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Spin Transport in Exchange Spring Superlattices

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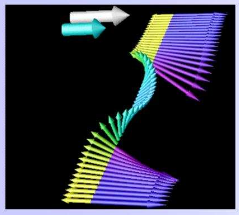
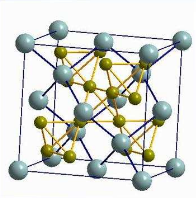
Spin transport phenomena are rich in exchange spring superlattices, owing to the non-collinear spin alignment. Low temperature GMR up to 32% was observed in $DyFe_2/YFe_2$ superlattices. Point contact Andreev reflection at 4.2 K was employed to determine the spin polarization of $DyFe_2$, YFe_2 and $ErFe_2$, the building blocks of our superlattices. Spin transfer torque induced spin waves are predicted.

1. Exchange Spring Systems

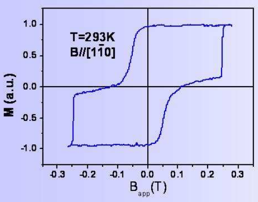


Non-collinear spin configurations, e.g. exchange springs, are established in hard/soft heterostructures when the externally applied field exceeds the bending field.

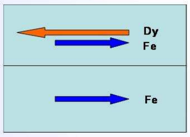


MBE grown antiferromagnetically coupled RFe_2 (R=Dy, Y and Er) superlattices were used to study exchange spring characteristics.

RFe_2 compound cubic Laves phase structure

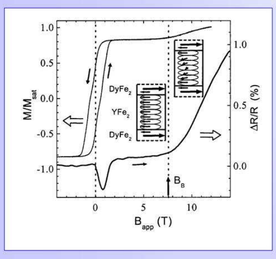


Easy axis MOKE loop for the superlattice [45 Å $DyFe_2$/180 Å YFe_2] ×18.

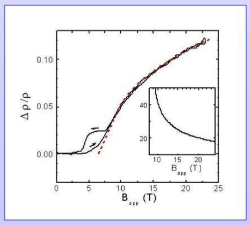


Effective magnetic coupling between Dy and Fe atoms

2. Giant Magneto Resistance (GMR)



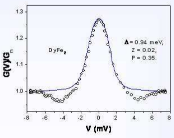
Spin dependent scattering of electrons from the non-collinear spins in a hetero-structure is a cause of resistivity differences between parallel and antiparallel configurations of the layer components.



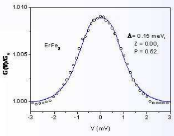
The GMR observed in $DyFe_2/YFe_2$ superlattices at low temperatures can be explained by the spin dependent scattering from domain walls.

3. Point Contact Andreev Reflection

The Andreev effect occurs at normal metal/superconductor interfaces when low energy electrons from the normal metal side flow into the superconducting side.

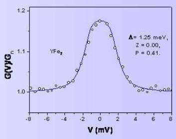


In the ideal case, an electron below the superconducting energy gap can only enter into the superconductor as Cooper pairs, leaving behind a hole moving away from the interface, thus doubling the zero bias conductivity.

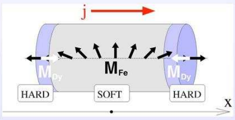


Unlike a normal metal/superconductor interface, this doubling will be suppressed at a ferromagnetic metal/superconductor interface. The degree of suppression is related to the spin polarization of the ferromagnet.

A modified Blonder-Tinkham-Klapwijk model was employed to extract quantitative information of the building blocks of our exchange spring systems. The spin polarization obtained from best fitting is P=0.35±0.02, 0.41±0.01 and 0.45±0.06 for pure $DyFe_2$, YFe_2 and $ErFe_2$ films respectively. The spin polarization of YFe_2 is close to that of Fe, P=0.42.

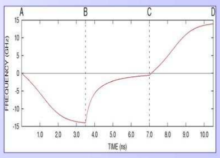


4. Spin Transfer Torque



When a current flows through a magnetic system, a torque is exerted on the magnetization vector; this arises from the transfer of spin angular momentum. This spin transfer torque effect can induce magnetization switching and excite magnons.

GHz spin waves excited by spin polarized current were predicted in an exchange coupled [50 Å $DyFe_2$ /400 Å YFe_2/50 Å $DyFe_2$] trilayer by micromagnetic simulation.



5. Conclusions

Various spin transport effects can be realized in exchange spring systems, mainly due to the inherent non-collinear spin configurations therein. GMR and PCAR have been realized in antiferromagnetically coupled $DyFe_2/YFe_2$ superlattices. The possibility of spin transfer torque excited spin waves has potential for spintronic applications.