E1-18: Measurement and analysis of the dark current in single quantum well structure

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Recent advances in semiconductor growth technology such as MBE, have made possible the fabrication of artificial microstructure with very thin layers of different bandgap semiconductor materials. When the thickness of these layers become comparable to de-Broglie wavelength, the structures show quantum features. Such structures can be used as Infrared photo detectors utilizing intersubband photo-transitions between quantum states. The optimization of the design of these detectors requires the knowledge of the process controlling the background dark current (I_d). In particular it is important to understand the role played by thermionic and tunnelling current contributions in order to optimize the structure.

The structure studied in this work was grown by molecular beam epitaxy and consisted of a single GaAs doped quantum well and undoped $Al_{0.3}Ga_{0.7}As$ barriers on either side. The structure is sandwiched between 2 heavily doped GaAs layers to which contacts were provided for the measurements.

In order to measure the dark current, the sample was mounted to the Closed Cycle Refrigerator head and covered with the radiation shield, to minimize the photo excited electrons within the well due to external radiation. Kethley-617 programmable electrometer and Kethley-166 microvolt DMM resistor were used to make I-V measurements. The variation of dark current (I_D) with temperature (T) at different bias voltages (V_B) and the variation of dark current with bias voltages at different temperatures were measured.

Current through the device was calculated by measuring the output voltage across a 100 kΩ load resistor connected in series with the device. This data was substituted to the semiclassical harmonic emission equation and the experimental I_D/T vs 1/T plots on semi-log scale. These plots show linear behaviour at temperatures above 70 kΩ and the gradients decrease as the bias voltage increases.

The linear behaviour of log I_D/T) vs 1/T plot at high temperatures, concludes the domination of thermionic emission process at higher temperatures. Also the variation of the gradient with bias voltage clearly shows the band bending due to external bias.

Using the growth parameters of the structure (GaAs layer thickness-well width, Al concentration-barrier height, doping density within the well) we obtained the effective barrier height for electrons in the well, at zero bias voltage. These numbers agreed very well with the experimentally obtained barrier height at the lower bias voltage.