OVONICS

Does the Ovshinsky Effect signify a new era in semiconductors?

BY JOHN P. ROBINSON, JR.

DOES THE IDEA of a miniaturized computer so small it could be used in your home, the classroom, or even your automobile sound interesting? Or, if you were an electronic equipment manufacturer, do you think electronic switches and memory cells that are smaller and less expensive than transistors would sound appealing? Would military equipment that is resistant to radiation make the Department of Defense happier?

All of these things can be achieved through the use of a hitherto neglected semiconductor material—glass! This may sound strange. Glass is used in telescopes, microscopes, drinking utensils, windows, and a host of other applications. But as a semiconductor—never!

It's perfectly possible, says Stanford R. Ovshinsky, a remarkable, self-educated man of 46 who lives in Troy, Michigan, a suburb of Detroit, with his wife Iris, who has her PhD in biochemistry. Leading physicists from all over the world apparently agree with him and are cautiously calling his devices a major breakthrough greater than the tunnel diode, possibly exceeding the laser.

The principle on which the new devices are based is called the Ovshinsky Effect. Briefly stated, it is the ability of certain boron- and oxide-based glasses and materials composed of tellerium and/or arsenic (in combination with other elements including germanium and silicon) to function as semiconductors. (In the 1950's, a Russian team at Leningrad conducted intensive experiments on these materials—but unsuccessfully. Despite their painstaking investigations, they missed being the first to discover the Ovshinsky Effect.)

These materials are called amorphous (shapeless) or disordered because of their random, irregular, and unpredictable atomic structure. They contrast sharply with conventional semiconductor materials which are crystalline in atomic structure and are therefore regular, orderly, geometric, predictable, and measurable. The latter are the materials used to make transistors and diode rectifiers with which we are so familiar; and semiconductor research for the last 20 years has been concentrated in this area. Little attention has been given to

Stanford R. Ovshinsky, President, and Dr. Iris M. Ovshinsky, Vice President, of Energy Conversion Devices, Inc. visualize a great future for Ovonics.

semiconductors that are amorphous in structure.

Now, threshold switches and memory cells are being manufactured and tested at Ovshinsky's plant, Energy Conversion Devices. Called "Ovonic" devices, each unit consists of a thin film of amorphous, semiconductor glass connected to two leads. The unit, or cell, suddenly changes from a nonconductor to a conductor when a preset voltage is applied. By varying the composition or the thickness of the vacuum-deposited glassy film, the firing voltage can be made to be anywhere between two and two hundred volts.

It is claimed that Ovonic memory units can store information for prolonged periods of time even though power has been removed. Conventional memory cells must have electric power applied constantly. Tests made on Ovonic memories seemingly prove both their ability to store information for a minimum period of six years and their durability, inasmuch as information has been stored on them and then erased over a million times.

Ovshinsky has attracted the attention of eminent scientists from many parts of Europe. One of them is Sir Nevill Mott, director of the Cavendish Laboratory at Cambridge University, England, who, early in November, reportedly called the Ovshinsky development one of the newest, biggest, most exciting discoveries in the physical sciences at the present time. There is some indication that the Ovshinsky Effect represents a completely new area of knowledge. Others interested in Ovonics are Isador Rabi, Nobel Laureate and retired professor of physics at Columbia University; physicists at Stanford, Harvard, Penn State and Delaware; as well as Jan Tauc of the Czechoslovak Academy of Sciences in Prague.

Who is Ovshinsky? Not a scientist in the formal sense of having a degree, Ovshinsky graduated from Hower Trade School in Akron, Ohio and has worked as a machinist. Despite his lack of formal education, his colleagues in the physical sciences are quick to admit how well read he is and how extensive is his knowledge of physics.

Although he had been experimenting with amorphous materials since 1958 and started up his modest firm in 1960 to continue his research and manufacture Ovonic devices, the prime information on their chemical composition was a closely guarded secret until 1966 when he was granted the first of his patents. Once he had received patent protection, he decided to publish a short technical paper explaining his discovery. This paper appeared in Physical Review Letters, November 11, 1968. Until that time the physical data behind his discovery was unknown except to a few companies with whom he had licensing agreements, granted with the proviso that any security leaks nullified the agreement.

