Analytical Instrumentation, Methods & Materials

Flexible Germanium Lateral PIN Diodes and 3-D Arrays for Photodetector Applications

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The Wisconsin Alumni Research Foundation (WARF) is seeking commercial partners interested in developing a flexible lateral PIN diode for photodetector applications made of germanium.

Overview

Flexible single-crystalline semiconductors used in high-performance micro- and macro-electronics have been intensely studied in recent years. Thin-film transistors using single crystalline silicon, gallium arsenide and gallium nitride on plastic substrates have been developed to maintain the beneficial properties of plastics (bendable, light weight and shock resistant) while also maintaining the high-performance characteristics of transistors (high carrier mobility and multi-gigahertz operation capability). Germanium offers higher absorption coefficients across a large range of wavelengths and higher hole mobility, making it the preferred material for the membrane, but it only has been demonstrated on rigid substrates.

Most potential flexible germanium photodetector applications are in the realm of camera lenses and solar cells. Devices like digital cameras record images by allowing light to pass through a lens that focuses the light to land on a photodetector. Lenses are typically bulky and expensive, but potentially can be replaced by flexible photodetectors curved in such a way to absorb the light directly. Solar cells are designed to absorb as much light as possible across a wide range of wavelengths to get the most energy out of the incident sunlight, so allowing the highly absorbent germanium membranes to be flexible is very desirable. Other applications, such as Laser radar (LADAR) and electronic switches benefit from these flexible photodetectors as well.

The Invention

UW-Madison researchers have developed a flexible lateral PIN diode made of germanium for photodetector applications. The flexibility of the diode gives it the unique ability to be formed into flexible two- or three-dimensional arrays. Each diode is composed of a flexible layer of single-crystalline germanium on top of a flexible substrate. The middle of the single-crystalline semiconductor is the intrinsic (I) semiconductor layer, which is disposed laterally between an N- and a P-type doped region. These individual diodes are shaped like irregular polygons and can be formed into hemisphere shaped arrays.

The arrays can be used in photodetector applications such as digital cameras, solar cells or LADAR devices, and the individual diodes can be used for electronic switch applications. Digital cameras can use the arrays to capture light at its natural incident angle instead of bulky and expensive lenses that focus the light. Omnidirectional, three-dimensional LADAR systems for military surveillance applications can be formed by creating a hemispherical array made up of numerous vertical cavity light emitting sources, each surrounded by the photodetector diodes. The individual flexible, lightweight diodes also can be used in high-frequency switching applications where their flexibility is desired. These diodes have the advantage of utilizing high-performance active components while still incorporating low-cost plastic substrates.

Applications

- Flexible photodetector applications

- Solar cells
- Digital cameras
- LADAR imaging devices
- Flexible switch applications
- High-frequency electronic switches

Key Benefits

- Low cost
- Low weight
- Flexible
- Thin
- High hole mobility
- Increased absorption coefficients

Additional Information

For More Information About the Inventors

- Zhenqiang Ma
- Max Lagally

Related Intellectual Property

- View Continuation Patent in PDF format.

Publications

- Qin G., Yuan H.C., Celler G.K., Zhou W. and Ma Z. 2009. Flexible Microwave PIN Diodes and Switches Employing Transferable Single-Crystal Si Nanomembranes on Plastic Substrates. J. Phys. D. 42, 234006-234014.
- Yuan H.C., Qin G., Celler G.K. and Ma Z. 2009. Bendable High-Frequency Microwave Switches Formed with Single-Crystal Silicon Nanomembranes on Plastic Substrates. Appl. Phys. Lett. 95, 043109.
- Zhang et al. 2017. Origami Silicon Optoelectronics for Hemispherical Electronic Eye Systems. Nat. Commun. 8, 1782. doi:10.1038/s41467-017-01926-1

Tech Fields

- Analytical Instrumentation, Methods & Materials : Optics
- Semiconductors & Integrated Circuits : Other semiconductor technologies

For current licensing status, please contact Jeanine Burmania at jeanine@warf.org or 608-960-9846