Dot-in-Well Quantum-Dot Infrared Photodetectors

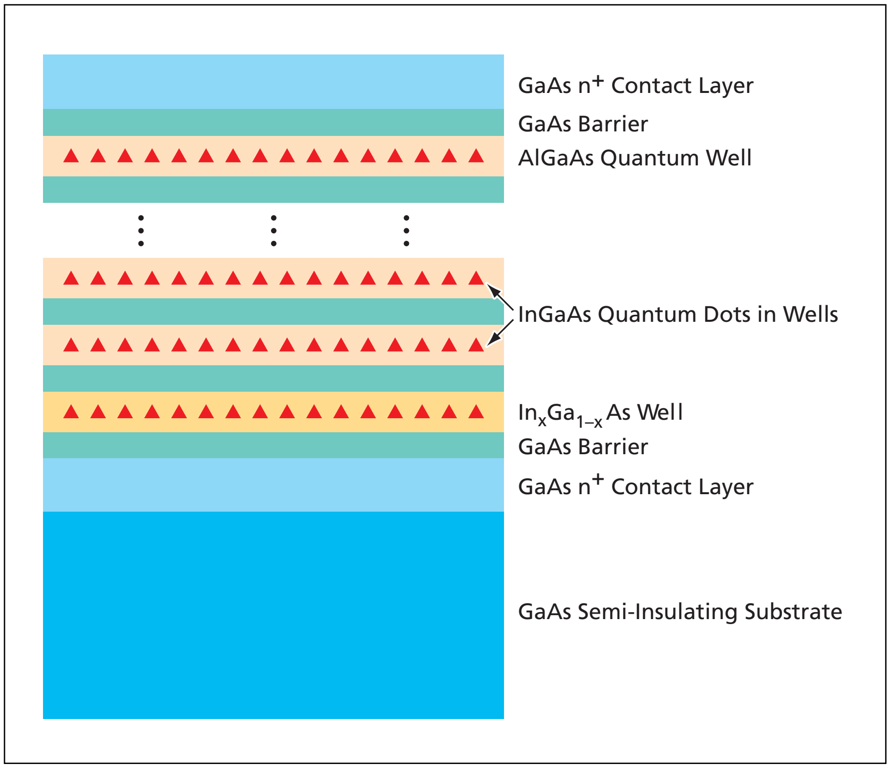
The goal is to develop high-performance radiation-hard QDIPs for focal plane arrays.

NASA's Jet Propulsion Laboratory, Pasadena, California

Dot-in-well (DWELL) quantum-dot infrared photodetectors (QDIPs) [DWELL-QDIPs] are subjects of research as potentially superior alternatives to prior QDIPs. Heretofore, there has not existed a reliable method for fabricating quantum dots (QDs) having precise, repeatable dimensions. This lack has constituted an obstacle to the development of uniform, high-performance, wavelength-tailorable QDIPs and of focal-plane arrays (FPAs) of such QDIPs. However, techniques for fabricating quantum-well infrared photodetectors (QWIPs) having multiple-quantum-well (MQW) structures are now well established. In the present research on DWELL-QDIPs, the arts of fabrication of QDs and QWIPs are combined with a view toward overcoming the deficiencies of prior QDIPs. The longer-term goal is to develop focal-plane arrays of radiation-hard, highly uniform arrays of QDIPs that would exhibit high performance at wavelengths from 8 to 15 μm when operated at temperatures between 150 and 200 K.

Increasing quantum efficiency is the key to the development of competitive QDIP-based FPAs. Quantum efficiency can be increased by increasing the density of QDs and by enhancing infrared absorption in QD-containing material. QDIPs demonstrated thus far have consisted, variously, of InAs islands on GaAs or InAs islands in InGaAs/GaAs wells. These QDIPs have exhibited low quantum efficiencies because the numbers of QD layers (and, hence, the areal densities of QDs) have been small — typically five layers in each QDIP. The number of QD layers in such a device must be thus limited to prevent the aggregation of strain in the InAs/InGaAs/GaAs non-lattice-matched material system.

The approach being followed in the DWELL-QDIP research is to embed InGaAs QDs in GaAs/AlGaAs multi-quantum-well (MQW) structures (see figure). This material system can accommodate a large number of QD layers without excessive lattice-mismatch strain and the associated degradation of photodetection properties. Hence, this material system is expected to enable achievement of greater densities of QDs and correspondingly greater quantum efficiencies. The host GaAs/AlGaAs MQW structures are highly compatible with mature fabrication processes that are now used routinely in making QWIP FPAs. The hybrid InGaAs-dot/GaAs/AlGaAs-well system also offers design advantages in that the effects of variability of dot size can be partly compensated by engineering quantum-well sizes, which can be controlled precisely.



Quantum Dots Are Embedded in Quantum Wells in a multiple-quantum-well structure. The multiplicity of wells makes it possible to attain a high areal density of QDs for high quantum efficiency.

Heretofore, a typical QDIP has exhibited high dark current attributable partly to a high-band-gap ohmic contact layer and partly to the fact that because of the low density of QDs, the QDs do not occupy all of the cross section presented to incident light and, hence, some of the current flowing in the device does not pass through the detector material. The undesired effect of the high-band-gap contact layer can be overcome by adding a high-band-gap barrier layer or placing an undoped spacer layer of GaAs, between about 500 and 600 Å thick between the quantum wells and the top contact layer. It has been previously demonstrated that such spacer layers can significantly reduce tunneling injection currents from contacts to quantum-well regions, thereby reducing dark currents.

Recently, it has been discovered that QDIPs exhibit strong QWIP-like intersubband absorption. The practical significance of this discovery is that it should be possible to increase the coupling of light into QDIPs, thereby increasing quantum efficiencies, by use of two-dimensional gratings.

This work was done by Sarath Gunapala, Sumith Bandara, David Ting, Cory Hill, John Liu, Jason Mumolo, and Yia Chung Chang of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). *NPO-43977*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-42362, volume and number of this NASA Tech Briefs *issue, and the page number.*