In his recently published paper, Ovshinsky described components which switch from a nonconducting to a con-

Editor's Note: The unusual solid-state effect discussed in this article has been described as a phenomenon shrouded in mystery. Few unbiased scientists will comment on the Ovshinsky Effect; some researchers have reported parallel developments, but mostly our "sources" adopted a wait-and-see attitude. For what it's worth—here are the facts as they stand on December 15, 1968.

ducting condition in the incredible time of only 150 trillionths of a second. A typical Ovonic device which consists of 48% tellerium, 30% arsenic, 12% silicon and 10% germanium is made up of a microscopic layer of this material sandwiched between two electrodes. This material acts as a barrier until the voltage reaches a predetermined level. Conduction starts and continues until the voltage drops below the firing level.

There is a second type of glassy material developed at Energy Conversion Devices which remains in the conducting state indefinitely, without the necessity for continued application of external voltage. To return this device to its nonconducting state, all that is needed is the application of a second voltage pulse.

Ovshinsky has made it very clear that the principle he discovered is not based on transistor technology, and furthermore, he is not competing with transistors.

Another characteristic of these devices is their ability to operate on alternating current, a virtue not possessed by crystalline semiconductors, which are unidirectional and can only operate on direct current. Conventional semiconductors require at least two units to function efficiently on a.c.—one for the positive cycle, the other for the negative cycle.

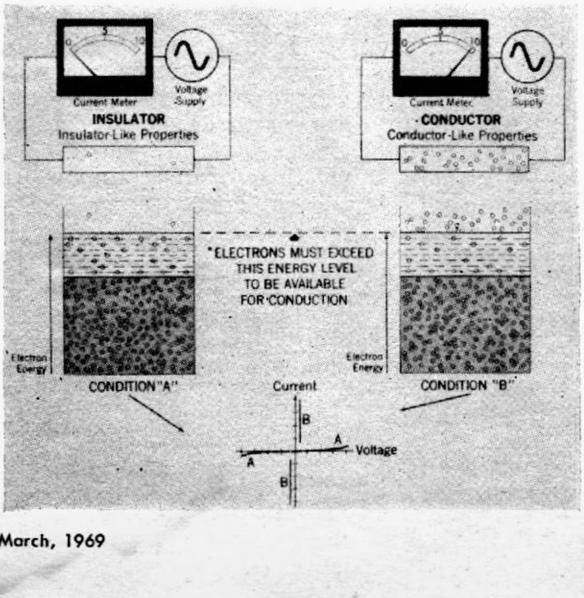
Easy to Manufacture. Industrially, the new materials have practical advantages. Manufacture is relatively cheap and simple. The chemicals for the devices are weighed out on a simple scale, mixed with a paddle, and then put into an oven to bake for 24 hours until they fuse into a lump of opaque glass having a dark gray color.

This is a simple procedure compared to the very careful methods used to manufacture conventional semiconductor devices, which have to have a high degree of purity, must be grown from "seeds," and then precisely doped with very carefully measured impurities.

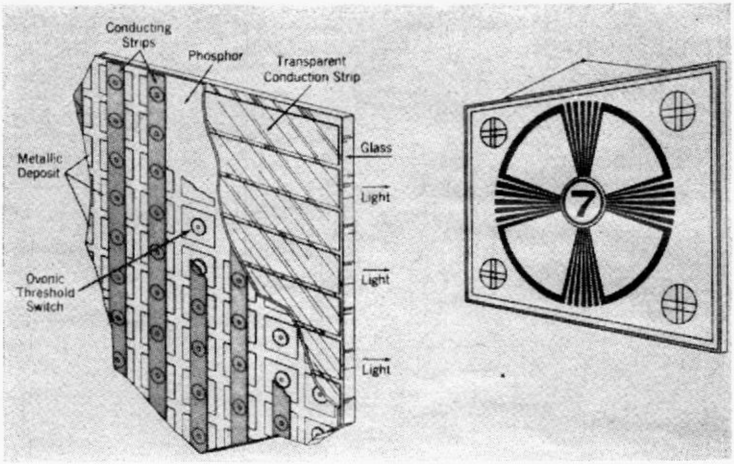
Conventional crystals are easy to work with because their atomic structures are arranged in such predictable patterns that the various changes that take place in them can be measured with high accuracy. Because of this measurable characteristic, it was possible during the last two decades to improve the techniques of manufacture of transistors, diodes, and integrated circuits.

