Stripped uranium may bare faults in QED

The inner electrons of a heavy atom are bound to the nucleus by very strong electric forces. It takes therefore a great deal of energy to strip a heavy atom of all its electrons and come up with a bare nucleus. The Lawrence Berkeley Laboratory (LBL) in Berkeley, Calif., is the place where heavy ion physics is pursued with the highest energies in the world, and physicists there recently succeeded in producing bare nuclei of uranium, the heaviest element naturally present on earth. According to Harvey Gould of LBL, the leader of the group, the only other places such bare uranium, U^{92+}, might be made is in the centers of stars or possibly in a thermonuclear bomb blast.

The way to make bare uranium, which Gould described at last week's meeting in San Francisco of the American Physical Society, is to accelerate partially ionized uranium (it is not difficult to strip off the first few, outer electrons) to speeds where the ion is moving forward faster than the electrons are going in their orbits around the nucleus. If the ion then passes through a solid foil it will start leaving its inner electrons behind.

LBL's ion accelerator, the Bevalac, can deliver uranium with energies up to a billion electron-volts energy per proton and neutron in the nucleus. This translates to 87 percent of the speed of light.

The Bevalac, which has internal strippers, delivers the uranium as U^{68+}. Gould and his associates, Douglas Greiner, Peter Lindstrom and T.J.M. Symons of LBL and Henry Crawford of the University of California Space Science Laboratory, designed an apparatus to get rid of the remaining 24 electrons. Passage through a foil of mylar plastic yields a mixture of U^{80+} and U^{81+}. Then a thick tantalum foil does the rest, yielding a sample that is 85 percent bare nuclei and 15 percent hydrogen-like (one electron) atoms with an occasional helium-like (two electron) or lithium-like (three electron) atom.

Many things can be done with such highly stripped uranium. Gould stresses two particularly.

LBL has plans to build a very high energy ion accelerator that could collide beams of accelerated ions with each other. The Bevalac would serve as injector for this machine. If the Bevalac can be arranged to deliver fully stripped, bare nuclei to the new machine, that would make the new machine much easier to design and operate with sizable savings in time and money.

Starting in January, Gould and associates will be using the helium-like uranium atoms to run a test of the theory of quantum electrondynamics (QED). QED is the theory of electric and magnetic behavior on the atomic scale. Much that physicists know, or think they know, about the structure and behavior of atoms and molecules depends on their confidence in the theory.

Quantum electrodynamics has been tested in many aspects in many different ways and has never been found wanting. This experiment will test an aspect not probed before. As Gould puts it: "Is the physics of the atom the same when you've got a nucleus of very small charge ... as when you have a large charge like uranium?" QED calculations are easiest for atoms that have few electrons. For hydrogen and helium the permitted energy states of the electrons and the wavelengths of radiation they emit or absorb as they go from one state to another have been precisely calculated. The same is true for helium-like uranium, but it wouldn't be practical or perhaps even possible for uranium with 92 electrons.

The calculation shows, Gould says, that the situation for helium-like uranium is qualitatively as well as quantitatively different from that of actual helium. The QED contribution to the energy of the transition they want to study is a power series, a sum of successive terms, each of which involves higher and higher powers of the atomic number of the atom divided by 137 (the fine structure constant). For hydrogen or helium the higher terms of this series are negligible and their effect unobservable. For uranium the higher order terms dominate. A situation might arise where a discrepancy involving these terms would be observable in helium-like uranium, but would never have been observable in hydrogen or helium. Uranium is about as high an atomic number as anyone would want to go, Gould says. "Nobody would want to assemble several ounces of weapons grade plutonium and put it through the accelerator."

The observers will not be able to record directly the radiation from the transition of interest so they will observe a transition that follows it, and from the timing of the later transition determine the lifetime of the state that produces the one they want. Using a well-known formula they can then calculate the energy of the wanted transition. *—D. E. Thomsen*

Cleaner clean rooms for better wafers

Companies in the semiconductor manufacturing industry have long suspected that cigarette smokers breathe out microscopic particles that can contaminate and ruin the highly polished surfaces of silicon wafers used for building electronic integrated circuits. A recent study has provided the first quantitative data showing that a smoker emits up to 40 times as many particles as a nonsmoker, even hours after finishing a cigarette. The emitted particles, less than a micron (a millionth of a meter) in size, were detected by a laser counter; the particles appear to be tiny saliva droplets and clumps of dead cells originating in the mouth.

Stuart A. Hoenig of the University of Arizona in Tucson, who conducted the study as part of research on microcontamination control, says basic research related to contamination problems has long been neglected. This situation is changing as semiconductor circuit elements themselves approach submicron sizes. Many semiconductor manufacturers are concerned that today's "clean rooms," facilities specially designed to remove and exclude contaminants, are no longer fastidious enough to cope with fragments of hair, skin flakes, bacteria, lint and other particles that people continually shed. Cigarette smoking compounds the problem.

Hoenig's aim is to develop methods that will allow people to work in clean rooms under more normal conditions without contaminating increasingly intricate semiconductor devices. So far, among such possible methods, none of the masks that Hoenig tested effectively filters out microscopic contaminants, including those generated during cigarette smoking. As a follow-up, Hoenig hopes to look at the effects of using toothpastes and mouthwashes (and perhaps eating various foods) on the number and type of particles that people emit.

In many cases, Hoenig's work ventures into research areas that no one has yet thought to study. "There is a great deal of concern now about bacteria because bacteria are full of sodium and potassium," says Hoenig. These two elements have a particularly devastating effect on the properties of metal-oxide semiconductors. Using a sterilization process to kill the bacteria is not enough, Hoenig says, because the dead fragments still contain the contaminating elements. There's also a lot of interest in detecting traces of lint and in finding new laundering techniques that damage or break fewer fibers, he says.

Robert M. Burger of the Semiconductor Research Corp. in Research Triangle Park, N.C., says, "You either have to improve your clean room technology to allow people to operate on a semiconductor production line, or you have to ... automate the line so that no people are in the production environment." Both alternatives are very expensive, he says.

Alex Schwarzkopf of the National Science Foundation (NSF) in Washington, D.C., says that if there is sufficient industry interest, the NSF will consider establishing an industry-university cooperative research center for microcontamination control studies at the University of Arizona. He says, "Right now there are a lot of companies that appear interested in the area and willing to support it. *—I. Peterson*