Semiinsulator Radiation Detector

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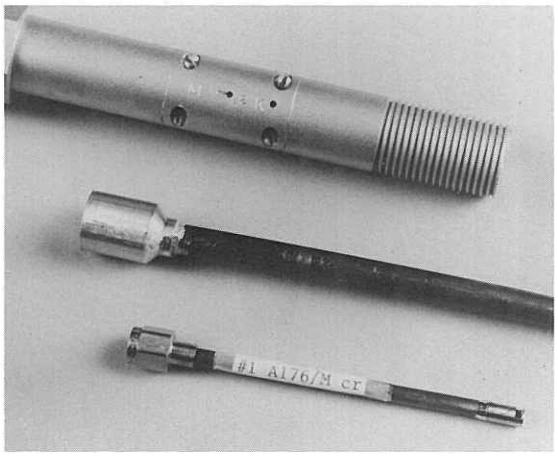

Three sizes of semiinsulator radiation detectors mounted in high-speed coaxial transmission housings. In the detector, incident radiation produces a current by exciting electrons from the valence band to the conduction band; the whole volume is sensitive to radiation. Electrons recombine and are immediately ready for "use" again.

Harsh radiation environments, like those encountered in the research to develop fusion power reactors, often destroy conventional radiation detectors in less than a day of use. A new kind of semiinsulator detector, developed by researchers at Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and EG&G, Inc., is so resistant to radiation damage that it can survive in such an environment thousands of times longer. The new detector is also very much faster, simpler to make, and less costly than those in general use. It can measure all types of radiation, from the infrared to high-energy gamma rays, a spectrum that includes ultra-violet, soft and hard x-rays, and charged particles, protons, and electrons. Unlike conventional detectors, which are damaged by neutron radiation, the new detector increases in resistivity and in speed when irradiated. These many advantages earned the Semiinsulator Radiation Detector a 1991 R&D 100 Award, meaning that it was selected as one of the one hundred most significant technical innovations of the year by *Research and Development Magazine*.

The Invention—Principles of Operation and Advantages

The semiinsulator detector is made from chrome-doped semiinsulating gallium arsenide. The addition of small amounts of chrome (doping) increases resistivity and reduces leakage current in the detector enough so that the detector measures only radiation. Because leakage interferes with radiation measurements, the lower the leakage current the more sensitive the measurement. To control leakage and to create a space-charge region that is sensitive to radiation, other detectors, like the semiconductor silicon diode, use junctions and "reverse bias." The new detector has neither junctions nor reverse bias to control leakage; it requires only simple contacts, and its whole volume, not just a space-charge region, is sensitive to radiation. A consequence of its unique design is sensitivity: the greater the volume of semi-insulated material, the more sensitive the detector. Another reason for its sensitivity is that neutron radiation, which reduces resistivity in silicon diodes, actually increases resistivity, and thus the speed of response, in the new detectors.

In both kinds of detectors incident radiation can be measured because it moves electrons out of position to create electron-hole pairs, which streak through the detector. In the new detector, the generation and recombination of the electron-hole pairs produces measurable electronic current pulses. The more the detector is irradiated, the faster the electron-hole pairs recombine and the more quickly the detector responds to the pulses. Under certain conditions the response time is as fast as 30 picoseconds. It is typically 0.5 nanosecond, ten times faster than the response time of silicon diodes of comparable size. When the detector is used in a compression mode, its dynamic range, or range of current pulse output, can be increased more than five orders of magnitude. In addition, its linearity, or faithful replication of response to increased radiation, is about 1.5 times better than the linearity of the silicon diode for the same voltage.

Applications

This new kind of radiation detector is expected to be particularly useful in harsh radiation environments that damage other detectors. It will give high-speed measurements of high-flux radiation in research using fast-pulse lasers, plasmas, pulsed x-ray sources, and pulsed accelerators. It is already being used to determine pulse characteristics in fast-pulse accelerators at a number of research institutions in the United States and Europe, including Los Alamos, the Nevada Test Site, Stanford, the Naval Surface Weapons Laboratory, and EG&G, Santa Barbara. Arrays of the new detectors can be used for radiation imaging of plasmas in fusion research and for obtaining the energy spectrum in a magnetic spectrometer. With further development, it may have important uses in space and in the planned superconducting supercollider.

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For more information about the Semiinsulator Radiation Detector, please contact Dr. Ronald E. Barks, Industrial Applications Office, Los Alamos National Laboratory, P.O. Box 1663, Mail Stop M899, Los Alamos, NM 87545, Telephone (505) 667-3839.

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Ronald S. Wagner, a Los Alamos National Laboratory staff member in the Mechanical and Electronic Engineering Division, has been designing solid-state radiation detectors since 1966, when he was an electronics research associate for the low-energy physics group at Johns Hopkins University. In 1969, he joined EDAX International to run that company's solid-state detector group. By the time he left in 1974 to come to Los Alamos, he was EDAX vice-president for manufacturing. Since then he has been developing rugged, sensitive, high-speed radiation detectors for Los Alamos National Laboratory. His current work is the development of soft x-ray detectors, using natural and epitaxial diamond.

Wagner won an Award of Excellence at the Laboratory in 1986 for the development of ultra-high-speed photoconductive radiation detectors for diagnostics in the underground testing of nuclear weapons. In 1991 he won a Distinguished Performance Award for the development of long-wavelength photon drag detectors for weapons diagnostics. He holds patents on the high-speed, iron-doped, indium-phosphide photoconductor, an extremely fast and sensitive detector used to measure rapid changes in radiation. It can measure a pulse of less than 50 picoseconds with a recovery time of less than 3 picoseconds, after which it can accurately measure another very small pulse. In the new semiinsulator detector, doping with chrome was used to get similar speed and more sensitivity. Wagner has studied chemistry, physics, and electrical engineering at Baltimore Polytechnic Institute, Johns Hopkins University, the Illinois Institute of Technology, and the University of New Mexico.


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Ronald Wagner uses the detector to measure infrared response.

The other inventors of the semiinsulator detector are C. L. Wang, physicist, M.D. Pocha, engineer, and J. E. Flatley, technical specialist, all of Lawrence Livermore National Laboratory, and B. A. Davis and K. Moy, both of EG&G, Inc.

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