Oscillatory Structures in GaAs/(AlGa)As Tunnel Junctions

Recently, Hickmott *et al.*[1] reported a remarkable oscillatory structure with period $e\Delta V = \hbar\omega_{LO}$, the longitudinal-optic phonon energy, in the low-temperature reverse-bias $J(V)$ characteristics of n^+GaAs/(AlGa)As/n^-GaAs/n^+GaAs devices. The structure was observed only in magnetic fields (B) above 4 T which, they claimed, reduced ionized-impurity scattering by inducing freezeout onto shallow donors. This permitted sequential ballistic acceleration of electrons up to the LO phonon emission threshold.

We have studied similar molecular-beam-epitaxy–grown, 200-μm-diam mesas with layer thicknesses and doping as follows: substrate and buffer, 200 μm, 2×10^{18} cm^{-3}; n^- layer, 1 μm, 1×10^{15} cm^{-3}; $Al_{0.35}Ga_{0.65}As$ barrier, 168 ± 10 Å, undoped; top layer, 1 μm, 2×10^{18} cm^{-3}. Figure 1 shows typical $J(V)$ plots. Mesas of type A have $J(V)$ of similar overall form to those in Ref. 1, but of much larger amplitude ($\sim10^3$ larger at $V=-0.1$ V). Mesas of type B have an additional low-bias ($V>-0.2$ V) contribution to J which may arise from imperfections (e.g., microchannels) in the (AlGa)As barrier. *Even* at $B=0$, derivative plots of both mesa types show oscillatory structure (Fig. 2) of comparable relative amplitude (e.g., $\sim2\%$ at -0.2 V) to that in Ref. 1. The periodicity of the main peaks is $\hbar\omega_{LO}/e$. Structure is clearly visible (Fig. 2, curves *c* and *d*) even at temperatures (30 K) at which the majority of donors are ionized. The weaker intermediate extrema, seen only for $T<4$ K, probably arise from higher harmonic structure in $J(V)$; at 4 K some peaks in d^2J/dV^2 are only 2 mV wide. Note that our barriers are $\sim20\%$ narrower than those in Ref. 1 and that J is exponentially sensitive[2] to barrier height and width. Calculation shows that $J(V)$ of Fig. 1 (type A) is fully consistent with the barrier-tunneling characteristics. The larger $J(V)$ passed by our devices may be crucial for observation of oscillatory structure even at $B=0$ and up to 30 K and for understanding of its origin.[3,4] The low reverse-bias shoulder on $J(V)$ in type-B mesas is removed by modest (≈5 T) transverse magnetic fields ($J\perp B$), suggesting that it may be due to microchannels in the barrier.[5] However, oscillations for $V>0$ are not observed.[5] Oscillatory structure in both mesa types for $V<-0.2$ V is essentially unaffected by magnetic fields ($\parallel$ and $\perp J$) up to 12 T.

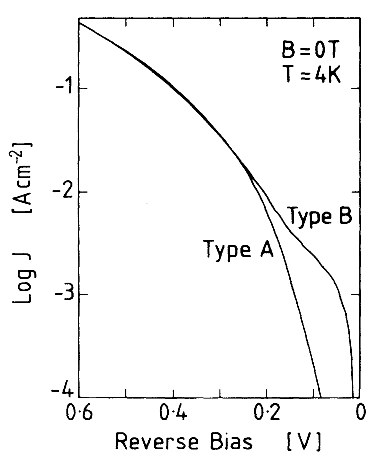

FIG. 1. Log$J$ vs $-V$ for two of our devices.

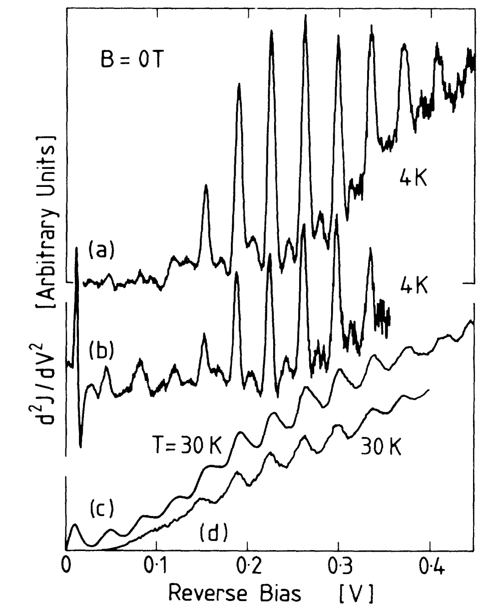

FIG. 2. d^2J/dV^2 vs $-V$: Curves *a* and *d*, type-A mesas; curves *b* and *c*, type-B mesas.

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