Fabrication of a Cryogenic Terahertz Emitter for Bolometer Focal Plane Calibrations

The methods used produce an emitter that features greater precision.

Goddard Space Flight Center, Greenbelt, Maryland

A fabrication process is reported for prototype emitters of THz radiation, which operate cryogenically, and should provide a fast, stable blackbody source suitable for characterization of THz devices. The fabrication has been demonstrated and, at the time of this reporting, testing was underway. The emitter is similar to a monolithic silicon bolometer in design, using both a low-noise thermometer and a heater element on a thermally isolated stage. An impedance-matched, high-emissivity coating is also integrated to tune the blackbody properties.

This emitter is designed to emit a precise amount of power as a blackbody spectrum centered on terahertz frequencies. The emission is a function of the blackbody temperature. An integrated resistive heater and thermometer system can control the temperature of the blackbody with greater precision than previous incarnations of calibration sources that relied on blackbody emission.

The emitter is fabricated using a silicon-on-insulator substrate wafer. The buried oxide is chosen to be less than 1 micron thick, and the silicon device thickness is 1–2 microns. Layers of phosphorus compensated with boron are implanted into and diffused throughout the full thickness of the silicon device layer to create the thermometer and heater components. Degenerately doped wiring is implanted to connect the devices to wire-bondable contact pads at the edge of the emitter chip. Then the device is micromachined to remove the thick-handle silicon behind the thermometer and heater components, and to thermally isolate it on a silicon membrane. An impedance-matched emissive coating (ion assisted evaporated Bi) is applied to the back of the membrane to enable high-efficiency emission of the blackbody spectrum.

In operation, the heater is supplied with a voltage that is PID-controlled (proportional-integral-derivative-controlled) by the output of the thermometer. Both components are quiet, and require low-noise readout and power supplies to function correctly. The fabricated chip is mounted and heat-sunk to a copper housing that directs and collimates the beam of terahertz power emitted from the chip. Filtering in the optical column in the copper housing with metal mesh or neutral density components is also possible. The implanted silicon is highly reliable and stable. The Bi coating is robust but may require passivation if the environment for installation has corrosives (i.e., acid flux, heavy solvents from a Dewar).

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-16131-1

Fabrication of an Absorber-Coupled MKID Detector

This allows for multiplexed microwave readout and, consequently, good spatial discrimination between pixels in the array.

Goddard Space Flight Center, Greenbelt, Maryland

Absorber-coupled microwave kinetic inductance detector (MKID) arrays were developed for submillimeter and far-infrared astronomy. These sensors comprise arrays of lambda/2 stepped microwave impedance resonators patterned on a 1.5-mm-thick silicon membrane, which is optimized for optical coupling. The detector elements are supported on a 380-mm-thick micro-machined silicon wafer. The resonators consist of parallel plate aluminum transmission lines coupled to low-impedance Nb microstrip traces of variable length, which set the resonant frequency of each resonator. This allows for multiplexed microwave readout and, consequently, good spatial discrimination between pixels in the array. The transmission lines simultaneously act to absorb optical power and employ an appropriate surface impedance and effective filling fraction. The fabrication techniques demonstrate high-fabrication yield of MKID arrays on large, single-crystal membranes and sub-micron front-to-back alignment of the microstrip circuit.

An MKID is a detector that operates upon the principle that a superconducting material's kinetic inductance and surface resistance will change in response to being exposed to radiation with a power density sufficient to break its Cooper pairs. When integrated as part of a resonant circuit, the change in surface impedance will result in a shift in its resonance frequency and a decrease of its quality factor. In this approach, incident power creates quasiparticles inside a superconducting resonator, which is configured to match the impedance of free space in order to absorb the radiation being detected. For this reason MKIDs are attractive for use in large-format focal plane arrays, because they are easily multiplexed in the frequency domain and their fabrication is straightforward.

The fabrication process can be summarized in seven steps: (1) Alignment marks are lithographically patterned