Spin switching effect in GdN/NbN/GdN superconducting spin valves

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The interplay between ferromagnetism and superconductivity causes very interesting interfacial phenomena in a hetero-structure of ferromagnetic and superconducting ultra-thin layers. Interfacial exchange field[1] acting on a superconductor (SC) thin layer sandwiched by two ferromagnetic insulators (FI), so-called superconducting spin valves (SSVs), can be sufficiently large to affect the superconductivity and controllable by the relative configuration of the two magnetizations. This enables us to switch the conducting states from a superconductive to normal state reversibly, thereby resulting in exchange field tunable infinite magnetoresistance. This effect is referred to as spin switching effect (SSE).

Perfect SSE has been reported in only pure metal such as V (critical temperature $T_C \sim 4$ K), Al ($T_C \sim 1$ K) and Nb[4] ($T_C \sim 9$ K) with a long coherence length[2-4]. NbN is an attractive candidate for the SSV as it is a strong coupled, high critical temperature (16K) and field robust superconductor that is widely used in many applications. However, the SSE in NbN had not been observed yet due to the very short coherence length approximately 5 nm and difficulty in controlling the required optimum interfaces. In this work, we demonstrate SSE signals in an SSV with NbN and GdN as the FI by atomically tuning the interface structure to enlarge the interfacial exchange fields.

SSVs with optimal GdN(27 nm)/NbN(3.5 nm)/GdN(13 nm) trilayers, fabricated with reactive sputtering technique in a UHV system. Pure Gd layers were added at the interfaces between GdN/NbN layers in order to compensate for its nitrogen richer composition, as revealed by polarized neutron reflectivity (PNR) studies. The cross-sectional transmission electron microscopic images show that the interfaces were sharp.

We observe SSE signals for a SSV with the Gd layers as shown in Fig. 1. The difference in the T_C of NbN for parallel and anti-parallel configuration of the two FI layers was 0.3 K, which was 30X enhanced from the value of 0.01 K without the inserted Gd layers. To evaluate the strength of the interfacial exchange field various theoretical models were applied. None of the models, assuming the spacer layer thickness << coherence length, gave any reasonable value. Clearly more experimental and theoretical studies are needed. Our results will be presented and discussed.

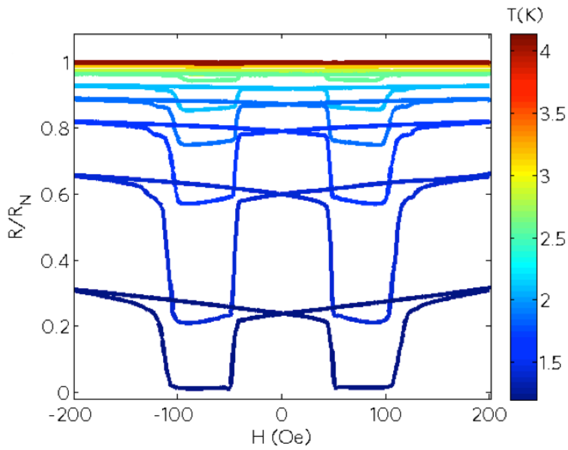

Fig.1 Normalized resistance vs applied field (SSE signal) for various temperatures in a GdN/NbN/GdN superconducting spin valve with Gd insertion layers.

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