Hybrid Physical-Chemical Vapor Deposition of MgB_2 Thin Films

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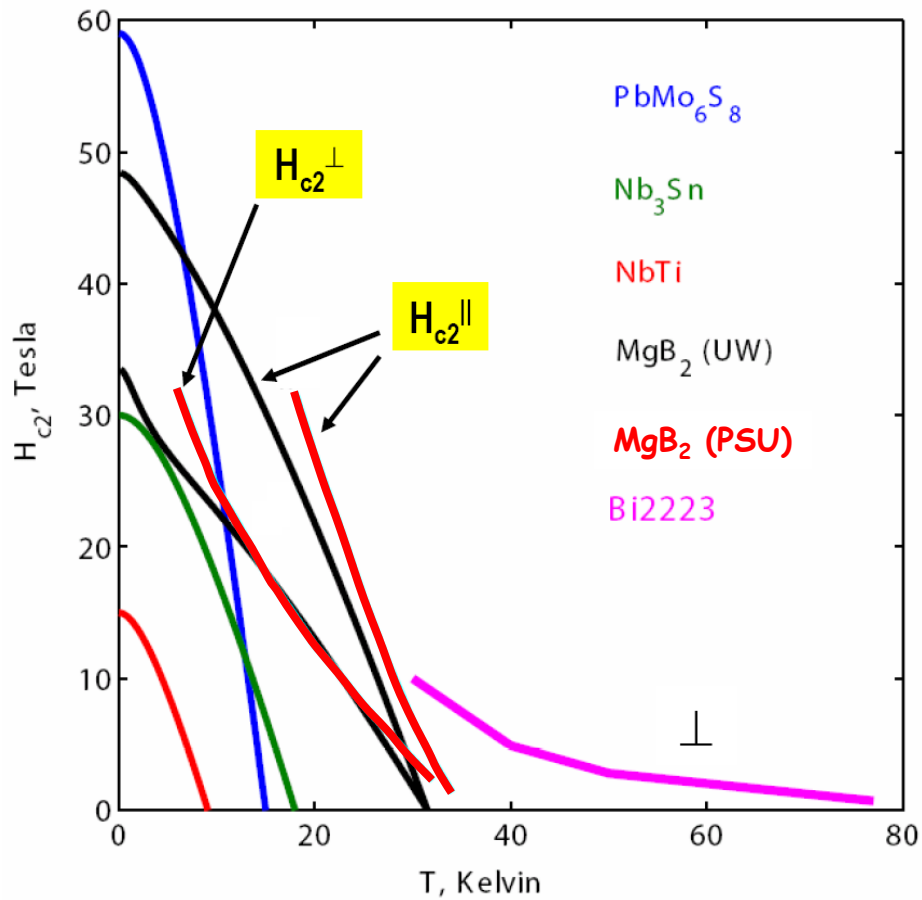
DMR-0306746

MgB_2 displays great potential to be a very good high-field superconductor. Our HPCVD technique deposits MgB_2 films with a self-field critical current density J_c of $5x10^7$ A/cm^2 at 4.2K. By doping it with carbon, we have shown high H_{c2} which extrapolates to 70 Tesla at 0K, a record high value ever reported. This is much higher than the current high field superconductors NbTi and Nb_3Sn. J_c in the carbon-doped film remains high to much higher magnetic fields than in pure films, indicating stronger pinning. The results demonstrate that MgB_2 is very promising for high-field applications such as in MRI magnets.



(Data compiled by A. Gurevich, U. Wisconsin-Madison.)

Motion of electrons in electrical circuits is usually detected by measuring the current, which is a flow of millions of electrons. The situation is much different in the case of nanoscale objects, called quantum dots whose behavior is dominated by only a few loosely bound electrons. Working in the field of quantum information science, we have shown that it is possible to control the rate at which the electrons escape the quantum dots. For example, we have developed devices such as a Single Electron Transistor (SET) that can be switched on or off with the addition of a single electron. With our collaborators from Bell Laboratories, we have used a special type of SET and detected the motion of individual electrons in and out of a semiconductor quantum dot. The experiment was done at temperatures only a few hundredth of a degree above absolute zero. We measured the output signal from the SET in a coded way and transformed it so we can see the changes in the SET signal in real time. Our group observed sudden changes in the SET output and showed that these changes correspond to individual electrons moving in and out of the tiny semiconductor dot in roughly ten millionth of a second. This is the first time that individual electron flow had been determined via an SET, and is of considerable interest from the standpoint of new quantum device development. This work was published in the May 22, 2003 issue of Nature.

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Education:

Five undergraduates (Rory Donovan, Amber Beckley, David M. Lishego, Eric Maertz, and Dean Walker) and two graduate students (Yi Cui and Daniel Lamborn) contributed to this work. The undergraduate students were supported by NSF through the REU program.

Societal Impact:

The high H_{c2} and $J_c(H)$ are very important parameters for making superconducting magnets. Our results may lead to MgB_2 magnets for applications such as MRI, either ~ 2T at T ~20K or at higher field at T ~ 4K.

The PI watched girls from grades 9 and 10 in their hand-on activities on superconducting levitation. The PI participated on two weekends in the Douglass Science Weekend Academy at Rutgers University.