

Observation of a spin polarized current through single atom quantum point contacts

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Abstract

We study the conductance of single atom point contacts made between a gold STM tip and a gold layer evaporated on top of the half metallic ferromagnetic manganite $\text{La}_{2/3}\text{Sr}_{1/3}\text{MnO}_3$. The conductance histogram shows the typical peak corresponding to the last gold contact before rupture at a value smaller than the quantum of conductance, indicating that the current through the single atom contact is partially spin polarized. We discuss the possible use of this effect as a method to measure the spin polarization of spin active electronic devices.

Key words: Spin polarized transport; STM; Quantum Point contacts

Single atom quantum point contacts have now been widely fabricated and characterized using a variety of techniques[1]. For instance, the repeated indentation procedure with a low temperature STM [2–4] easily leads to high quality contacts, if the experiment is done using both tip and sample made of simple metals, as e.g. in Au,Pb,Al,Ni or Bi. The gold contacts are best understood and characterized, and their main feature is that the last contact before rupture, corresponding to the single atom point contact, presents a value very close to the quantum of conductance $\sigma_0 = 2e^2/h$. This can be related to the monovalent nature of gold[1,5], and the number 2 in the expression for σ_0 comes from the spin degeneracy of the electrons passing through the contact. Here we study the behavior of gold contacts done with an STM between a gold tip and a layer of gold evaporated on top of the half metallic ferromagnetic LSMO. We find that the contacts show a conduction

tance smaller than σ_0 because the ferromagnet acts as a spin polarizer.

The experiment has been performed using a conventional low temperature STM set-up in a ${}^4\text{He}$ cryostat working at 4.2K. A 20 nm gold layer was evaporated on top of a previously polished single crystal of LSMO. Before the evaporation, we heated the sample to 800 K for one hour to eliminate parasitic layers from the surface. The continuity of the gold layer was checked with room temperature AFM, and using the scanning mode of the low temperature STM. We used a gold tip mechanically cleaned before cooling down, positioned on top of the evaporated layer, as shown schematically in Fig.1a. The contacts were made following the repeated indentation procedure described in [2]. Special care was taken to avoid possible damage of the gold layer, by making always small displacements of the tip with respect to the sample. The obtained work functions after rupture of the contacts were of the order of several eV. We have also checked that the results discussed here do not depend on the bias voltage, up to

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200 mV.

In Figure 1b we show typical conductance-distance curves. The single atom contact is clearly identified, as it corresponds to the last plateau before going into the tunneling limit, where the conductance drops exponentially to zero. Its conductance equals σ_0 to within 10% in typical, well known gold-gold contacts (lines)[2,6]. If the contact is done on the layer evaporated on LSMO (dashed lines) we find a smaller value. Making a histogram out of several thousand of these curves leads to the Figure 1c. As expected, the histogram for pure gold-gold contacts (line in Fig.1c) shows a very pronounced peak at σ_0 and a series of smaller structures at larger values. The peak is clearly asymmetric. This is due to backscattered electrons, which slightly decrease the value of the conductance below σ_0 [6]. Remarkably, the histogram corresponding to the contacts done on the layer evaporated on LSMO (dashed lines) shows the same features, but displaced down to lower values of conductance. This must be due to the presence of the ferromagnetic manganite, which acts as a spin polarizer. If we assume that completely polarized electrons lead to single atom contacts with half of σ_0 , we get that the electrons flowing through the contact are spin polarized up to a value of 55%. Previous measurements of the spin polarization of LSMO thin films, using the tunneling technique of Ref.[9], lead to a value of 72%[7], and Andreev reflection experiments in single crystals report values of about 78%[8]. This is clearly larger than the value we find here. The reason for this difference may lie in depolarizing effects due either to the quality of the interface between LSMO and the gold layer, or to spin orbit coupling within the gold layer.

The present result shows a new way of measuring the spin polarization, complementary to the available techniques, which can be used to the study of spin polarization through interfaces between a ferromagnet and a layer of a simple metal. This is important for the development of new spin injection devices, which are fabricated in some cases using gold electrodes (see e.g. [7] and references therein). Note that the tunneling technique used in Refs.[7,9] needs careful preparation of evaporated Al layers, and the Andreev reflection technique[8], in spite of being very versatile, is very difficult to use on evaporated thin films, and may suffer in some cases from problems related to the reproducibility and interpretation of the results.

In conclusion, we have shown that quantum point contacts of gold can carry a spin polarized current. We find that the single atom point contacts performed here carry a current polarized up to a value of about 55%.

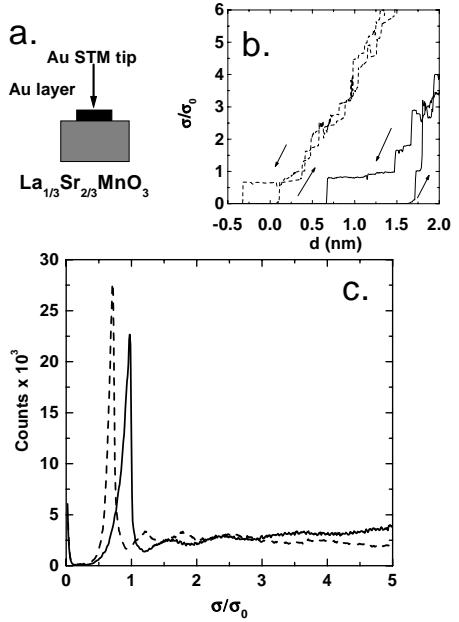


Fig. 1. In a we show the experimental arrangement discussed here. Lines in b and c correspond to a typical quantum point contact arrangement when done with an STM, with tip and sample of gold. Dashed lines in b and c correspond to contacts done on top of a gold layer evaporated onto a half metallic manganite. In b we show typical conductance-distance curve in gold-gold contacts. The arrows indicate the direction of the movement of the tip with respect for the sample (stretching the contact or indenting). In c we show a histogram made out of a sample of 5000 conductance-distance curves.

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