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Fabrication of ferromagnetic-metal/molecule/ferromagnetic-metal nanoscale junctions utilizing thin-film edges and their structural and electrical properties

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Nanoscale junctions have attracted interest due to their fascinating phenomena and potential application in electrically switching devices, magnetic sensors, and biosensors. Typically, it is well known that the quantization of the conductance $G = G_0\ (= 2e^2/h)$, where e is the electric charge and h is Planck's constant, has been observed in metals, molecules, and magnetic metals. Molecular switching or negative differential resistance (NDR) with a high on/off ratio has also been observed in metal/self-assembled monolayers (SAMs)/metal nanoscale junctions. Moreover, giant magneto-resistance (GMR) effect at low temperature has been measured in ferromagnetic-metal/molecule/ferromagnetic-metal nanoscale junctions. Conventional methods for the fabrication of such nanoscale junctions include lithographic techniques, such as optical, electron-beam, and nanoimprinting lithography, and other methods such as break junction methods and nanoindentation method. Recently, we have proposed a new method for the fabrication of nanoscale junctions utilizing thin-film edges. In this method, the edges of two metal thin films are crossed, and molecules, metal-oxide, etc. are sandwiched between their two edges. The junction area is determined by the film thickness, in other words 10 nm thick films could produce 10×10 nm^2 nanoscale junctions. This method offers a way to overcome the feature size limit of conventional optical lithography. Moreover, the resistance of the thin-film electrodes can be reduced down to as low as a few kΩ because the width of the films can be easily controlled to ~mm. The reduction in the electrode resistance makes it possible to suppress the heat generation, which leads to the creation of low energy-consumption devices, that is, solving the energy challenging problems. Furthermore, novel spintronics devices, such as GMR devices and spin-filter devices, could be created when magnetic materials are used as metal thin films. In this presentation, we report the detail fabrication technique for nanoscale junctions and discuss the structural and electrical characteristics in various nanoscale junctions. The results include the observation of ohmic characteristics in Ni/Ni devices, nanoscale tunneling phenomena in Ni/NiO/Ni devices, and the ballistic regime of nanoscale molecules in Ni/poly(3-hexylthiophene):6,6-phenyl C61-butyric acid methyl ester (P3HT:PCBM) /Ni devices. Moreover, we report ongoing spintronics devices utilizing stray magnetic fields as a new type of spin-filter device. This device consists of inorganic complexes or quantum dots (QDs) sandwiched between two crossed edges of magnetic thin films. In this structure, a high magnetic field could be locally generated in the inorganic complexes or QDs due to the contributions of the stray field from both edges of the magnetic thin films. Since a large magnetic field produces a large Zeeman effect, energy splitting of the inorganic complexes or QDs can be enhanced. Therefore, a large spin-filter effect can be expected. In this talk, we will focus on the structural and magnetic properties in our proposed nanoscale spintronics devices.

Keywords: nanoscale junctions; molecules; thin-film edges; magnetic materials.