CHARACTERIZATION OF MIS TUNNEL JUNCTIONS BY IETS

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Tunnelling in metal-insulator-semiconductor (MIS) junctions is studied at low temperature by measuring the second derivative d^2I/dV^2 of the current-voltage characteristics as function of the applied voltage in Inelastic Electron Tunnelling Spectroscopy (IETS) experiments. The analysis of the tunnelling spectra of lattice vibrations of the two electrodes (aluminium gate and silicon substrate) shows the main phonon modes. The deconvolution of these vibration band spectra are compared with data in other experiments[1,3] Both the (100) and (111) silicon orientations were investigated.

Fig. 1 demonstrates the ability of the IETS technique on Al-SiO_2-Si (n+) capacitor fabricated on a degenerate silicon sample. Silicon lattice vibrations appear in the first range of the energy corresponding to voltage bias in the range of 25 mV to 65 mV. The band vibration of the silicon dioxide phonons are more difficult to detect and are located in the voltage range of 130 to 170 mV. Some molecular vibrations may occur in the remaining part of the voltage bias.Their corresponding IR energy allows an identification of the species formation in the tunnel oxide barrier.

Figure 2 permit us to compare the phonon modes spectra on both (111) and (100) silicon orientation. This spectra are deconvoluted in essentially three peaks for (111) orientation and four modes for the (100) microelectronics orientation. These modes can be identified relatively to the conventional points and axes in the Brillouin zone of the f.f.c. lattice. For instance, the optical phonon (Γ point) at 65.3 mV is the more intense structure on (111) silicon[3]. For (100) silicon the strongest peak is the TO mode in direction ΓX located at 60.1 mV, associated with the conduction band minimum at $k=0.85\ k_{BZ}$ [1].

Fig. 3 shows the first part of an Al-SiO_2-Si (p+) (100) tunnelling spectrum. A strong structure appears in the low voltage region from 20 to 40 mV and corresponds to a large relative conductance change in the first derivative (about 12%). This spectrum has been observed for the first time by J.Klein et al[4] in a metal-insulator-metal (MIM) junction and assigned to the phonon structure in granular aluminium. The two peaks (25.6 and 34.6 mV) are in good agreement with the phonon spectrum for bulk Al from neutron scattering.

Other results presented in this communication contribute to demonstrate the capabilities of IETS in analysing the MOS tunnelling junctions requiring thickness insulators of 2 nm. Not only the phonon modes of the three parts (metal, oxide, semiconductor) of the device are detected, but also contaminants accidentally incorporated during the fabrication process may be identified.

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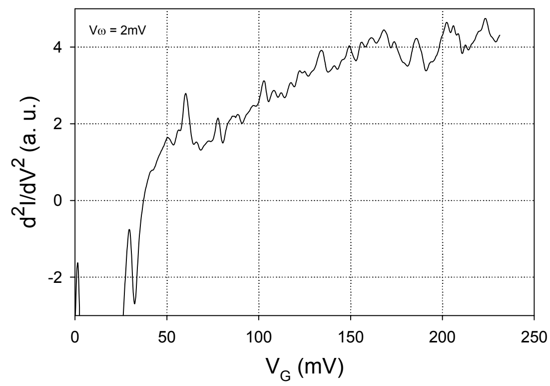

Fig.1 : IET spectrum of an Al-SiO_2-Si (n+) (100) tunnelling junction.

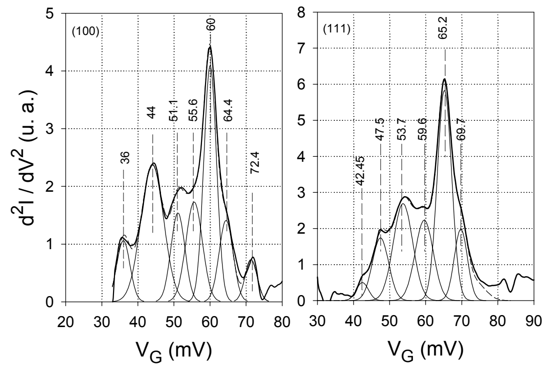

Fig.2 : Deconvolution of spectrum for silicon orientation <100> and <111>.

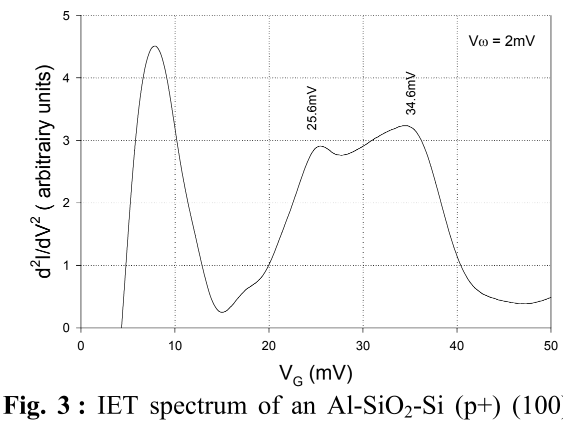

Fig. 3 : IET spectrum of an Al-SiO_2-Si (p+) (100) tunnelling junction