Spin-dependent phenomena in Co-Al_2O_3 ferromagnetic nanocomposites – the effect of magnetic field on their growth and properties

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In ferromagnetic nanocomposites (FMNCs) transition metal nanoparticles (NPs) are incorporated in a dielectric matrix in technologically controlled way with the required dimensions and shapes. The concentration of ferromagnetic metal in FMNCs determines the dimensions of NPs and magnetic properties of FMNCs, covering both ferromagnetic, spin glass, and superparamagnetic state below a characteristic transition temperature. We examine magnetic, magnetotransport, and thermoelectric properties of Co-Al_2O_3 FMNCs grown in external magnetic field.
Electron beam evaporation of Co and Al_2O_3 from two crucibles was used for deposition of FMNC granular layers on dielectric substrates. The growth of eight sets of FMNCs was carried out in magnetic field applied in the plane of the layer (expected easy magnetization plane) or normal to it. The SEM images of the layers confirm the influence of magnetic field on the process of FMNC formation which is observed as a preferable orientation of long axis of Co NPs in the direction of magnetic field gradient.
Thermoelectric measurements of Co-Al_2O_3 FMNCs revealed at low temperatures a giant thermoelectric power strongly depending on magnetic field. The effect is expected to stem from electronic transport mechanism: spin-dependent hopping through a tunnel-transparent alumina layers between ferromagnetic NPs (under the influence of a temperature gradient). Similar mechanism was recently proposed as the physical origin of negative magnetoresistance effect also observed in these FMNCs with the maximum value of 4% demonstrated for the samples grown in magnetic field perpendicular to the layer plane. For the samples grown in magnetic field the lowering of the percolation threshold for electron transport (from 43 to 27 at.% of Co) was observed and assigned to the reduced height of tunnel barrier between Co NPs.
Magnetic properties of Co-Al_2O_3 FMNCs were studied by magnetization and ferromagnetic resonance (FMR) measurements. The transition to the spin glass state for FMNCs samples formed in the magnetic field applied perpendicular to the sample plane was found to take place at temperatures substantially higher (about 20 K) than for the case of field parallel to the layer (below 5 K). Analysis of the angular dependence of the FMR spectra revealed the magnetic shape anisotropy field of 700 Oe and a disappearance the FMR line below the transition temperature to the spin glass state. The maximum value of the FMR resonant field was found to be not correspond to the magnetic field orientation along the normal to the layer. The declination from this direction corresponds to the direction of long axises of Co NPs explained by geometrical effects of technological setup used for deposition of FMNCs.