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Master Material-Maker Provides the Stuff For Harvard and Chicago Experiments Reported in 'Science'

Santa Barbara, Calif.--Ask Arthur Gossard, materials professor at the University of California at Santa Barbara (UCSB), about the research that has led to his being an author of two unrelated articles in the September 29 issue of Science Magazine. He goes to his laboratory, stands before the Molecular Beam Epitaxy (MBE) machine, and explains reverently how it works.

Gossard is a master material-maker. And his material of choice is the compound semiconductor, so important for optoelectronics. The particular compound semiconductor Gossard and his students made for the experiments reported in Science alternates layers of gallium arsenide and aluminum arsenide.

"Take," said Gossard, "buckets of solid gallium and arsenic and heat them up. The idea is to deposit evaporated gallium and arsenic on a substrate wafer, two-inches in diameter, to form a semiconductor film."

The elements deposited on the substrate are also "doped." Small amounts of other elements such as silicon, carbon, or beryllium are incorporated into the molecular structure of the elements being deposited in order to improve the ability to conduct electricity.

The next step for the materials grown for the Science articles is to carve up the layers to provide pathways for electrons. That step was done by the Harvard and Chicago research teams that conducted the experiments whose results are reported in Science.

"Both of these are really physics measurements," said Gossard, "which explore fundamental materials properties. Neither Harvard nor Chicago have a way of making the semiconductor layers that the experiments require."

The Harvard experiment, "Imaging Coherent Electron Flow Through a Quantum Point Contact," was performed by a team of five Harvard scientists associated with the Division of Engineering and Applied Sciences and the Department of Physics. Of the five M.A. Topinka is the first author. Gossard and his student Kevin Maranowski are the other authors of the paper.

Gossard explains the Harvard experiment by analogy: "Imagine a little pipe connecting a lagoon and the ocean. The lagoon is a foot higher than the ocean. Let's say you start with the pipe pinched shut and gradually enlarge the opening. The amount of water that will flow from the lagoon to the ocean will increase smoothly in direct proportion to the size of the opening."

By contrast, instead of changing continuously, the flow of electrons through a channel--narrowed to a sub-micron point--increases or decreases in quantized steps as the point is enlarged or constricted. Predicted and detected by measurements of current some 10 years ago, this effect is imaged for the first by the Harvard experimenters, using a scanning probe microscope.

Along with Gossard and his student Ken Campman, the material samples for the Chicago experiment, "Quantum Hall Ferromagnetism in a Two-Dimensional Electron System," were supplied by a German researcher. The other three authors are associated with the James Franck Institute and Department of Physics at the University of Chicago.

The Chicago experiment detects, according to the paper's abstract, "the presence of novel two-dimensional ferromagnetism with a complicated magnetic domain dynamics." The experiment investigates unusual dynamics in the fractional quantum Hall effect.

The theoretical positing and the experimental demonstration of the fractional quantum Hall effect won the 1998 Nobel Prize in Physics. Gossard was at Bell Labs back in 1982, and he made the material which his colleagues there who won said was indispensable to their prize experiment.

What Gossard values is his pivotal point of view between physics and engineering. Perfecting the material-making techniques that lead, on the one hand, to practical devices such as better cell phones and, on the other hand, to explorations of fundamental materials properties provides, he said, "a rich context for doing science. The same material originally made for the Nobel Prize winning physics experiment on the fractional quantum Hall effect also enabled the making of faster, more sensitive microwave transistors."

Images

Media Contact

Tony Rairden
trairden@engineering.ucsb.edu
805.893.4301