Point contact model and its applications, Domain wall resistance and tunneling in ferroelectric tunnel junctions

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Abstract:

The recently developed works [1,2] show a novel electron transport problem approach of the pointlike contact model. This model explains electron transport through a nanoconstriction (and planar contact) between two ferromagnets. Model includes the non-magnetic limit, where ferromagnets can be replaced by non-magnetic materials. Theory represents a solution of the kinetic equations for the charge current density, accounting the second-order derivatives of the related quasiclassical Green functions along the transport direction. The main benefit of the mathematical solution is a novel methodology, which is fully alternative to the classical Boltzmann-based and tight-binding transport models. Theoretical approach allows, for example, simulate domain wall resistance, *I*-*V* curves of the tunnel-based nanoscale devices, substituting the related potential energy profiles into the point contact area. The derived approach of the spin-resolved current covers a complete range of the order parameter (*l* / *a*) including quantum, ballistic (*la*), quasi-ballistic (*l* ~*a*) and diffusive (*la*) transport regimes. Approach has a smooth transition between these conditions without additional empirical variables. As a result, theory allows to make a fitting of experimental data more precisely, e.g. the approach of the model with total range of transport conditions explains well a domain wall resistance in magnetic nanowires [3]. The previously developed works, using only the related tunnel-responsible term of the model, reproduce and predict following effects, demonstrating a model's universality: **a)** Spin transfer torque manipulation in magnetic ferroelectric tunnel junctions; **b)** Explanation of anomalous tunnel magnetoresistance (TMR) in magnetic tunnel junctions (MTJs) with embedded nanoparticles [4]; **c)** Voltage and temperature dependence of the TMR in MTJs; **d)** Prediction of the quantized spin transfer torque; **e)** Explain tunnel electroresistance in ferroelectric tunnel junctioins [5], f) Ballistic magnetoresistance in nanojunctions, etc.

Definitions: *a* – radius of the point contact (nanoconstriction), *l* – mean free path of electron.

References:

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4. Useinov, et al, *Sci. Rep.***7** (2017) 8357
5. Useinov, et al. *ACS Appl. Electron. Mater.***4** (2022) 2238-2245