Focal-Plane Arrays of Quantum-Dot Infrared Photodetectors

Electron-beam lithography would be used to make arrays sufficiently uniform.

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Focal-plane arrays of semiconductor quantum-dot infrared photodetectors (QDIPs) are being developed as superior alternatives to prior infrared imagers, including imagers based on HgCdTe devices and, especially, those based on quantum-well infrared photodetectors (QWIPs). HgCdTe devices and arrays thereof are difficult to fabricate and operate, and they exhibit large nonuniformities and high 1/f (where f signifies frequency) noise. QWIPs are easier to fabricate and operate, can be made nearly uniform, and exhibit lower 1/f noise, but they exhibit larger dark currents, and their quantization only along the growth direction prevents them from absorbing photons at normal incidence, thereby limiting their quantum efficiencies. Like QWIPs, QDIPs offer the advantages of greater ease of operation, greater uniformity, and lower 1/f noise, but without the disadvantages: QDIPs exhibit lower dark currents, and quantum efficiencies of QDIPs are greater because the three-dimensional quantization of QDIPs is favorable to the absorption of photons at normal or oblique incidence. Moreover, QDIPs can be operated at higher temperatures (around 200 K) than are required for operation of QWIPs.

The main problem in the development of QDIP imagers is to fabricate quantum dots with the requisite uniformity of size and spacing. A promising approach to be tested soon involves the use of electron-beam lithography to define the locations and sizes of quantum dots (see figure). A photoresist-covered GaAs substrate would be exposed to the beam generated by an advanced, high-precision electron-beam apparatus. The exposure pattern would consist of spots typically having a diameter of 4 nm and typically spaced 20 nm apart.

The exposed photoresist would be developed by either a high-contrast or a low-contrast method. In the high-contrast method, the spots would be etched in such a way as to form steep-wall holes all the way down to the substrate. The holes would be wider than the electron-beam spots — perhaps as wide as 15 to 20 nm, but may be sufficient to control the growth of the quantum dots. In the low-contrast method, the resist would be etched in such a way as to form dimples.

Electron-Beam Lithography and Molecular-Beam Epitaxy would be used to grow quantum dots with a relatively high degree of uniformity in size and spacing.
the shapes of which would mimic the electron-beam density profile. Then by use of a transfer etching process that etches the substrate faster than it etches the resist, either the pattern of holes or a pattern comprising the narrow, lowest portions of the dimples would be imparted to the substrate. Having been thus patterned, the substrate would be cleaned. The resulting holes or dimples in the substrate would serve as nucleation sites for the growth of quantum dots of controlled size in the following steps. The substrate would be cleaned, then placed in a molecular-beam-epitaxy (MBE) chamber, where native oxide would be thermally desorbed and the quantum dots would be grown.

This work was done by Sarath Gunapala, Daniel Wilson, Cory Hill, John Liu, Samith Bandara, and David Ting of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41236

Microrectenna: A Terahertz Antenna and Rectifier on a Chip
Microscopic rectennas would supply DC power to microdevices.
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A microrectenna that would operate at a frequency of 2.5 THz has been designed and partially fabricated. The circuit is intended to be a prototype of an extremely compact device that could be used to convert radio-beamed power to DC to drive microdevices (see Figure 1).

The microrectenna (see Figure 2) circuit consists of an antenna, a diode rectifier and a DC output port. The antenna consists of a twin slot array in a conducting ground plane (denoted the antenna ground plane) over an enclosed quarter-wavelength-thickness resonant cavity (denoted the reflecting ground plane). The circuit also contains a planar high-frequency low-parasitic Schottky-barrier diode, a low-impedance microstrip transmission line, capacitors, and contact beam leads. The entire 3-D circuit is fabricated monolithically from a single