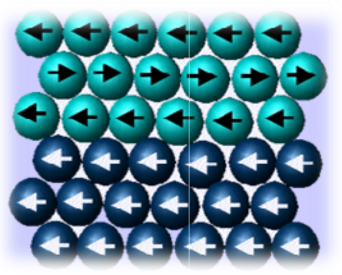
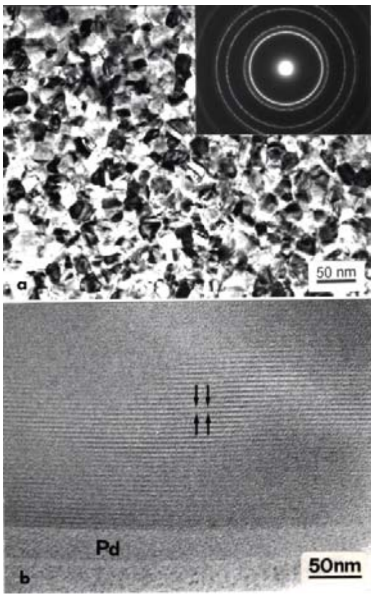
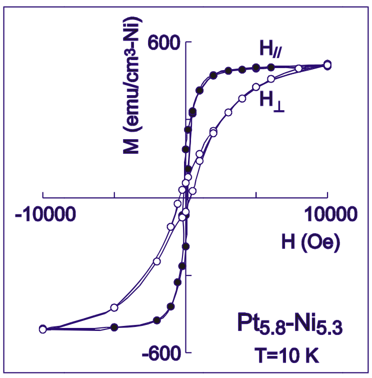


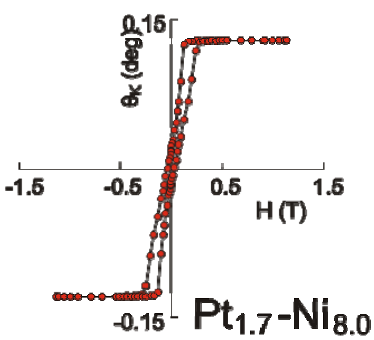
Coupling effects in CMMs



TEM imaging of Pd-Co multilayers



In plane anisotropy in Pt-Ni CMMs



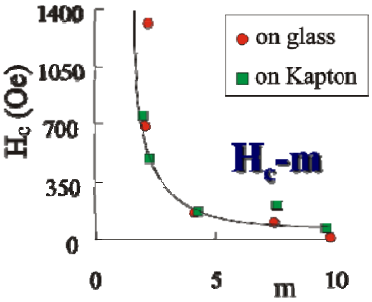
Out of plane anisotropy in CMMs

In early 80's multilayered structures seemed a wild dream for scientists while today they appear in numerous technological applications, such as magnetic recording media and automobile sensors.

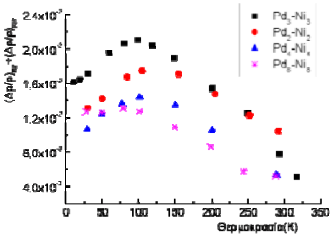
Magnetic multilayers are superlattice structures, in which magnetic layers are separated by non magnetic layers exhibit various effects in which there has been significant recent interest. Among these effects, one may distinguish the giant magnetoresistance (GMR) effect and the oscillatory exchange coupling. The GMR is the change in resistance when relative orientation of the magnetization in neighboring layers is switched by applying magnetic field. The oscillatory exchange coupling is the coupling between the magnetic layers that oscillates in sign as a function of the spacer layer thickness. The main task of the present thesis was the controlled fabrication of magnetic multilayered materials based on systems adequate for technological applications. The systematic structure and physical property study that followed, was performed in the framework of development, interpretation and correlation of these properties with multilayer modulation.

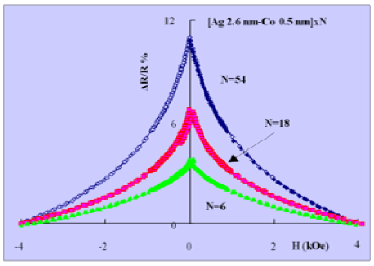
Magnetic Compositionally Modulated Multilayers (CMMs) have been prepared in a three-source evaporation system under ultra high vacuum. The total number of samples exceeded 300. The substrates were mica, glass, Si and polyimide, while the growth temperature varied between 300-500K. The general formation of the CMMs included sequential deposition of a magnetic (Fe, Co, Ni) and a non-magnetic element (Cu, Pd, Pt, Si); the number of the atomic planes of the magnetic (non-magnetic) constituent in a modulation period will be denoted as n (m). A new design based on intentionally alloying of the one constituent is hoped to improve the technological efficiencies of them. Excellent modulation sequence was evidenced in Pd-CoPd multilayers surprisingly without columnar growth. Moreover new types of granular multilayers were prepared combining the properties of multilayers and granular alloys in a unique way. Correlation of structures characteristics with interesting technological features was given in a successful way.

