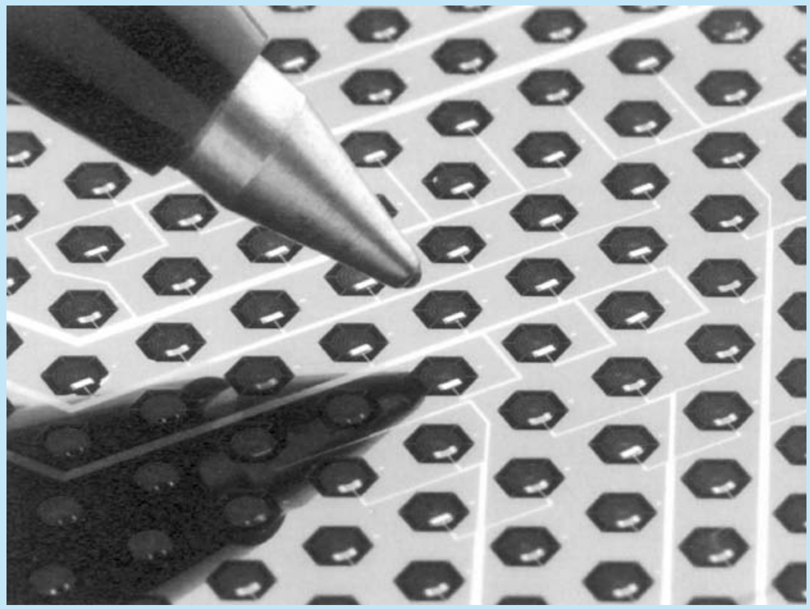
Physical Sciences

Array of Bolometers for Submillimeter-Wavelength Operation

This is a prototype of arrays for astrophysical imaging and photometry.

NASA's Jet Propulsion Laboratory, Pasadena, California

A feed-horn-coupled monolithic array of micromesh bolometers is undergoing development for use in a photometric camera. The array is designed for conducting astrophysical observations in a wavelength band centered at 350 μm. The bolometers are improved versions of previously developed bolometers comprising metalized Si_3N_4 micromesh radiation absorbers coupled with neutron-transmutation-doped Ge thermistors. Incident radiation heats the absorbers above a base temperature, changing the electrical resistance of each thermistor. In the present array of improved bolometers (see figure), the thermistors are attached to the micromesh absorbers by indium bump bonds and are addressed by use of lithographed, vapor-deposited electrical leads. This architecture reduces the heat capacity and minimizes the thermal conductivity to 1/20 and 1/300, respectively, of earlier versions of these detectors, with consequent improvement in sensitivity and speed of response.



This **Array of Micromesh Bolometers** was designed for photometry at a wavelength of 350 μm. Each device includes a 725-μm-diameter micromesh absorber with a grid spacing of 72.5 μm and a grid filling factor of 0.077. A thermistor is located on one side of each absorber and is electrically addressed by two leads deposited on a single 18-μm-wide supporting member. The pixel spacing is 1.75 mm.

The micromesh bolometers, intended to operate under an optical background set by thermal emission from an ambient-temperature space-borne telescope, are designed such that the random arrival of photons ("photon noise") dominates the noise sources arising from the detector and readout electronics. The micromesh is designed to be a highly thermally and optically efficient absorber with a limiting response time of about 100 μs. The absorber and thermistor heat capacity are minimized in order to give rapid speed of response. Due to the minimization of the absorber volume, the dominant source of heat capacity arises from the thermistor.

The array demonstrates a dark noise-equivalent power of $2.9 \cdot 10^{-17}$ W/(Hz)$^{1/2}$ and a mean heat capacity of 1.3 pJ/K at a detector temperature of 0.390 K from a 0.300 K cold plate. The optical efficiency of the bolometer and feedhorn array, measured by comparing the responses to blackbody calibration sources, lies between 0.4 and 0.6. Photon noise dominates over detector noise arising from phonon, Johnson, and amplifier noise, as measured under the design background conditions. The ratio of total noise to photon noise is found to be 1.21 at an absorbed optical power of 2.4 pW. The array shows high stability with excess noise found to be negligible at frequencies as low as 30 mHz.

This work was done by James Bock and Anthony Turner of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30290

Delta-Doped CCDs as Detector Arrays in Mass Spectrometers

Improved performance is obtained with reduced size, mass, and power.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a conventional mass spectrometer, charged particles (ions) are dispersed through a magnetic sector onto an MCP at an output (focal) plane. In the MCP, the impinging charged particles excite electron cascades that afford signal gain. Electrons leaving the MCP can be read out by any of a variety of means; most commonly, they are post-accelerated onto a solid-state detector array, wherein the electron pulses are converted to photons, which, in turn, are converted to measurable electric-current pulses by photodetectors. Each step in the conversion from the impinging charged particles to the output current pulses reduces spatial resolution and increases noise, thereby reducing the overall sensitivity and performance of the mass spectrometer. Hence, it would be preferable to make a direct measurement of the spatial distribution of charged particles impinging on the focal plane.

