Poster

Coulomb blockade and low frequency noise anomalies in magnetic tunnel junctions $Co|Al_2O_3|Si|Al_2O_3|Py$.

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The discovery of large tunnelling magnetoresistance at room temperature [1,2] has strongly renewed the interest in spin tunnelling phenomena. Up to very recently the main efforts were concentrated on the increase of tunnelling magnetoresistance values by using ferromagnetic electrodes with the highest possible spin polarization (half metallic ferromagnetism). Another possible research direction, which remains however poorly explored, is related to tunnelling in complex (hybrid) junctions. Indeed, the manipulation of the barrier by doping with magnetic or nonmagnetic impurities, or inserting magnetic, nonmagnetic (even superconducting) nanoparticles (quantum dots), would add a new degree of freedom to spin polarized tunnelling and strongly enhance the versatility of spintronic devices. This work demonstrates the possibility to detect the breakdown in the Coulomb blockade phenomena in an array of Si nanoclusters embedded in an insulating barrier of a magnetic tunnel junction by measuring low frequency resistance noise.

We have studied a series of magnetic tunnel junctions with a silicon layer placed in an asymmetric position inside the barrier. The thickness of the silicon layer (δ) , was varied from 0 up to 1.8Å. The upper thickness values exceed the atomic radius of the silicon, which is about 1.1Å. Conductance of the junctions is strongly affected by the presence of the silicon when the thickness is greater than the silicon atomic radius (Figure 1a). The tunnelling magnetoresistance (TMR) is also influenced by the silicon layer (Figure 1b). Inclusion of Si suppresses the magnetoresistance at room temperature, but for T<80K the influence of the silicon becomes much less evident as shown in Figure 1b.

The noise power spectrum has the usual 1/f contribution, added to thermal or shot noise contributions, being these last noise sources independent of frequency [3]. At low temperatures, for samples with δ>1.2 Å, the thermal noise contribution is nearly absent and Lorentzian-type anomalies dominate the low frequency noise spectrum. In order to characterize quantitatively the noise spectrum we used a total integral of the spectrum for the frequency interval between a few Hz and kHz (V_{RMS}). Figure 2 shows several typical V_{RMS} as a function of the bias voltage. The lower curves of both graphs correspond to a sample with δ = 0.6 Å, where the main source of noise was shot noise. The upper curves correspond to a δ = 1.8 Å (Figure 2a) and a δ = 1.5 Å (Figure 2b). The integrated noise magnitude V_{RMS} increases at a certain voltage showing an asymmetric dependence on the bias voltage.

We suggest a Coulomb blockade suppression mechanism as an origin for the observed anomalies both in the conductance and noise. The experimental data clearly show a crossover between different regimes happening when δ is approximately the atomic radius, and the Si coverage is around 1 ML. We suppose suppression of the Coulomb blockade for δ > 1.1 Å with electron transport and noise being controlled by the capacitance and the electron population of the silicon layer.

References:

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[2] T. Miyazaki and N. Tezuka, Journal of magnetism and magnetic materials **139**, (1995) L231.
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Figures:

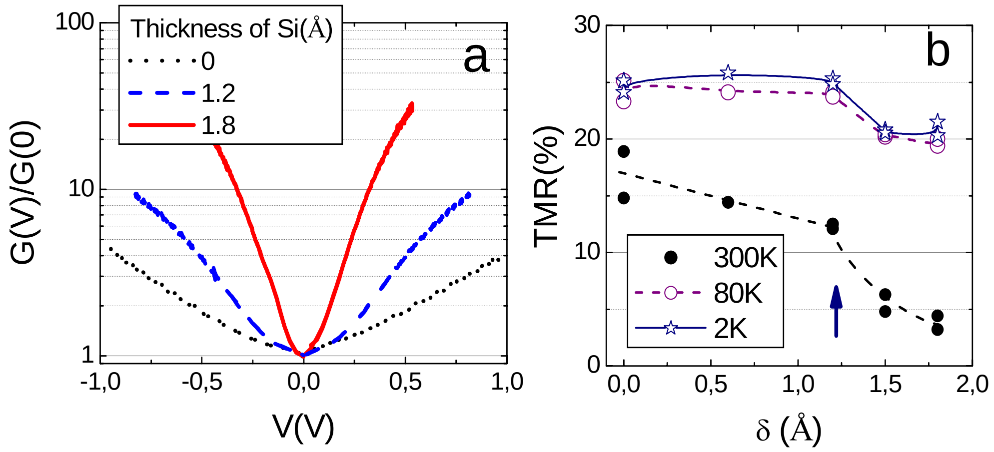

Figure 1: (a) Dependence of the normalized conductance on the bias voltage at T=2K for different thicknesses of the silicon layer. (b) Tunneling magnetoresistance at different temperatures, zero bias voltage and for different silicon thicknesses (δ).

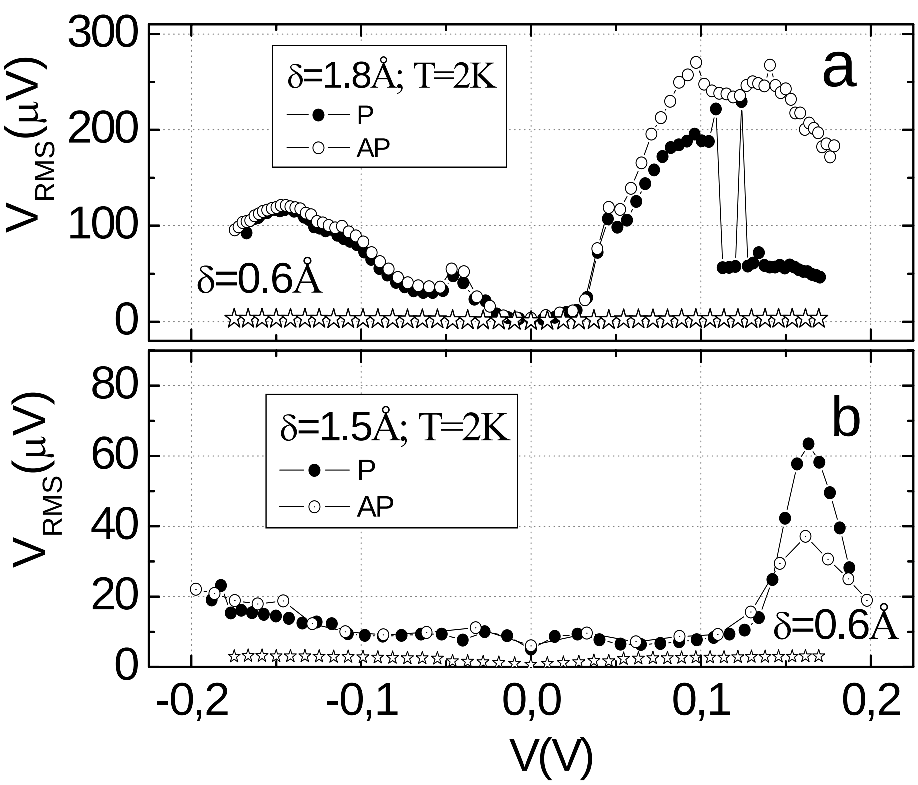

Figure 2: Voltage dependence of V_{RMS}. In this figure the anomalous increase of the noise is shown, as well as the asymmetry in the voltage dependence. Lower curves present the V_{RMS} of a δ = 0.06 Å sample, which show the noise corresponding to the lower thickness range.