KIST Spintronics 발표 5

# Efficient spin filtering in GaAs/MgO/Fe structure and with EuO tunnel barriers

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The injection of spin-polarized carriers into (and out of) semiconductors is one of the central critical issues for the realization of spin-based devices such as the spin-transistor. To achieve efficient spin injection (detection) scheme, the use of an appropriate tunnel barrier is a good possibility. We have investigated the spin filtering effects of GaAs/MgO/Fe structures using the spin dependent photocurrent measurement technique. The structures contained 2-5 nm thick MgO tunnel barriers followed by a 7 nm Fe layer grown on n-type (001) GaAs substrates by MBE. The photocurrent at room temperature was measured with lock-in techniques, using superconducting magnet to supply the field. A photo-elastic modulator was used to produce left- and right-circularly polarized light from a diode laser (850 nm, 10 mW).

Measurements show about 180° phase shift of the spin-dependent photocurrent ($I_{SD}$) induced by the switching of the out-of-plane H-field (2.5 T) to the opposite direction. In the forward bias region (0.25-0.6V, depending on the sample structures), a sizeable spin filtering effect was observed. After subtracting the magnetic circular dichroism effect, the spin filtering efficiency reached approximately 30% at 0.54V for the 4 nm thick MgO tunnel barrier sample. The spin filtering efficiency is defined as $\Delta I_{SP} / I_{ph}$, where $I_{ph}$ is the unpolarized light-induced total photocurrent, $\Delta I_{SP} = I_{SD} - I_0$, and $I_0$ is the zero field spin-dependent photocurrent. The observed steep rise of spin filtering efficiency, peaking at 0.54V, followed by a rapid decrease has been attributed as related to the transport processes, i.e., tunneling and thermionic emission. The efficient room temperature spin filtering for GaAs/MgO/Fe structures observed here has not been reported yet for Fe/GaAs or $Fe/Al_2O_3/GaAs$ structures.

In our investigation of spin filtering in other magnetic semiconductors, near 100% spin filtering has been observed with EuO tunnel barriers. EuO with a Curie temperature of 69.6K is an excellent candidate as a spin filtering tunnel barrier. With its large exchange splitting (0.54eV) of the conduction band, in principle, it can achieve total spin filtering of the tunnel current. However, so far the measured spin polarization using Meservey–Tedrow (M–T) technique has yielded only 30% value. Controlling the interfaces of EuO and the metal electrodes was observed to be of critical importance, as proven by our careful interfacial and magnetic studies down to an atomic layer using XAS, XRS and XMCD. Information obtained from such studies allowed us to fabricate trilayer structures such as Al/EuO/Y/Al, and reach 97% spin filtering of the tunnel current. The tunnel junction resistance ($R_J$) versus temperature variation nicely followed the magnetization data for EuO film with thickness in the range of 4–6 monolayers. Fitting the $R_J$ vs T data to tunneling theory, an exchange splitting of ~ 0. 3 eV was deduced and observed near complete spin filtering. Thus the procedure also allowed us to determine the exchange splitting down to the monolayer level of this Heisenberg ferromagnet EuO for the first time.

We are grateful to the research funding from KIST–MIT project.