



## Manufacturing & Prototyping

### Fabrication of a Cryogenic Bias Filter for Ultrasensitive Focal Plane

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A fabrication process has been developed for cryogenic in-line filtering for the bias and readout of ultrasensitive cryogenic bolometers for millimeter and submillimeter wavelengths. The design is a microstripline filter that cuts out, or strongly attenuates, frequencies (10–50 GHz) that can be carried by wiring staged at cryogenic temperatures. The filter must have 100-percent transmission at DC and low frequencies where the bias and readout lines will carry signal. The fabrication requires the encapsulation of superconducting wiring in a dielectric-metal envelope with precise electrical characteristics. Sufficiently thick insulation layers with high-conductivity metal layers fully surrounding a patterned su-

perconducting wire in arrayable formats have been demonstrated.

A degenerately doped silicon wafer has been chosen to provide a metallic ground plane. A metallic seed layer is patterned to enable attachment to the ground plane. Thick silicon dioxide films are deposited at low temperatures to provide tunable dielectric isolation without degrading the metallic seed layer. Superconducting wiring is deposited and patterned using microstripline filtering techniques to cut out the relevant frequencies. A low  $T_c$  superconductor is used so that it will attenuate power strongly above the gap frequency. Thick dielectric is deposited on top of the circuit, and then vias are pat-

terned through both dielectric layers. A thick conductive film is deposited conformally over the entire circuit, except for the contact pads for the signal and bias attachments to complete the encapsulating ground plane. Filters are high-aspect-ratio rectangles, allowing close packing in one direction, while enabling the chip to feed through the wall of a copper enclosure. The chip is secured in the copper wall using a soft metal seal to make good thermal and electrical contact to the outer shield.

*This work was done by James Chervenak, Ari Brown, and Edward Wollack of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16130-1*

### Processing of Nanosensors Using a Sacrificial Template Approach

**This technique can be applied to a variety of applications, including leak detection, personal health monitoring, and environmental monitoring.**

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A new microsensor fabrication approach has been demonstrated based upon the use of nanostructures as templates. The fundamental idea is that existing nanostructures, such as carbon nanotubes or biological structures, have a material structure that can be used advantageously in order to provide new sensor systems but lack the advantages of some materials to, for example, operate at high temperatures.

The approach is to start with a template using nanostructures such as a carbon nanotube. This template can then be coated by an oxide material with higher temperature capabilities. Upon heating in air, the carbon nanotube template is burned off, leaving only the metal oxide nanostructure. The resulting structure has a combination of the crystal structure and surface morphology of the carbon nanotube, combined with the material durability and high-temperature-sensing properties of the metal oxide. Further, since the metal

oxide nanocrystals are deposited on the carbon nanotube, after burn-off what is left is a metal oxide porous nanostructure. This makes both the interior and the exterior of this nanostructured sensor available for gas species detection. This, in effect, increases the surface area available for sensing, which has been shown in the past to significantly increase sensor performance.

There are a number of advantages to improving the capabilities of sensor materials such as metal oxides. For example, gas sensors based on polycrystalline tin oxide offer many advantages over current technologies for detecting reducing gases, such as low cost, long lifetime, and high selectivity and sensitivity. In general, a major emphasis of research is to produce sensors that are small in size, easy to batch-fabricate, and feature low power consumption.

The fabrication of these microsensors includes three major steps: (1) synthesis of the porous metal or metal oxide

nanotubes using a sacrificial template, (2) deposition of the electrodes onto alumina substrates, and (3) alignment of the nanotubes between the electrodes. This invention was reduced to practice using tin oxide nanotubes while using carbon nanotubes as the template.

A room-temperature methane microsensor based on porous tin oxide nanotubes has been developed using carbon nanotubes as templates. The sensor was fabricated integrating microfabrication techniques with the alignment of the nanostructures. The sensor was operated at room temperature, and detection of 0.25% methane in air was demonstrated. The room-temperature methane microsensor has the advantages of low power consumption, small size, simple to batch-fabricate, and is high in sensor yield.

The room-temperature methane microsensors developed have two major unique and novel attributes. First is the use of the microfabrication process to fabricate microsized sensor electrodes.

The application of photolithography and sputtering processing to fabricate sensor electrodes enables the sensor to have small sizes. The electrodes consist of a sawtooth pattern, which would be very difficult to make with other processes. The electrodes are batch-fabricated with low-cost, high-yield, and robust structure. Second is the use of porous tin oxide nanotubes and the unique design of the sensor structure. By having sawtooth patterned electrodes, the use of dielectrophoresis to align the nanostructures becomes more feasible. Dielectrophoresis exploits the dielectric difference between the solvent and the nanostructures in the solvent to induce temporary dipoles that align with the imposed electric field. The electric field is

greater at the tips of the sawtooth electrodes, which accounts for the preferential alignment of the nanotubes between the tips of opposing sawtooth electrodes.

The technology takes advantage of the structural and morphological properties of lower-temperature sensing materials, and uses them as templates for the formation of sensors with improved durability and temperature range. This approach specifically targets template materials demonstrated for their own ability to detect chemical species. In principle, any material that has advantageous sensor properties and is eliminated through higher-temperature processing can be used as a template. For example, biological materials that have a surface morphology designed for se-

lected detection of chemical species can serve as templates in this process. Thus, a biological material that inherently has structural and morphological properties that facilitate the detection of other species, such as carbon dioxide, can be used as a template to potentially improve the sensing properties of a metal oxide or metal.

*This work was done by Azlin M. Biaggi-Labiosa and Gary W. Hunter of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18768-1.*