Technology

Look, Ma—No Junctions!

A radically simpler transistor, 85 years after it was proposed BY DAVIDE CASTELVECCHI

The transistors at the heart of every computer, today numbering in the billions on a single chip, have generally been based on the concept John Bardeen, Walter Brattain and William Shockley first turned into a prototype at the Bell Labs in 1947. Physicists have now demonstrated a radically simpler transistor design, first patented by Austrian physicist Julius Edgar Lilienfeld in 1925 but never turned into a practical device until now. This simpler version could push computers to become faster and to consume less power.

In every transistor, an electrode, called the gate, governs whether current can run along a semiconductor strip, thereby defining an on or off state essential to a computer's binary function. Traditionally, the semiconductor strip is structured like a sandwich, with one type of material between two layers of another type. In the "off" position the sandwich acts as an electrical insulator, but the gate can turn it into a conductor, typically by creating an electric field. In chip fabrication the sandwich is obtained from a strip of silicon "doped" with other elements. For example, the middle section can be created by adding in atoms that tend to hog extra electrons; the side sections get atoms that tend to give electrons away. Each section separately could conduct electricity, but electrons will refuse to move across the middle section unless the gate is turned on.

The boundaries between consecutive sections are called junctions. As transistor size shrinks, it is becoming a challenge to produce sharp boundaries where doping concentrations change abruptly over distances of just nanometers, says Jean-Pierre Colinge of the Tyndall National Institute in Ireland.

A solution, then, is to eliminate those boundaries. Following Lilienfeld's idea, Colinge and his team have built a transistor with one type of doping only and thus no junctions. The new device is a one-micron-long nanorod of heavily doped silicon, with the gate crossing over its middle section. An electric field from the gate turns the transistor off by depleting that middle section of its electrons, preventing the flow of current through the rod. The team describes its result in the March *Nature Nanotechnology* (*Scientific American* is part of Nature Publishing Group).

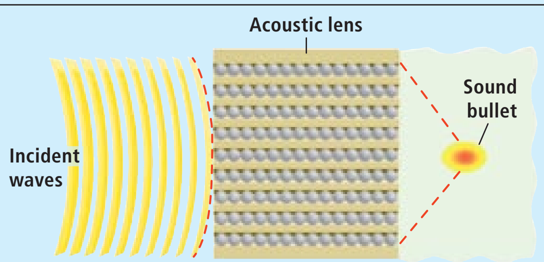
An effective depletion of electrons requires the rod to be just 10 nanometers thick, a feat that has only recently become possible in large-scale manufacturing. "The device should be able to be integrated in silicon chips quite readily," because it is compatible with existing fabrication processes, Colinge says. The junctionless design is more effective at switching currents on and off, he says, which means it could work at lower voltages, producing less waste heat, and at faster speeds. (After increasing for decades, computer clock speeds have essentially been stuck at about three gigahertz for the past several years.)

Thomas Theis, director of physical sciences at the IBM Watson Research Center in Yorktown Heights, N.Y., says that the junctionless transistor could be useful if the authors can make it much shorter than the current one micron, to better match existing components. Colinge says that shrinking it down to 10 nanometers should be feasible, and his team is working on getting there. Since the paper's publication, Colinge says, several semiconductor companies have shown interest in the transistor, perhaps getting ready to give new meaning to a future that has no boundaries.

Acoustic Lens Turns Sound into Sonic Bullets

The manipulation of sound waves has led to critical technologies such as ultrasound imaging. Alessandro Spadoni and Chiara Daraio of the California Institute of Technology have now developed a new type of acoustic lens to make sound waves even more powerful.

Acoustic lenses focus sound in much the same way optical lenses focus light. Instead of using glass and mirrors, the duo designed an acoustic lens using 21 rows of 21 stainless-steel spheres. But instead of firing sound waves at the lens, they actually strike the first sphere in each row "so that we send a compressive wave down each stack or row," Spadoni explains. The researchers effectively tune the focal point of the lens by changing how hard they strike the lens (affecting the waves' amplitude) and the size of the spheres (affecting wavelength). The waves are then transmitted into an object, such as a human limb, where they focus down to a point.



ACOUSTIC LENS, consisting of rows of stainless-steel balls, can focus incident compression waves to a small area for better ultrasound imaging or even tumor destruction.

GEORGE RETSECK

The ability to focus could improve ultrasound imaging, according to Spadoni, who described the work online in the April 5 *Proceedings of the National Academy of Sciences USA*. Even more daring would be "sound bullets" for nonintrusive surgical operations, the researchers say. Acoustic energy can heat tissue, an effect already used in hyperthermia therapy. The Caltech nonlinear acoustic lens could aid in the treatment of tumors by increasing the temperature of cancerous tissue to lethal levels without affecting healthy tissue. —*Larry Greenemeier*