Manufacturing & Prototyping

Fabrication of a Cryogenic Bias Filter for Ultrasensitive Focal Plane

Goddard Space Flight Center, Greenbelt, Maryland

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 superconducting 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 patterned 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.

John H. Glenn Research Center, Cleveland, Ohio

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.