

## 11.0 Ultralow-Temperature Measurements of Submicron Devices

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Resulting in a large part from the work of Prof. P.A. Lee, a unified theory has emerged to explain the fluctuations of the conductance in very small conductors. In our collaborative research with Professors H.I. Smith and D.A. Antoniadis, we have used Si MOSFET's to explore these fluctuation phenomena experimentally.

The theory predicts that for long, narrow disordered conductors at zero temperature, there will be exponentially large fluctuations of conductance from one sample to another, one value of the Fermi energy to another or one value of applied magnetic field to another. If one could make the samples arbitrarily short, the theory predicts that the fluctuations would become smaller when the sample length  $L$  becomes smaller than the localization length. When this happens, that is, when the electronic states are extended over the entire sample, the fluctuations are predicted to have magnitude  $e^2/h$  independent of sample size or geometry.

In addition to these zero-temperature predictions, a theoretical description of the behavior at finite temperatures has been developed based on the experimental studies of narrow Si MOSFET's by groups at MIT, IBM and AT&T Bell Labs. The MIT experiments provided the first clear evidence that, in the exponentially-large-fluctuation regime, the fluctuations result from the limitation of the current by a single localized state in the one-dimensional MOSFET. This led Lee to propose his model of one-dimensional photon-assisted hopping. The MIT experiments also provided the first observation of the universal ( $e^2/h$ ) fluctuations in one-dimensional MOSFET's. Chu, Antoniadis, Smith and Kastner reported the first observation of such fluctuations in short wide MOSFET's.

A wide variety of quantum-effect devices are being fabricated by students of Antoniadis, Smith, Orlando and Kastner using Si MOSFET's as well as GaAs two-dimensional electron gas structures. The experience of IBM and AT&T as well as the MIT group is that the understanding of the electronic phenomena in submicron devices requires experiments at ultralow temperature. Kastner's JSEP program is therefore devoted to the development of the capability of characterizing submicron electronic devices at temperatures as low as 20 mK. A dilution refrigerator furnished with a 10 T superconducting magnet has been delivered and installation should be complete near the beginning of February 1987. The refrigerator is isolated from radio-frequency interference by a shielded enclosure. All information will be transferred into and out of the enclosure by a fiber-optic IEEE extender, to eliminate r.f. from the computer used

to control experiments and acquire data. These precautions are necessary because below  $\sim 0.1\text{K}$ , the electrons in submicron devices have poor thermal contact with the lattice. Any electrical noise then raises the electron temperature.

As temperature is increased from  $T=0$ , it is predicted that the decrease of the inelastic diffusion length will have the same effect as shortening the sample. That is, there will be a transition from localized states with exponentially large fluctuations to extended states with  $e^2/h$  fluctuations when the inelastic diffusion length becomes as short as the localization length. The first experiments with our dilution refrigerator will be a study of this transition. There are clear predictions of how the fluctuations will vary with the inelastic diffusion length and both depend on gate voltage in a MOSFET.