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Point-Contact Spectroscopy on Tunable Constrictions in GaAs

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Abstract. In quasi one dimensional channels formed in the two dimensional electron-gas (2DEG) of an AlGaAs/GaAs heterostructure, the second derivative d^2V/dI^2 of the voltage-current characteristic is measured at low temperatures as a function of the voltage drop V over the channel length. In increasing the lateral confinement, strong resonant structures appear at voltages V which correspond to energies of GaAs-phonon density of states maxima. Compared with metal point-contact spectroscopy this technique offers reproducible tunability of buried point-contacts.

Point-contact spectroscopy has been performed previously on metals[1] in order to study the electron-phonon interaction function α^2F (Eliashberg function) from an analysis of the d^2V/dI^2 characteristic in the limit of contact dimensions small compared to the effective mean free path l_e. In the following we show that the second derivative d^2V/dI^2 of a point-contact in a 2DEG directly reflects structures in the phonon density of states (DOS).

Samples were prepared from a GaAs/$Al_{0.3}Ga_{0.7}As$ heterostructure (grown by molecular beam epitaxy) with carrier density $n = 2.1\times10^{11}$ cm^{-2} and a zero-field mobility of $\mu = 3.0\times10^5$ cm^2/Vs at T = 4 K. This corresponds to a transport mean free path of 2.5 μm and a Fermi energy $E_F = 7.2$ meV. By means of focused Ga^+-ion beam (FIB) insulation writing with a spot diameter of 100 nm and a dose of 1×10^{13} cm^{-2} we create an In-Plane-Gate. In combination with an insulating line written from the sample edge close to the gate this gives a tunable constriction[2] (see Fig.1). We denote the shortest distance across the constriction between the center points of the FIB-exposed spots as the geometrical width which is $w_{geo} = 2\mu$m. By applying different gate voltages both the effective width and the carrier concentration of the constriction can be increased (positive gate voltage) or decreased (negative gate voltage), respectively. All measurements are performed in a bath cryostat at 4.2 K.

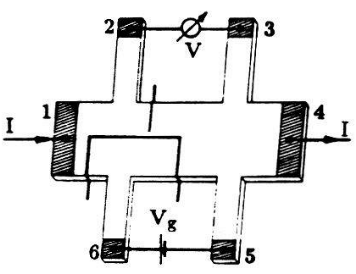

Fig.1: Sketch of the sample. The FIB written path is indicated by the bold lines.

In Fig.2 we present the second derivative d^2V/dI^2 as a function of the bias for different gate voltages. Non-linearities at 8 mV and 30 mV appear as positive peaks in d^2V/dI^2 as indicated by arrows in Fig.2. At the bottom of Fig.2 we have plotted the phonon DOS of GaAs for purpose of comparison. The marked structures in the second derivative are very close to maxima in the phonon DOS. This strongly indicates that d^2V/dI^2 is a measure of the energy dependence of the electron-phonon interaction as in the case of point-contact spectroscopy on metals, thereby reflecting the phonon DOS.

In order to rule out the possibility that the Fermi energy of the 2DEG ($E_F = 7.2$ meV) might affect

the position of the peak at V ≈ 8 mV we have prepared samples in the same way as the samples discussed above but from a AlGaAs/GaAs heterostructure with carrier density n = 4.8×10^{11} cm^{-2} which yields a Fermi energy E_F = 16.5 meV. As can be seen from Fig.2 there is no shift in the position of the peak even though the Fermi energy differs by more than a factor of two.
In contrast to conventional point-contact spectroscopy the width w of the constriction can be tuned continously via the In-Plane-Gate in our samples. This gives us the possibility to adjust different ratios w/l_e. Since in point-contact spectroscopy the condition $w < l_e$ must hold, we expect resonances which become more pronounced the smaller w is, in consistence with the observed phenomena. Another advantage of this method is due to the fact that the current does not flow through a free surface as is the case in a metal point-contact. In our samples the point-contact is formed within the 2DEG. Thus, spectra of the same constriction are well reproduced even after warming up the sample or exposing it to air.
Point-contact spectroscopy on 2D electron systems promises to be a useful tool to study the phonon DOS in semiconductors especially for those materials for which neutron-diffraction data can not be obtained because of the lack of volume crystals (e.g. AlGaAs).

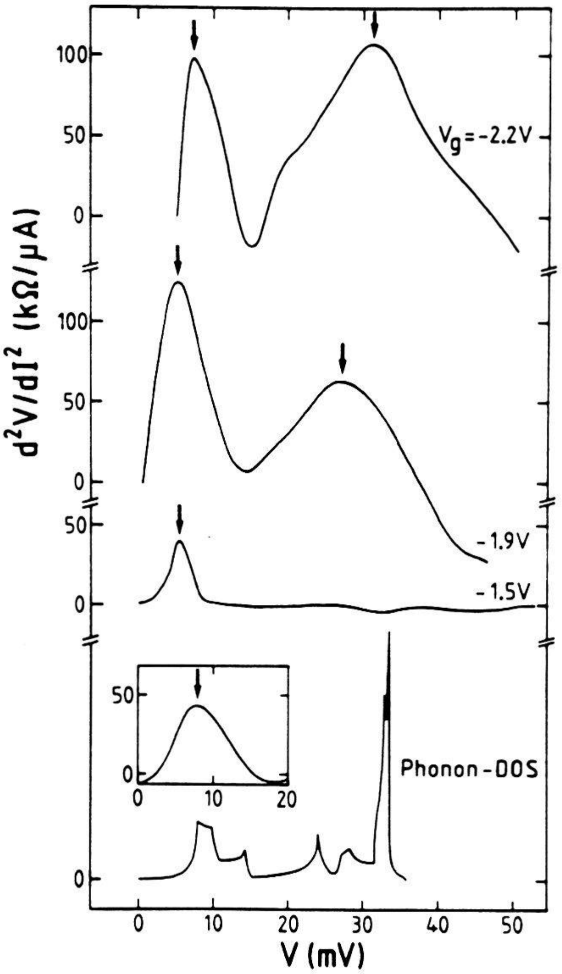

Fig.2: Second derivative of the voltage-current characteristics of the constriction at T=4.2K for gate voltages V_g as indicated in the figure. The Fermi energy of the 2DEG adjacent to the constriction is E_F = 7.2 meV (n = 2.1×10^{11} cm^{-2}). The curve in the inset is obtained for a sample with higher Fermi energy E_F = 16.5 meV (n = 4.8×10^{11} cm^{-2}), gate voltage V_g = -3.95 V and geometrical width w_{geo} = 1.5 μm. The lowest curve in the figure represents the energy dependence of the phonon DOS of GaAs in arbitrary units on the vertical scale.

References

[1] I.K.Yanson, Zh.Eksp.Teor.Fiz. **66**, 1035 (1974) [Sov.Phys.-JETP **39**, 506 (1974)].
[2] A.D.Wieck and K.Ploog, Appl.Phys.Lett. **56**, 928 (1990).