Scanning Nanowire Quantum Dot

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Ultrasensitive detectors play an important role in exploring the electronic and magnetic properties of the increasingly rich playground of novel quantum materials and nanoscale devices. Imaging of local electronic density with high resolution and sensitivity, with low invasiveness, could give important insights concerning the development of devices for quantum computation and the quantum phenomena of 2D systems. Ideally, a suitable detector would furthermore be able to function under a wide variety of experimental circumstances, for example in the presence of high magnetic fields or elevated temperatures. Finally, high measurement bandwidths are desired, since this would give the capability of imaging dynamic phenomena and to reduce the influence of ubiquitous low-frequency noise in the measurement.

Here, we propose the development and application of a new kind of scanning probe microscope, which employs gated quantum dots (QDs) embedded in semiconductor nanowires (NWs) as a sensitive probe of charge and electronic density in nanoscale samples. The NWs will be integrated on cantilevers especially customized for this purpose through focused ion beam (FIB) lithography, which will allow us to implement them into conventional scanning probe setups. The scanning NW QD will be an extremely sensitive detector of charge, with an estimated sensitivity of 10^{-5} – 10^{-3} e $Hz^{-1/2}$, with e the electron charge. Importantly, such gated QDs are highly tunable [1], allowing to stay sensitive under varying experimental conditions, including inhomogeneous electric fields, magnetic fields of several T, and temperatures exceeding 4 K. Finally, the use of microwave reflectometry techniques [2, 3] will allow scanning probe measurements with bandwidths in the MHz regime, enabling spatial imaging of dynamics at short timescales with high signal-to-noise ratios.

The main goals of this project are to:
Fabricate scanning probe cantilevers hosting a NW with embedded gated QDs.
Image the electronic density of nanoscale samples with unprecedented sensitivity.
Implement high-bandwidth scanning probe imaging using microwave reflectometry techniques.
Image and study the dynamics of charge fluctuators in semiconducting devices.

References

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