Spin injection based on spin pumping in microfabricated ferromagnetic metal/nonmagnetic semiconductor junctions

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Electron spin waves are a spatial spin rotation of moving electrons under spin-orbit induced effective magnetic field. Their use in semiconductors opens new paradigm of technology implementing wave-based parallel information processing and multiplexing [1]. The integration of the electron spin wave-based information processing requires the creation, manipulation and detection of electron spin wave in semiconductor materials by exploiting ferromagnets. In order to achieve these goals, we need a way to overcome the impedance mismatch problem between semiconductor layers and ferromagnetic metallic layers, which opposes the spin injection. Spin pumping is a candidate technique bypassing the impedance mismatch problem [2]. For electron spin wave-based information processing, however, such spin injection using spin pumping should be demonstrated in a microfabricated device structure, which has not been reported yet. As a first step to electrically create the electron spin wave, in this study, we have investigated the injection of spin current from a CoFe ferromagnetic layer into a GaAs by conventional non-local spin-valve (NLSV) technique. Then, based on the knowledge obtained by NLSV experiment, we have designed the microfabricated device working with the spin injection by spin pumping.

The NLSV devices were fabricated using the following stacking structures: 3 nm capping layer / 10 nm CoFe / 15 nm heavily n-doped GaAs (or InGaAs) / 15 nm dopant gradient GaAs / 1 μm lightly n-doped GaAs (from top to bottom) on a GaAs substrate, where Al-O or Pt was selected as the capping layer. The widths of CoFe injection and detection electrode were fixed at 1 μm and 500 nm, respectively, and their length was fixed at 10 μm. The channel length between these electrodes (*l*) were varied in the range from 500 nm to 1.2 μm. These devices showed clear NLSV signals at measurement temperature (*T*) lower than 150 K. The resistance change of NLSV increased as *T* was reduced or *l* was decreased. These results indicate that the spin transport is mainly governed by a spin diffusion phenomenon. Also, the successful NLSV measurement suggests that the current microfabrication process is applicable for the preparation of micro-sized spin pumping device. The spin pumping device has an injection electrode that is connected with a coplanar waveguide and the detection electrode exploits the inverse spin Hall effect. We observed the excitation of spin dynamics in the CoFe layer by applying the rf current to the designed Pt layer of the spin pumping electrode, and successfully detected the spin dynamics in the micro-sized electrode using the spin torque ferromagnetic resonance technique. In the presentation, we will explain the spin injection experiment in the micro-sized spin pumping device.

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