In spite of technical advancements in the preparation of crystalline semiconductors, however, many are rejected because of flaws of one kind or another. Alternatively, amorphous semiconductors do not have to be doped because their conduction characteristics are inherent in the device itself. For this reason, plus some of the other advantages mentioned above, technologists conclude that the amorphous devices are cheaper and easier to manufacture.

James Perschy of the Applied Physics



The Ovonic device has a voltage sensitive threshold and, in the absence of any applied voltage, the device acts like an insulator. If voltage is applied across the Ovonic device, the electron energy in the thin film is increased until a point is reached where conduction takes place. This transition from the property of an insulator to a conductor takes place in an incredibly short time. The threshold may be adjusted by the chemical mix in the very thin film. Some Ovonic devices even remain "on" after the applied voltage has been removed.



Looking into the future, a flat screen TV picture may evolve using Ovonic devices. The face of the tube would be prepared in a matrix involving conducting strips, phosphor and Ovonic threshold switches. The TV picture quality would be similar to that obtained through a shadow mask used in color TV transmissions.

Laboratory at Johns Hopkins University, where glass semiconductor switches are being tested in memory addressing circuits, has stated that the devices are potentially very reliable because they can probably be manufactured in batches. This means they require fewer processing steps than are needed to prepare conventional semiconductor circuits. Perschy said this reliability results because the glass material does not require a junction between dissimilar metals, as some conventional semiconductors do.

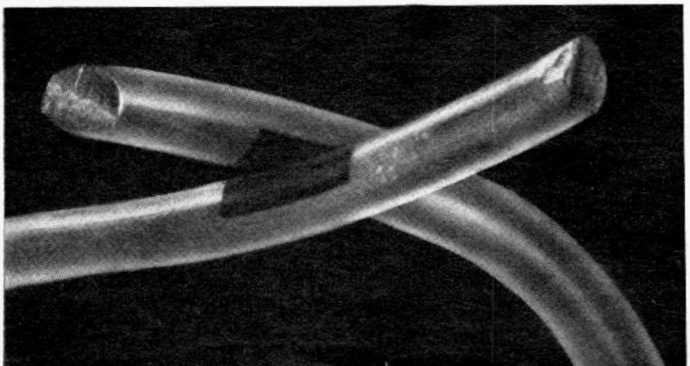
It is Ovshinsky's feeling that the carriers (holes and electrons) in glass semiconductors do not hop like those in crystals. Instead, they polevault or play leapfrog. By selecting glassy materials having strong covalent bonds, the scientist is able to work with carriers which are locked in place. The degree of locking is related directly to the energy band gap in the material. This determines the threshold voltage needed to dislodge the carriers. When the carriers are knocked out of their locked-in position by the proper voltage, they bombard other carriers and dislodge them. This starts an avalanche effect and conduction begins.

In crystalline semiconductors, carrier collisions and thermal effects recombine electrons and holes, thereby cutting off carrier movement. In glass semiconductors, this does not seem to take place. The reason, according to Ovshinsky, is the exceptionally high mobility of the carriers which lowers their mass allowing them to zoom past or through the recombination centers.

Physicists admit that much remains to be learned about the "how" and the "why" of the physics of glass semiconductors, but they are working on them with zeal and enthusiasm.

In the area of miniaturization, it is felt that Ovonics can be integrated into other circuits easily in that a glass chip in the amorphous state can be applied over another device.

Scientists, industrialists, financiers and even average citizens are watching with great interest the activities going on under Mr. Ovshinsky's direction. Perhaps something as memorable will emerge from the American Troy as that which came from ancient Troy. —30—



This highly magnified view is of a rudimentary Ovonic device. Between the two wire conductors is a thin film insulating ion with Ovonic qualities. At some low voltage threshold the insulator switches over to conduction. Manufacturing Ovonic devices is claimed to be easy.