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Magnetotransport in Colloidal FePt Nanoparticle Granular System

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Interest in magnetotransport in metal-nonmetal granular thin films is growing recently because they exhibit large tunneling magnetoresistance (TMR), which makes them potential materials for spintronics technology [1]. For example, nanostructured Co-Al-O granular films have been studied and spin-dependent single-electron tunneling, TMR oscillation, and spin accumulation have been observed [2]. However, most of the granular films were fabricated using inorganic matrices (e.g. metal oxides). Moreover, experimental investigations of granular systems with molecule-based matrices have only been initiated recently [3, 4]. Here, we studied magnetotransport in chemically synthesized FePt nanoparticles encapsulated with organic molecules. We observedthat the device shows a large and inverse magnetoresistance effect, as well as magneto-switching effect.

We fabricated the devices with Permalloy/FePt-nanoparticles/Permalloy configuration and measured their magnetotransport properties in lateral geometry. The electrodes were fabricated using electron beam lithography and lift-off technique. The nanoparticle-solvent suspension was dispersed drop-wise on the substrate to trap the nanoparticles inside the electrode gap. The solvent was let to evaporate naturally at room temperature. The magnetotransport was measured in the two-terminal configuration.

We found that the devices show magnetoresistance as much as 10^6 % at H = 10 kOe, V = 10 V, and T = 10 K where, H, V, and T are applied magnetic field, bias voltage, and temperature, respectively. The devices exhibit inverse magnetoresistance effect the device resistance increases significantly when a magnetic field is applied to it. We also confirmed that the magnetoresistance does not significantly depend on the direction of the field, which indicates that mechanical artefacts, magnetostriction effect, etc. can be excluded as the origin of the large magnetoresistance. Current-voltage (I-V) characteristics of the device show that the electron transport is strongly spin-dependent and suggest that magnetic-field-modulatory high-low resistance transition is the origin of the magnetoresistance.

Conventional transport models (e.g. higher-order tunneling, spin accumulation, etc. [1]) cannot explain the large and inverse magnetoresistance that we observed. We propose that hybridization of the electronic states of the magnetic nanoparticle and the organic molecule at the interface is a possible mechanism for the magnetoresistance. The molecular states near the particle-molecule interface become spin-dependent thus theelectron transport in this region becomessensitive to applied magnetic field.

Finally, we demonstrated a reproducible magneto-switching effect, which has an on-off ratio of 180 % between 0 Oe and 100 Oe. The on-off ratio (sensitivity of the switch) of the device can be controlled by tuning magnetic field and bias voltage. This result shows the potentiality of our device to be used for spintronics technology.

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Bias Dependent Tunneling Magnetoresistance of GaAs Diodes with Ferromagnetic (Ga,Mn)As Layers

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Electronic devices utilizing spin manipulation are expected to accelerate the integration of information processing and storage. Especially the advent of diluted magnetic semiconductors (DMS) boosted the research on spin electronics, because of the specific functions not expected from ferromagnetic metals. Various heterostructures involving GaMnAs, the most known DMS, have shown interesting properties such as spin-dependent light emission, gate-controlled ferromagnetism, and current-induced magnetization reversal. Recently a spin-valve-like tunneling anisotropic magnetoresistance was observed in a heterostructure with a single GaMnAs layer.[1] It was found to be strongly bias-dependent,[2] and an interpretation based on anisotropic density of states at the interface was provided.

We have fabricated epitaxial p-i-n diode structures, containing a single GaMnAs layer, by molecular beam epitaxy. For vertical transport measurements, the samples were patterned into mesa structures by using standard photolithography. Low temperature magnetoresistance showed a strong bias voltage dependence, even including sign-changes. The magnetoresistance seems to originate from inherent in-plane magnetic anisotropy and spin-orbit interaction of (Ga,Mn)As. The bias voltage dependence is (partly) in accord with theoretical calculations based on a coherent tunneling model. We will also present the effect of the carrier density on the magnitude of tunneling magnetoresistance.

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