said the temperature more than 42 degrees Celsius can necrotize the cancer cell. When an implant is put in a malignant tumor and a high frequency magnetic field from the outside of human body is applied, an implant run a fever for hyteresis loss or eddy current loss of the magnetic material. Then, cancer cells around the implant are necrotized. Because the temperature of the magnetic implant is coordinated in a Curie point automatically (Fig.4), a magnetic material with a Curie point near 50 degrees Celsius is most suitable for hyperthermia. We suggested a Fe-Pt alloy as an alloy implant and succeeded in treatment in the clinical fundamental researches of a brain tumor and the cancer of the tongue. Furthermore, we discovered that MgFe_2O_4 of the spinel type had very big calorific value as powder magnetic implant materials.

References
12. “Research on Hyperthermia Implant Materials from a Point of View of Material Science”, M.


[5] Super magnetostriction on the morphotropic phase boundary and magnetic easy axis boundary

The magnetostriction is a phenomenon that a magnetic material does elastic deformation when a magnetic field is applied. So, the whit displacement of materials is easily controlled by using a magnetic small coil. In addition, as for various actuators, the torque sensor, the supersonic wave oscillator, the applied range is wide because we can applied it to a sensitive displacement sensor by a reverse magnetostriction phenomenon. Materials with the magnetostriction of around several hundred ppm striction are

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**Fig.5** Thermotherapy for the cancer of the tongue using Fe-Pt implant, (1) before the treatment, (2) and (3) just after the treatment, (4) one month later after treatment. (Ref.14).

**Fig.6** polycrystalline magnetostriction of \( f(Tb,Dy)Fe_{2-x}(Tb,Ho)Fe_{2}x \) as a function of temperature. On the magnetic easy axis boundary (MEAB) of \([100]-[111]\), the maximum of magnetostriction is observed for each sample. The result is in good agreement with theory.
called super magnetostriction materials in a low magnetic field less than 1kOe. By theory analysis, it was recognized that the magnetostriction showed a maximum on the morphotropic phase boundary (MPB) or on the magnetic easy axis boundary (MEAB). In the present research, we aim the establishment of super magnetostriction materials search standard and the newly super magnetostriction materials development. I tested it about (Tb,Dy)Fe₂, (Tb,Dy,Ho)Fe₂, (Tb,Ho)Fe₂ so far and already established a part of the search standard of soft magnetic materials with a super magnetostriction search standard. The details are cf. Toyota Institute of Physical and Chemical Research report.