Semimagnetic II-VI resonant tunneling diodes – spin filtering by tunneling through 0d states and growth control by XRD

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Semimagnetic resonant tunnelling diodes (RTDs) based on wide gap II-VI semiconductors can be used as voltage controlled spin-filters, as shown in [Gould et al. *Phys. Rev. Lett.*, **97**, 017202, (2006)] or in [Fang et al *Appl. Phys. Lett.*, **91**, 022101, (2007)]. The tunnel current and resonance voltage of such structures depend critically on the thickness and composition of the tunnel barriers and the embedded semimagnetic quantum well or quantum dots.

We show that by analysis of x-ray diffraction (XRD) patterns of (Zn,Be,Mn,Cd)Se based RTDs accurate structural information can be obtained, even though the tunnel barriers are typically only ~6 nm thick and are embedded in a complex layer structure which includes the needed contacts and buffer layers. The technique makes use of the high tensile strain of (Zn,Be)Se tunnel barriers with respect to the GaAs substrate, which clearly distinguishes the diffraction patterns originating from the double barrier structure from those coming from all other layers.

Using these XRD optimization techniques several series of II-VI RTDs have been fabricated by molecular beam epitaxy, with current-voltage characteristics showing up to five resonance peaks and a peak to valley ratio of up to 2.5 in measurements at 4.2 K. Gradual increases in the barrier thickness from 4.8 to 7.0 nm, as determined by XRD, lead to a monotonic decrease of the resonant tunneling current by six orders of magnitude, confirming the correlation of XRD results with electrical transport data.

For experiments on nanostructured RTDs that may allow the formation of a zero dimensional resonant tunneling state and control of the resonance by a lateral gate voltage, it is important to fabricate RTDs with the first resonance as close as possible to the injector Fermi level. This has been achieved by lowering the bandgap in the semimagnetic (Zn,Mn)Se quantum well by alloying with Cd. The resonance shifts from 170 mV for a $Zn_{0.92}Mn_{0.08}Se$ quantum well down to 60 mV for a $Zn_{0.82}Mn_{0.08}Cd_{0.1}Se$ quantum well, and effectively to zero for higher Cd contents.

RTDs with electrons tunneling through zero dimensional states in a single self assembled CdSe quantum dot have also been fabricated, showing clear dot resonances at a few mV applied bias with few pA peak current at 4.2 K. To optimize such structures the electronic and optical properties of CdSe quantum dots embedded in $Zn_{0.8}Be_{0.2}Se$ tunnel barriers have been studied systematically by photoluminescence, atomic force microscopy and XRD. When the dots are placed in a semimagnetic RTD they show clear spin splitting of the resonance peak by several mV in a magnetic field of 6 T and a remanent splitting of less than a mV at zero field. The resonance behaviour, peak splitting, magnetic and spin injection properties will be discussed and related to composition, layer thickness, lateral size and dimensionality of the RTD structures.