Spin transport and structural characterization of carbon nanotubes

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In spintronics devices, the electron spin is manipulated to produce the desired electrical response. This devices can be used to investigate new physical phenomena and are promising for applications. Carbon nanotubes are an ideal system to study spin transport and a good candidate for novel devices: depending on their chirality they can be metallic or semiconducting, they can show ballistic transport and sustain a very high current density. To be able to detect spin dependent transport in carbon nanotubes it is necessary to produce contacts which have both good electrical and magnetic properties.

We developed a scheme by using Palladium and Iron which ensures a uniform magnetization and transparent contacts. Contacts with different shapes will have different coercive fields allowing a crossover between the parallel and antiparallel configuration. The relative orientation of two contacts can be controlled by an external magnetic field applied parallel to the contacts.

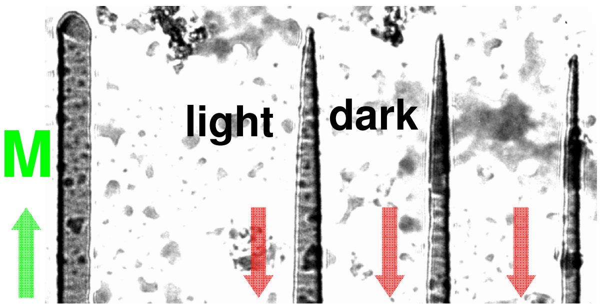

Figure 1: When sweeping the external magnetic field to 7.3 mT, the broadest (rightmost) contact switches magnetisation M.

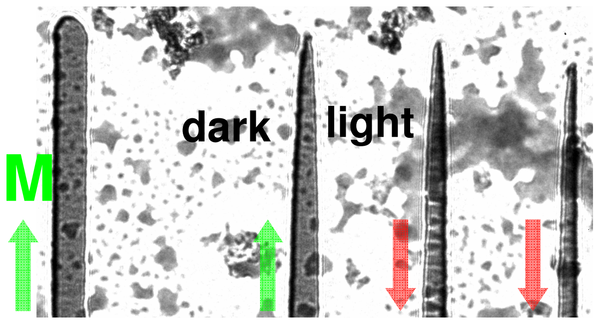

Figure 2: At 14.6 mT, the second (to the left) contact switches. This can be seen from the magnetic contrast changing from dark to light et vice versa.

Lorentz microscopy is a powerful tool which allows to investigate the micromagnetic properties of the contact: in particular it is possible to study the dynamics of domain walls. We used this technique to characterize several contacts and we found a single domain switching behavior. Moreover we tuned the contact shape in order to maximize the difference in the switching fields.

We used selected area electron diffraction (SAED) on CVD-grown carbon nanotubes on a membrane: by comparing the measured data with a simulation we can distinguish between single wall, double wall and small bundles. For single and double wall carbon nanotubes we can also identify the chiral indices (n,m).

For this purpose, we succeeded to grow carbon nanotube partially laying on a membrane where slits where patterned: on these samples, we will combine magnetic characterization of the contacts, transport measurements and structural characterization of the nanotubes. This information will allow direct comparison theoretical predictions with measured data.

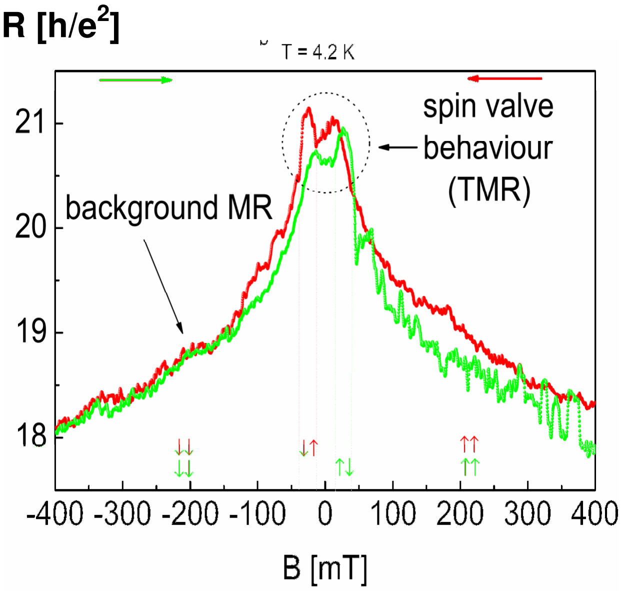

Figure 3: TMR effect in a SWCNT sample with ferromagnetic contacts. The pairs of arrows indicate the two contacts' relative magnetization at the given external magnetic field.

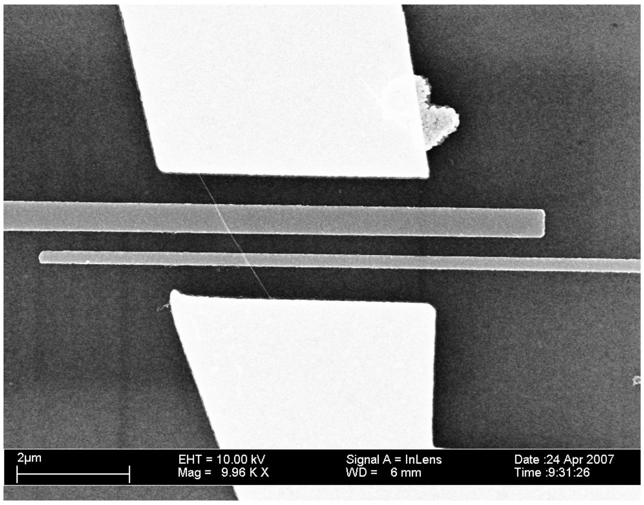

Figure 4: SEM picture of a typical sample. The two inner contacts on the CNT are made of PdFe and the outer ones of Au.

We performed low temperature measurements on both single and multiwall carbon nanotube samples with aluminium and silicon oxide backgate. The magnetoconductance shows hysteretic switching that we attribute to spin transport. We observed a gate-dependent spin valve effect of up to five percent.
Control experiments with one ferromagnetic and one gold contact has been carried out in order to rule out other effects.