MAGNETOTRANSPORT IN DISORDERED TUNNELING NANODEVICES

M. Amado[1], *F. Domínguez-Adame*[1] *and E. Diez*[2]
[1]*Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain*
[2]*Departamento de Física Teórica, Universidad de Salamanca, E-37008 Salamanca, Spain*
marioam@material.fis.ucm.es

Resonant tunneling through double-barrier structures (DBs) make these systems very promising candidates for a new generation of ultra-high speed electronic devices. For instance, a GaAs-GaAlAs DBs operating at THz frequencies has been reported in the literature [1]. The basic reason for RT to arise in DBs is a quantum phenomenon whose fundamental characteristics are by now well understood: There exists a dramatic increase of the electron transmission whenever the energy of the incident electron is close to one of the unoccupied quasi-bound-states inside the well [2]. In practice, a bias voltage is applied to shift the energy of this quasi-bound-state of nonzero width so that its center matches the Fermi level. Consequently, the characteristics present negative differential resistance when the quasi-bound-state lies well below the Fermi level.

In actual samples, however, the situation is much more complex than this simple picture. Scattering by phonons, electrons or defects reduces the required quantum coherence and, in fact, deviations from the above simple description are observed, and the decrease of electron mobility due to rough surfaces even in good-quality heterostructures [3].

We present a novel two-dimensional model to calculate vertical transport properties such as conductance and current in unintentionally disordered double barrier GaAs-AlGaAs DBs [4] (see Figure 1). The source of disorder comes from interface roughness at the heterojunctions. We model the interface roughness by protrusions of the GaAs in AlGaAs (and viceversa). The lateral and vertical sizes of the islands are stochastic variables with given average values from few Angstroms up to few nanometers. Both lateral and vertical disorder break translational symmetry along the lateral direction and therefore electrons can be scattered off the growth direction. The model correctly describes channel mixing due to these elastic scattering events, yielding a reduction of the dc conductance. We then apply a magnetic field perpendicular to the system plane, and numerically study the magneto-conductance by means of a 2D transfer matrix technique. Suitable boundary conditions are chosen along both growth and transversal direction directions. The single resonant peak in the absence of field splits into Landau levels after applying the field, as seen in Figure 2. We discuss the effects of the magnitude of the disorder on the Landau splitting.

References:

[1] T. C. L. G. Sollner, W. D. Goodhue, P. E. Tannenwald, C. D. Parker and D. D. Peck, Appl. Phys. Lett. **43**, 588 (1984).

[2] B. Ricco and M. Ya. Azbel, Phys. Rev. B **29**, 1970 (1984).

[3] U. Penner, H. Rücker and I. N. Yassievich, Semicond. Sci. Technol. **13**, 709 (1998).

[4] I. Gómez, E. Diez, F. Domínguez-Adame and P. Orellana, Physica E **18**, 372 (2003).

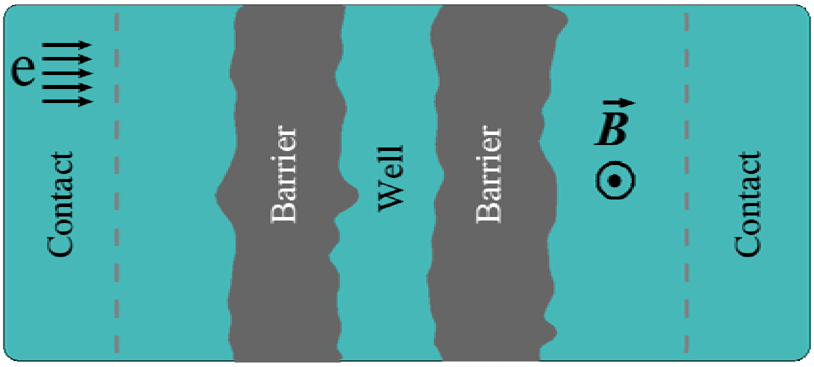

Figure 1: Schematic view of the two barriers forming the tunnel diode, showing the interface roughness., The magnetic field is applied perpendicular to the system plane.

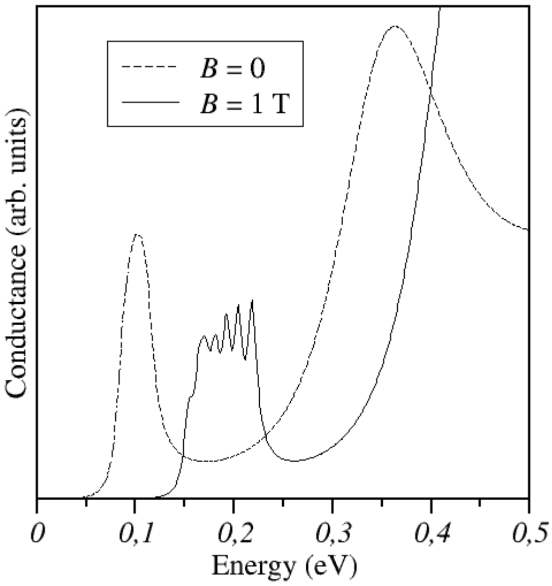

Figure 2: Conductance as a function of the Fermi energy at zero temperature without magnetic field (dashed line) and with applied magnetic field (solid line). The barrier height is 0.3 eV and their width is 1.8 nm. The width of the quantum well is 5.1 nm. The maximum lateral (vertical) size of the roughness islands is 20 nm (0.3 nm, i.e., about one monolayer).