Application Note #000006

KeyWords
Nanonis, Tramea, Ge nanowire
Qubit

Nanonis ™

Characterization of Germanium nanowire

Guoping Guo and Shuxiao Li
Group of Quantum Devices at Key Lab of Quantum Information Chinese Academy of Science USTC

Using a combination of the Nanonis Tramea quantum transport measurement system fully integrated with an Oxford Instruments HelioxVL refrigerator, the energy levels of a qubit have been successfully measured in a Germanium nanowire. Due to the lower noise and faster speed of this measurement system, conductance measurements with greater detail are produced in shorter acquisition times.

Introduction

The operation of quantum computers relies on the formation of so called "qubits" where the state is not constrained to merely 0 and 1 as in traditional binary computers. Instead, each bit of information is represented by the state of a quantum particle which can be in a superposition of multiple states simultaneously. A wide variety of methods to form qubits are being investigated, and in this paper we study ones formed naturally via spatial confinement of holes provided by wires with dimensions close to the natural wavelength of the carrier as determined by quantum mechanics.

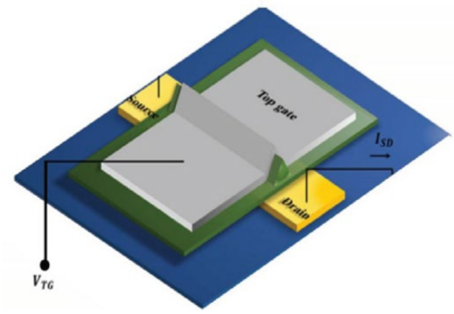

Figure 1 Schematic layout of device

Experiment

A rough schematic of the typical device is illustrated in Figure 1. A wire composed of Germanium is deposited on to a Silicon substrate and electrical contact is created lithographically. A third contact is added to apply a gate voltage in order to shift the energy levels of the confined hole up or down to block or permit current flow through the wire.

For this experiment the entire room temperature measurement electronics was fulfilled using only the Nanonis Tramea instrument. The Nanonis Tramea system is a fully digital, integrated package that provides the functionality of an oscilloscope, spectrum analyzer, voltage sweepers, voltmeters, lock-in amplifiers, and function generator etc in one compact package. It can also control eight inputs and eight outputs (expandable to 24 and 24) simultaneously in one user interface. All of these capabilities are housed within one unit, therefore the communication speeds, and hence the experiment times, are much shorter. Specifically, there is no need to incorporate slow bus connections between individual devices that traditional instruments rely on. The connection scheme between the device and the electronics is shown in Figure 2. A current amplifier is connected to the Drain contact and its output is sent to an input on the electronics. One output is connected to the Source side of the wire and a second output is connected to the Top Gate along the wire. All of these connections are therefore sourced from one single electronics instead of a disparate set of individual pieces tied together using custom software that communicates to everything simultaneously.

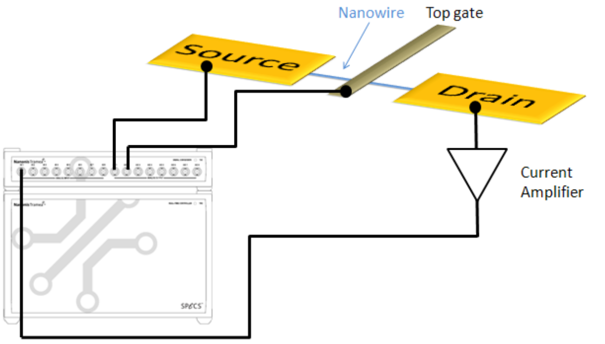

Figure 2 Connection diagram between Nanonis Tramea and device

Results

The device was placed in a HelioxVL Oxford dilution refrigerator and measured at a temperature of 270 mK. Early results are presented in Figure 3 where the familiar Coulomb diamonds are visible. As the S-D voltage is swept and a hole can enter the dot, Coulomb repulsion prevents additional carriers from tunneling into the dot until the voltage becomes large enough that an additional energy level becomes available for occupation. The finer structure visible in the lower left of the diagram is due to the excited states of the qubit combining to form multiple sets of conditions where levels line up and holes can move through the device. This finer structure was revealed when switching to the Tramea system compared to our older electronics measurement system composed of multiple instruments. Furthermore, since all of the parameters are downloaded into the Tramea, the entire acquisition proceeds autonomously and at high speed compared to traditional means with software running on a PC sequentially sending commands to each part of the measurement setup to set a voltage, take a reading, set another voltage, etc. The Nanonis Tramea is now a key instrument in our experimental design, as we are now planning to scale up our activities to have multiple qubits. However, we don't need any additional instruments since the Nanonis Tramea can accommodate 24 inputs and outputs using the same software interface.

Conclusion

We have used the Nanonis Tramea to investigate the energy levels of a qubit formed within a nanowire. Preliminary results reveal new details in the conduction through the device previously obscured by the noise level of our old measurement system. Additionally, the single instrument nature of the Nanonis Tramea permits a dramatic increase in acquisition speed by eliminating the slow bus protocol we used previously when combining individual components (DC voltage sources, lockin amplifiers, etc,) with our software package we developed ourselves.

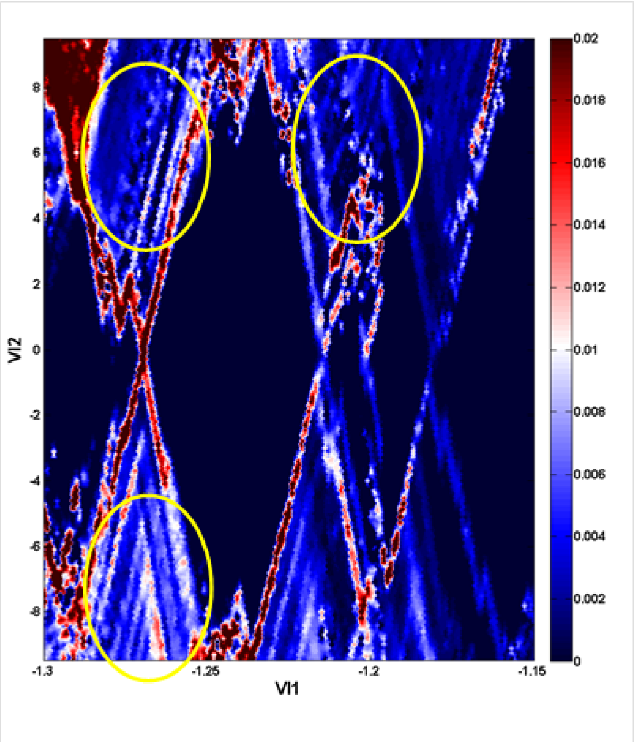

Figure 3 Differential conductance of device as a function of gate voltage (V2) and source-drain (V1). Note the fine details (yellow ovals) that emerge when using the Nanonis Tramea measurement electronics. The excited states were not visible with the previous measurement electronics.