



Carbon Nanotube Bonding Strength Enhancement Using Metal “Wicking” Process

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Carbon nanotubes grown from a surface typically have poor bonding strength at the interface. A process has been developed for adding a metal coat to the surface of carbon nanotubes (CNTs) through a “wicking” process, which could lead to an enhanced bonding strength at the interface. This process involves merging CNTs with indium as a bump-bonding enhancement.

Classical capillary theory would not normally allow materials that do not

“wet” carbon or graphite to be drawn into the spacings by capillary action because the contact angle is greater than 90°. However, capillary action can be induced through JPL’s ability to fabricate oriented CNT bundles to desired spacings, and through the use of deposition techniques and temperature to control the size and mobility of the liquid metal streams and associated reservoirs. A reflow and plasma cleaning process has also been developed and demonstrated

to remove indium oxide, and to obtain smooth coatings on the CNT bundles.

This work was done by James L. Lamb, Matthew R. Dickie, Robert S. Kowalczyk, and Anna Liao of Caltech; and Michael J. Bronikowski of Atomate Corporation for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46594

Multi-Layer Far-Infrared Component Technology

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A method has been developed for fabricating high-reflectivity, multi-layer optical films for the terahertz wavelength region. A silicon mirror with 99.997-percent reflectivity at 70 μm wavelength requires an air gap of 17.50 μm , and a silicon thickness of 5.12 μm . This approach obtains pre-thinned wafers of about 20 mm thickness in

order to measure their thickness precisely. A gold annulus of appropriate thickness is deposited to reach the required total thickness. This, in turn, has the central aperture etched down to the desired final silicon thickness. Also, the novel Bragg stack optics in this innovation are key to providing Fabry-Perot spectroscopy and improved spectral

component technologies of unprecedented resolution, free spectral range, and aperture.

This work was done by Oliver Edwards of Zyberwear for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15888-1

Germanium Lift-Off Masks for Thin Metal Film Patterning

This innovation has uses in the fabrication of transition edge sensors and microwave kinetic inductance detectors.

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A technique has been developed for patterning thin metallic films that are, in turn, used to fabricate microelectronics circuitry and thin-film sensors. The technique uses germanium thin films as lift-off masks. This requires development of a technique to strip or undercut the germanium chemically without affecting the deposited metal. Unlike in the case of conventional polymeric lift-off masks, the substrate can be exposed to very high temperatures during processing (sputter deposition). The reason why polymeric lift-off masks cannot be exposed to very high temperatures (>100 °C) is be-

cause (a) they can become cross linked, making lift-off very difficult if not impossible, and (b) they can outgas nitrogen and oxygen, which then can react with the metal being deposited. Consequently, this innovation is expected to find use in the fabrication of transition edge sensors and microwave kinetic inductance detectors, which use thin superconducting films deposited at high temperature as their sensing elements.

Transition edge sensors, microwave kinetic inductance detectors, and their circuitry are comprised of superconducting thin films, for example Nb and TiN.

Reactive ion etching can be used to pattern these films; however, reactive ion etching also damages the underlying substrate, which is unwanted in many instances. Polymeric lift-off techniques permit thin-film patterning without any substrate damage, but they are difficult to remove and the polymer can outgas during thin-film deposition. The outgassed material can then react with the film with the consequence of altered and non-reproducible materials properties, which, in turn, is deleterious for sensors and their circuitry.

The purpose of this innovation was to fabricate a germanium lift-off mask to be

used for patterning thin metal films. The germanium can either be thermally or electron-beam evaporated onto Si(001) wafers. The evaporation rates and deposited thicknesses are 0.2 nm/s and 0.5 nm/s, and 620 nm and 500 nm for thermal and electron beam evaporation, respectively. The germanium can be patterned either via polymeric lift-off, using 1 micron of LOR-5a (Microchem) and 1.3 microns of S-1811 (Shipley) photore-

sists, or with lithographic patterning using 1.3 microns of S-1811 photoresist. In both cases, the photoresist is exposed to UV light using a mask aligner (MA-6, SUSS) and developed in a commercially available developer. In the case of lift-off, the germanium is removed in 1165 (Microchem); in the case of lithographic patterning, the germanium is removed in a dilute hydrochloric acid solution. The photoresist can be stripped in ace-

tone. The desired metal thin film (Nb, TiN, NbN, Au) is deposited and is lifted-off in dilute hydrochloric acid. The reliability of the lift-off process is dependent upon the amount of undercut in the germanium mask during the germanium patterning process.

This work was done by Ari Brown of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16147-1