# Research Group for Molecular Spintronics

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Spintronics is an emerging technology taking advantage of the dual freedom of both charge and spin degrees. Since the discovery of the giant magnetoresistance of metal multilayers in 1988 (A. Fert and P. Grünberg, the 2007 Nobel Prize in Physics), spintronics has been developed based on inorganic substances like metals and semiconductors. Recent studies have started to shed light on spintronic applications of molecular materials including organic molecules and nanocarbons in which the spins of conduction electrons can be preserved for a long time and distance. We call this new field "Molecular spintroncis".

In molecular spintronics, efficient control of spin transport processes (spin injection, manipulation and detection) in molecular materials are of special importance to realize spintronic applications. Our group aims at elucidating the advantages of molecular materials as innovative spintronic materials by exploring novel systems for efficient spin transport control based on the hybrid systems of molecular materials and magnetic metals and also by developing cutting-edge spectroscopy techniques for the electronic and magnetic states of the molecular material-based structures and interfaces therein. Typical progresses in FY2011 are summarized in the following.

**Precise layer number control of graphene in ultra-high vacuum chemical vapour deposition**

After the discovery of the convenient fabrication method by the exfoliation from graphite (A. Geim and K. Novoselov, the 2010 Nobel Prize in physics), graphene has been attracting world-wide attention as an innovative electronic material. In the spintronics, graphene is expected to be an ideal spin-transport material due to the extremely long spin diffusion length and high carrier mobility. However, not only the non-uniformity in the carbon layer number and in the electronic states but also the polycrystalline nature of exfoliated graphene are making it impossible to control the spin transport properties in graphene. It can be said that a new fabrication method which enables tailoring of graphene is necessary for the development of spintronic applications.

From the above view point, ultrahigh vacuum chemical vapor deposition (UHV-CVD) can be an alternative fabrication method, because single-layer graphene is known to be epitaxially grown on the catalytic metal crystal. In UHV-CVD, graphene grows through the dissociation and polymerization of hydrocarbon precursors on the metal surfaces.

In this study [1], we focused on a UHV-CVD growth of microstructure-controlled graphene by using epitaxial metal thin films as a catalytic substrate and with *in-situ* spectroscopy. It was successfully demonstrated that single-crystalline graphene (single-layer and bilayer graphene) with the same number of carbon layer over the entire area can be obtained by precise control of the exposure amount of precursors. In addition, it was suggested that the uniformity of the electronic states in UHV-CVD graphene can be remarkably high compared to exfoliated graphene (see the Research Highlight for additional details).

Our findings would enable controls of spin transport properties of graphene and lead to the development of graphene-based spintronics and nano-electronics.

**Very high interface spin polarization and its mechanism in fullerene-magnetic metal system**

Generation of high spin polarization of conduction electrons at the interface between the magnetic electrode and molecular transport medium is essential for efficient spin injection. After 1988, magnetic metal crystals have been commonly used for a magnetic electrode in spintronic devices. However, it has been pointed out that much higher spin polarization than that in magnetic metal crystals or an appropriate barrier material is necessary to realize high spin injection efficiency overcoming the conductivity mismatch problem that can limit spin polarization of injected electrons into a molecular medium [2].

In this study, it was demonstrated that new compounds of fullerene and magnetic metal (e.g., $C_{60}$-Co compound, see Fig. 1) can be a promising barrier material which gives rise to nearly-complete spin polarization of conduction electrons at the interface with magnetic metal crystals. In order to elucidate the magnitude of spin polarization at the interface with the magnetic metal crystal, the characteristics of tunnelling current and magnetoresistance were analysed for the $C_{60}$-Co films consisting of a $C_{60}$-Co compound and a small amount of Co nanocrystals [3, 4]. It was revealed that spin polarization increases as high as 80% at the $C_{60}$-Co compound/Co crystal interface in comparison with that in Co crystal (30%). Our theoretical analysis [5] based on the X-ray absorption and magnetic circular dichroism spectroscopy indicated that the $C_{60}$-Co compound can work as a spin filtering barrier due to the exchange splitting in the LUMO region as represented in Fig. 1.

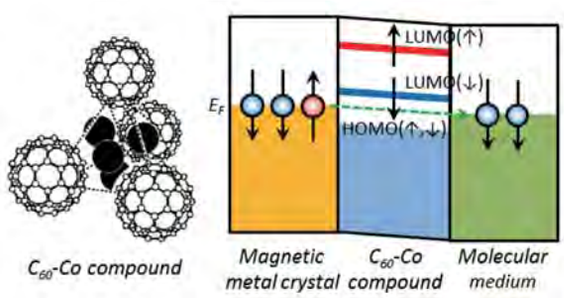


Fig. 1 Atomic structure of the $C_{60}$-Co compound (left) and a schematic view of the spin filtering effect of the $C_{60}$-Co compound as a tunnelling barrier for spin injection into a molecular medium (right) [5, 6]. LUMO/HOMO and up/down arrows in the right figure represent the lowest unoccupied/highest occupied molecular orbital and up/down spin, respectively. The HOMO-LUMO (band) gaps in the $C_{60}$-Co compound are smaller for the spin-down electrons (0.8 eV) than that for the spin-up electrons (1.9 eV), which causes spin filtering.

**References**

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