The structural characterization of CMMs was performed via x-ray diffraction and electron microscopy studies. Simulated x-ray diffraction patterns were reproduced in two cases: i) No interdiffusion is assumed to take place at the interfaces (rectangular composition profile) and ii) A variable amount of interdiffusion is permitted (realistic case for materials forming solid solutions). The results of this simulation support the excellent quality of the samples prepared. Electron microscopy studies included SEM, AFM, TEM and XTEM techniques. They allowed the determination of the structure and the investigation of the various defects (primarily twins and dislocations). In some systems (Pt-Ni) a columnar growth was observed. SQUID measurements have been performed in Ni and Co based CMMs at the temperature range between 10 K and room temperature. Pt-Ni samples present perpendicular anisotropy for n<5. For small n (~2) and at very low temperatures enormous hysteresis loops were recorded with remanence ratios over 80% and coercivities greater than 4 kOe. Two exceptional behaviors including the presence of perpendicular anisotropy for large n (when m is very small) and a tendency for perpendicular anisotropy as temperature increases were also recorded. Samples with small n and m > n are not ferromagnetic at room

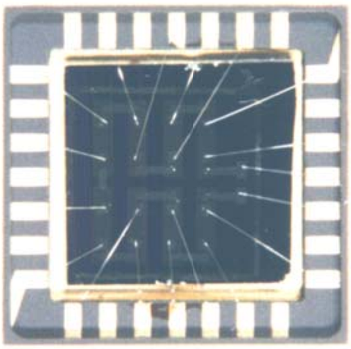


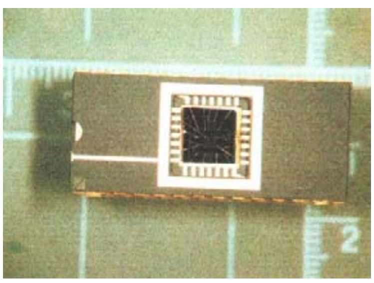
Modulation-dependent features


Anisotropic Magnetoresistance



Giant Magnetoresistance


8 element (2x4) GMR sensor chip


2D GMR sensor

temperature. By modulating Co with Pd or Pt interesting technological features arise such as square perpendicular loops combined with high saturation and remanence values. VSM measurements have been performed in Pd-Ni CMMs at temperatures between 10-300K. Weak perpendicular anisotropy is exhibited only for samples with n=2. Magneto-optical (Kerr effect) measurements were performed for Pd-Ni, Pt-Ni and Pt- Co CMMs at energies between 1.5-5.2 eV at room temperature. The high energy Kerr rotation maxima for easy-axis Pd-Ni CMMs (n=2) increase with n/m ratio (with Ni) but remain smaller than that of the bulk Ni. Measurements at constant energy (1.96 eV) reveal that Kerr rotation depend strongly (although non monotonically) on both m and n. The polar-Kerr effect saturation field of equatomic Pd-Ni CMMs presents a maximum for n=m=6, probably due to structural reasons.The Kerr rotation spectrum of Pt-Co CMMs having constant m (~ 7) reveal an increase of the Kerr rotation maxima with Co. Pt-Ni CMMs with n >> m < 4 present perpendicular anisotropy with the high-energy Kerr rotation maximum equal or greater to that of the pure Ni (~0.14 deg). This behavior is very promising for technological applications. Resistivity and magnetoresistance Pd-Ni CMMs at various temperatures. Giant magnetoresistance (~ 4.5%) has been recorded for Pd_2-Ni_2 at 77 K and it has been reduced to 2% at 300 K. Magnetoresistance curves for most of the samples presented hysteresis.

Anisotropic behavior was observed at samples of short modulation periods. Saturation magnetoresistance was found to vary strongly with the orientation of the magnetic field with respect to the film plane. The dependence of the MR ratio on the angle of the magnetic field with the film plane seems to follow a $\cos^2$ law. Actually, the MR ratio of a magnetic domain exhibits a similar dependence on the magnetic field geometry. The corresponding curves for Pd_1-Ni_1 and Pd_3-Ni_3 exhibited significant deviations, probably due to the initial configuration of the magnetic domains. Magnetotransport study may provide a hint for the magnetic anisotropy of the samples. In order to complement the transport studies resistivity measurements were performed at temperatures between 10-300 K.

The Ag-Co system was studied thoroughly as a potential candidate for a GMR sensor device. A series of samples was developed and structurally and electrically studied. After careful examination a peculiar sample was selected for the fabrication of the sensor. Its structure stands between multilayers and granular alloys and it is considered as a granular multilayer. By adjusting the growth parameters on this specific sample the best GMR signal was achieved which was ~16% at room temperature and ~34% at 30 K. Finally, a two dimensional array of eight (2x4) sensors was fabricated. The sensor's response was quite satisfactory and reproducible signals were measured.

Conclusively, magnetic multilayer modulation with non magnetic spacers provides a powerful tool in Materials' Science since customised properties may arise and be developed intentionally. Truly, the era of nanostructrures has begun with multilayers and continues its successful way towards a more promising future.