Superconductor-Insulator Transition in Isolated MoGe Nanowires

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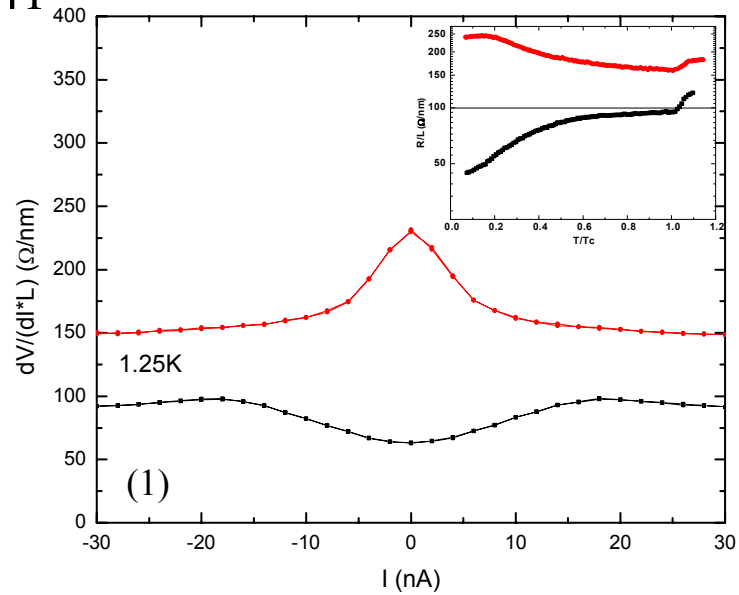
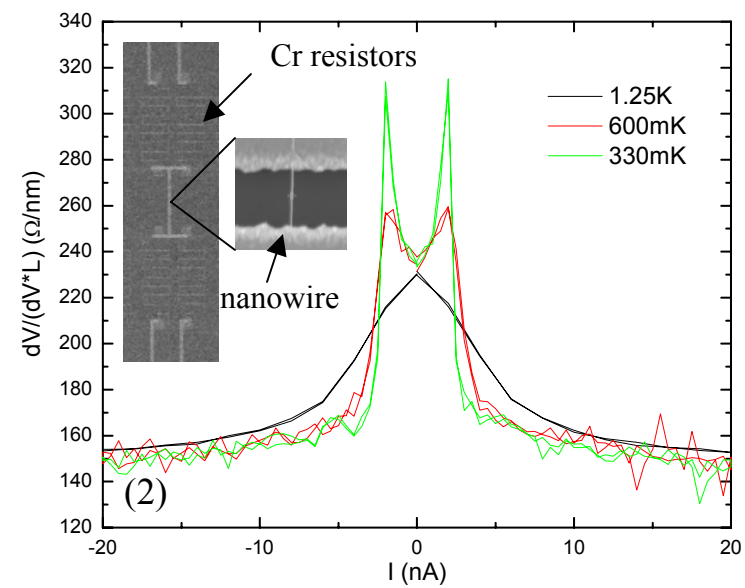
Our R(T) data (see inset of Fig.1) show that the superconductor-insulator (SI) transition in long MoGe nanowires (~300nm x ~10nm) appears to occur at a normal state resistance per unit length (R/L) around 100 Ω/nm. Our new measurements of the differential resistance (dV/dI), Fig. 1, show a corresponding *dip* at zero bias for wires with R/L below the SI transition, while wires above the SI transition show a *peak* at zero bias. Below 1K, we see an increase of the differential resistance in the insulating wires upon cooling at non-zero bias, while it remains relatively constant at zero bias. This feature, shown in Fig. 2, corresponds to the leveling off of R(T) below 1K seen in the top curve of the Fig. 1 insert. This dip has been seen in wires with on-chip Cr isolation resistors, shown in the inset of Fig. 2, cooled below 1K in a 3He insert. Further investigation is needed to determine the origin of this remarkable feature.





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Some metals (like aluminum) become “superconducting” , I.e., they loose all resistance to an electric current, when cooled below a “critical temperature” usually within a few degrees of absolute zero. This offers the possibility of applications, such as efficient magnets for magnetic resonance imaging in medicine and also advanced electronic applications, such as quantum computing. For compact electronics applications, the “wires” need to be miniturized to the “nano” scale. But there are theoretical reasons for expecting that below some critical diameter the superconducting property of zero resistance will be lost, and the material will show the “normal” electrical resistance seen at higher temperatures, or even become an “insulator” which shows a higher resistance at low temperatures than at high temperatures. Such properties would clearly limit the potential for applications of nano-scale superconductors.

In our work, we are testing such theoretical predictions by fabricating nanowires of a superconducting alloy MoGe and measuring their resistance vs. temperature and current level. Our results indeed show that below a certain diameter of about 10 nanometers (or above a certain normal resistance/length) the resistance *rise*s on cooling (insulating behavior), but it also shows a surprising peaked dependence on the current level through the wire. The objective of our ongoing work is to gain a fundamental understanding of this strange behavior, and to determine whether it would limit practical applications of somewhat thicker superconducting wires.

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Education and Outreach

Preparation of the samples and making measurements for this work introduces group members to cutting-edge nanotechnology and low temperature techniques. Participating in this work are two Harvard undergraduates, Jennifer Hou and James Murrett, a postdoc, William Neils, Harvard Fellow Nadya Mason, and visiting professor John Free, on sabbatical from Eastern Nazarene College. Both undergraduates have been heavily involved in setting up our new 3He insert and learning various lab skills. John Free will continue his participation as time allows after his sabbatical, and both Jennifer Hou and James Murrett will continue working with William Neils and Nadya Mason during the fall semester.

Contributing Group Members, from left to right: James Murrett, William Neils, Jennifer Hou, Nadya Mason, and John Free