Physical Sciences

$Nb_xTi_{1-x}N$ Superconducting-Nanowire Single-Photon Detectors

Potential applications include optical communications and quantum cryptography.

NASA's Jet Propulsion Laboratory, Pasadena, California

Superconducting-nanowire single-photon detectors (SNSPDs) in which $Nb_xTi_{1-x}N$ (where $x<1$) films serve as the superconducting materials have shown promise as superior alternatives to previously developed SNSPDs in which NbN films serve as the superconducting materials. SNSPDs have potential utility in optical communications and quantum cryptography.

NbN-based SNSPDs have exhibited, variously, high detection efficiency, low signal jitter, large dynamic range, and low dark counts, but it has been difficult to fabricate detectors that exhibit all of these desirable properties simultaneously. It has been even more difficult to produce NbN-based SNSPDs in high yield, especially in cases in which the detectors occupy areas larger than 5 by 5 μm.

$Nb_xTi_{1-x}N$ is a solid solution of NbN and TiN, and has many properties similar to those of NbN. It has been found to be generally easier to stabilize $Nb_xTi_{1-x}N$ in the high-superconducting-transition-temperature phase than it is to so stabilize NbN. In addition, the resistivity and penetration depth of polycrystalline films of $Nb_xTi_{1-x}N$ have been found to be much smaller than those of films of NbN. These differences have been hypothesized to be attributable to better coupling at grain boundaries within $Nb_xTi_{1-x}N$ films.

Four batches of prototype $Nb_xTi_{1-x}N$ SNSPDs fabricated thus far have shown a yield >60 percent — much higher than the yields of NbN SNSPDs. In two of the batches, the SNSPDs were fabricated in high-resonance-quality-factor (high-Q) cavities by use of commercial dielectric mirrors. The SNSPDs in the high-Q cavities simultaneously exhibited high detection efficiencies, low dark counts, small jitter, and high yield for a resonance wavelength of 1,064 nm. In the most recent two lots fabricated, the yield was high even for large-area (10 by 10 μm) SNSPDs.

This work was done by Jeffrey A. Stern, William H. Farr, Henry G. Leduc, and Bruce Bumble of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45603

Neon as a Buffer Gas for a Mercury-Ion Clock

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One aspect of the topic of "Compact, Highly Stable Ion Clock" (NPO-43075), *NASA Tech Briefs*, Vol. 32, No. 5 (May 2008), page 63, is examined in more detail. To recapitulate: A developmental miniature mercury-ion clock has stability comparable to that of a hydrogen-maser clock. The ion-handling components are housed in a sealed vacuum tube, wherein a getter pump is used to maintain the partial vacuum, and the evacuated tube is backfilled with mercury vapor in a buffer gas.

The development has included a study of gas-induced shifts of the clock frequency and of alternatives to the traditional use of helium as the buffer gas. The frequency-shifting effects of three inert gases (helium, neon, and argon) and three getterable gases (hydrogen, nitrogen, and methane) were measured. Neon was determined to be the best choice for the buffer gas: The pressure-induced frequency pulling by neon was found to be only about two-fifths of that of helium. Furthermore, because neon diffuses through solids much more slowly than does helium, the operational lifetime of a tube backfilled with neon could be considerably longer than that of a tube backfilled with helium.

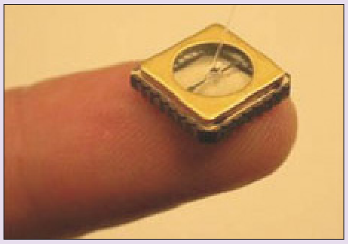
This work was done by John Prestage and Sang Chung of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-42919

Miniature Incandescent Lamps as Fiber-Optic Light Sources

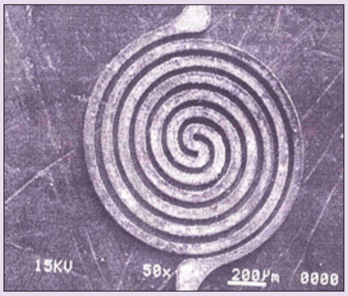
These lamps can be used without coupling optics.

