SPIN-DEPENDENT TRANSPORT IN NANOGRANULAR Cu-Co AND Ag-Co SPUTTERED THIN FILMS

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by

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Submitted

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Dedicated

To

My Parents and Teachers

CERTIFICATE

This is to certify that the thesis entitled **"Spin-dependent Transport in Nanogranular Cu-Co and Ag-Co Sputtered Thin Films"** being submitted by **Mr. Dinesh Kumar** to the Department of Physics, Indian Institute of Technology Delhi, for the award of the degree of **'Doctor of Philosophy'** is a record of bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for the submission of this thesis, which in our opinion has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree/diploma.

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ABSTRACT

Nanogranular films attract much interest not only due to its novel behavior in magnetic and magnetotransport, but also due to its potential applications in nanodevice and nanostorage. One of the main challenges of data storage and information technology is the miniaturization of magnetic data bits into the nano-regime without losing stability of the stored information. This requires the understanding of the interaction mechanism operative between nano-sized magnetic particles and correlation with their processing is the key to develop materials with more stable magnetic states at reduced dimensions. A complete understanding of the magnetic properties of granular systems is hindered by their complexity i.e., interparticle magnetic interactions and particle size distribution. In fact, it is extremely difficult to properly understand which factor plays a dominant role in the magnetic behavior of granular systems. Thus, the primary aim of this research thesis is to establish a relationship between the growth process with the magnetic microstructure and to investigate the effect interparticle magnetic interactions and particle size distribution on magnetic properties with special emphasis on the magnetotransport properties.

The DC-magnetron sputtering technique is employed to grow $Cu_{100-x}Co_x$ (x=15.1-30.9 at.%) nanogranular films. From the isothermal magnetoresistance (*MR*) behavior in 20-300K range, TEM analysis, and magnetization behavior, three different composition regimes are identified. These are: (i) $x \leq 15.1$, consisting of nearly spherical monodispersed single uncoalesced non-interacting small superparamagnetic (SPM) particles only; (ii) $15.1 < x \leq 21$, having two particle size distributions with small mono-dispersed SPM and weakly interacting bigger SPM particles and (iii) $x > 21$, having mono-dispersed small SPM particles and

ferromagnetic (FM) clusters having broad distribution with stronger interactions. This work provides an insight to understand the transition of spin dependent transport from SPM-SPM to SPM-FM and the gradual increase in the strength of magnetic interaction among the particles vis-à-vis cobalt concentration. As x=21 corresponds to the concentration for which strongest interactions among the SPM particles was detected, so thickness dependent study was performed on $Cu_{79}Co_{21}$ film. Detailed temperature and field dependent investigations of the *MR* and magnetization behavior of these films showed a correlation between film thickness, size and fraction of bigger particles. The role of self-annealing during growth (*in-situ*), via varying the film thickness, in controlling the interparticle magnetic interactions among the superparamagnetic particles, blocking temperature and coercivity is demonstrated.

Further, lattice mismatched and immiscible granular system of $Ag_{100-x}Co_x$($11.8 \leq x \leq 45.1$ at.%) has been investigated. This results in reasonably well contrasted TEM images of Co particles dispersed in Ag matrix, which is hardly possible in Co-Cu system because of the high coherency of Cu and Co lattices. For $x \leq 21.1$ films, it is demonstrated that *MR* fitting, taking explicitly into account both the interparticle magnetic interactions as well as the log normal distribution of magnetic moments, which takes care of both the bulk as well as surface scattering mechanisms gives better estimation of particle sizes than the magnetization data. In case of x>21.1 films, at 20 K, a transition from normal to complex magnetoresistance behavior, in conjunction with magnetic force microscopy evidence of the existence of a magnetic microstructure resulting in perpendicular magnetic anisotropy is detected for x=32.6 cobalt concentration film. The observed complex *MR* behavior and perpendicular magnetic anisotropy are attributed to the manifestation of the transition of interparticle magnetic interactions nature from dipolar to direct ferromagnetic ones.

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LIST OF SYMBOLS AND ACRONYMS

H	Magnetic Field
T	Temperature
t	Thickness
x	Concentration
M	Magnetization
m	Magnetic Moment
T_B	Blocking Temperature
SPM	Superparamagnetic
FM	Ferromagnetic
MR	Magnetoresistance
TMR	Transverse Magnetoresistance
LMR	Longitudinal Magnetoresistance
FC	Field Cooled
ZFC	Zero Field Cooled
TEM	Transmission Electron Microscopy
AFM	Atomic Force Microscopy
MFM	Magnetic Force Microscopy
SQUID	Superconducting Quantum Interference Device
EDX	Energy Dispersive Xay