The utility of delta-doped CCDs as detectors of charged particles was reported in two articles in *NASA Tech Briefs*, Vol. 22, No. 7 (July 1998): "Delta-Doped CCDs as Low-Energy-Particle Detectors" (NPO-20178) on page 48 and "Delta-Doped CCDs for Measuring Energies of Positive Ions" (NPO-20253) on page 50. In the present developmental miniature mass spectrometers, the above mentioned miniaturization and performance advantages contributed by the use of delta-doped CCDs are combined with the advantages afforded by the Mattauch-Herzog design. The Mattauch-Herzog design is a double-focusing spectrometer design involving an electric and a magnetic sector, where the ions of different masses are spatially separated along the focal plane of magnetic sector. A delta-doped CCD at the focal plane measures the signals of all the charged-particle species simultaneously at high sensitivity and high resolution, thereby nearly instantaneously providing a complete, high-quality mass spectrum. The simultaneous nature of the measurement of ions stands in contrast to that of a scanning mass spectrometer, in which abundances of different masses are measured at successive times.

This work was done by Shouleh Nikzad, Todd Jones, April Jewell, and Mahadeva Sinha of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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Refer to NPO-41378, volume and number of this NASA Tech Briefs *issue, and the page number.*

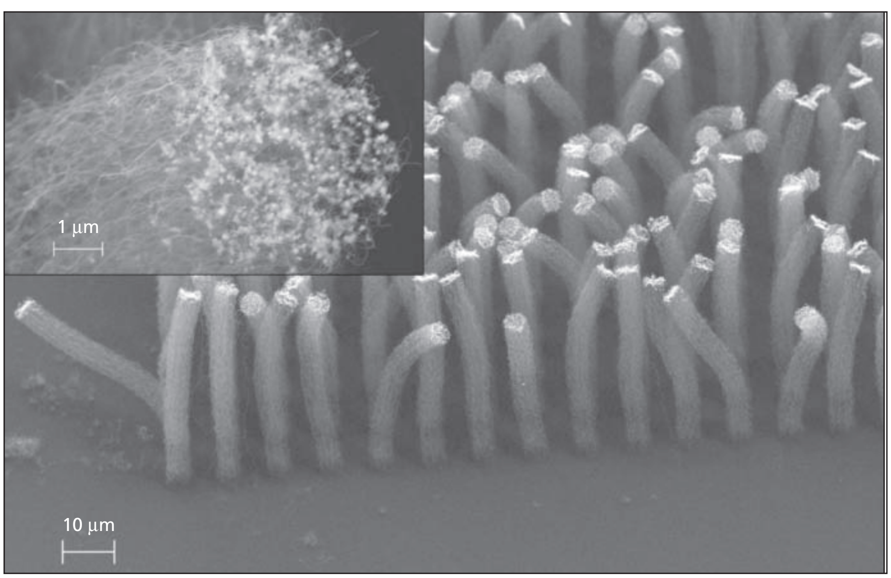
Arrays of Bundles of Carbon Nanotubes as Field Emitters

Area-averaged current densities exceed those of arrays of single nanotubes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that with suitable choices of critical dimensions, planar arrays of bundles of carbon nanotubes (see figure) can serve as high-current-density field emitter (cold-cathode) electron sources. Whereas some hot-cathode electron sources must be operated at supply potentials of thousands of volts, these cold-cathode sources generate comparable current densities when operated at tens of volts. Consequently, arrays of bundles of carbon nanotubes might prove useful as cold-cathode sources in miniature, lightweight electron-beam devices (e.g., nanoklystrons) soon to be developed.

Prior to the experiments, all reported efforts to develop carbon-nanotube-based field-emission sources had yielded low current densities — from a few hundred microamperes to a few hundred milliamperes per square centimeter. An electrostatic screening effect, in which taller nanotubes screen the shorter ones from participating in field emission, was conjectured to be what restricts the emission of electrons to such low levels. It was further conjectured that the screening effect could be reduced and thus emission levels increased by increasing the spacing between nanotubes to at least by a factor of one to two times the height of the nanotubes. While this change might increase the emission from individual nanotubes, it would decrease the number of nanotubes per unit area and thereby reduce the total possible emission current. Therefore, to maximize the area-averaged current density, it would be necessary to find an optimum combination of nanotube spacing and nanotube height.



This **Scanning Electron Micrograph** shows bundles of carbon nanotubes, each 70 μm high and 5 μm in diameter. The gaps between adjacent bundles are about 5 μm wide. The bundles stand up because their constituent nanotubes support each other. The inset is a magnified image of the top of one bundle, showing individual nanotube tips.

The present concept of using an array of bundles of nanotubes arises partly from the concept of optimizing the spacing and height of field emitters. It also arises partly from the idea that single nanotubes may have short lifetimes as field emitters, whereas bundles of nanotubes could afford redundancy so that the loss of a single nanotube would not significantly reduce the overall field emission.

In preparation for the experiments, planar arrays of bundles of carbon nanotubes having various bundle diameters, bundle heights, and bundle spacings were fabricated. The fabrication process can be summarized as follows: Electron-beam lithography was used to form planar arrays of iron dots having various thicknesses