John H. Glenn Research Center, Cleveland, Ohio

Miniature incandescent lamps of a special type have been invented to satisfy a need for compact, rapid-response, rugged, broadband, power-efficient, fiber-optic-coupled light sources for diverse purposes that could include calibrating spectrometers, interrogating optical sensors, spot illumination, and spot heating. A lamp of this type (see figure) includes a re-entrant planar spiral filament mounted within a ceramic package heretofore normally used to house an integrated-circuit chip. The package is closed with a window heretofore normally used in ultraviolet illumination to erase volatile electronic memories. The size and shape of the filament and the proximity of the fila-



LAMP WITH OPTICAL FIBER



SCANNING ELECTRON MICROGRAPH OF A TYPICAL FILAMENT

An **Extremely Compact Lamp** containing a spiral filament can be coupled directly to an optical fiber.

ment to the window are such that light emitted by the filament can be coupled efficiently to an optical fiber without intervening optics.

The components used for fabricating a lamp of this type are, more specifically, the following:

- The ceramic package is an appropriately sized commercially available leadless chip carrier containing gold contact pads. The package is chosen to have a contact-pad spacing of about 0.25 in. (≈6 mm) so that the filament fits between two of the pads.
- The window is part of a windowed lid for the leadless chip carrier, supplied with a preform made of gold/tin solder. The preform is to be used subsequently in bonding (by soldering) the lid to the leadless chip carrier.
- The filament is formed by chemical etching or laser ablation of a 25-μm-thick sheet of tungsten or a tungsten/rhenium alloy.
- Two commercially available contact-pad brazing preforms made of a silver/copper/indium/titanium alloy that has a liquidus temperature of 715 °C are needed for attaching (by brazing) the filament to two contact pads.

Once the aforementioned components have been prepared, the lamp is assembled as follows:

1. The brazing preforms are placed on two opposing contact pads.
2. The outer ends of the filament are placed on the brazing preforms.
3. The assembly as described thus far is placed in either a vacuum furnace at a pressure of 10^{-7} torr (1.3×10^{-5} Pa) or a furnace containing an inert atmosphere, and heated to ≈ 800 °C or until brazing alloy melts and wets the filament.
4. The assembly is cooled to harden the braze, then the furnace is opened to room air and the assembly is removed from the furnace.
5. Optionally, at this point, the assembly can be placed in a vacuum chamber, wherein the filament can be baked out by applying operating power to it. The assembly is then removed from the vacuum chamber.
6. A small nick is made in the solder preform on the lid to allow air to escape during step 8.
7. The lid is placed on the ceramic package, held in place by a weight or a clip. The package is placed in a vacuum furnace.
8. The vacuum furnace is pumped down to the desired vacuum for the interior of the lamp.
9. The furnace is heated to the eutectic temperature of the solder to melt and reflow the solder, then is cooled back to room temperature, then opened to air.

Lamps of this type containing tungsten and tungsten/rhenium filaments have been operated in laboratory tests at temperatures up to 2,650 and 2,725 °C, respectively. At an input power of ≈2 W, each lamp generates a luminous flux of about 1.5 lumens.

This work was done by Margaret Tuma of Glenn Research Center; Joe Collura of the Lighting Innovations Institute; Henry Helvajian of the Aerospace Corp.; and Michael Pocha, Glenn Meyer, Charles F. McConaghy, and Barry L. Olsen of Lawrence Livermore National Laboratory. 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: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17820-1.

Bidirectional Pressure-Regulator System

This system can be used in regenerative fuel cell systems.

John H. Glenn Research Center, Cleveland, Ohio

A bidirectional pressure-regulator system has been devised for use in a regenerative fuel cell system. The bidirectional pressure-regulator acts as a back-pressure regulator as gas flows through the bidirectional pressure-regulator in one direction. Later, the flow of gas goes through the regulator in the opposite direction and the bidirectional pressure-regulator operates as a pressure-reducing pressure regulator. In the regenerative fuel cell system, there are two such bidirectional regulators, one for the hydrogen gas and another for the oxygen gas. The flow of gases goes from the regenerative fuel cell system to the gas storage tanks when energy is being stored, and reverses direction, flowing from the storage tanks to the regenerative fuel cell system when the stored energy is being withdrawn from the regenerative fuel cell system. Having a single bidirectional regulator replaces two unidirectional regulators, plumbing, and multiple valves needed to reverse the flow direction. The term "bidirectional" refers to both the bidirectional nature of the gas flows and capability of each pressure regulator to control the pressure on either its upstream or downstream side, regardless of the direction of flow.

The system includes a computer that runs software formulated specifically to control the operation of the bidirectional pressure regulators. Each bidirectional pressure regulator includes the following components:

- A ten-turn needle valve;
- Two pressure sensors on opposite sides (upstream and downstream) of the valve;
- A stepping motor, connected to the shaft of the needle valve, for increasing or decreasing the valve orifice size as needed to decrease or increase the difference between the upstream and downstream pressures;