bath, such that it protrudes about 2 in. (about 5.1 cm) above the surface of the water. The bottom end of the cathode is held underwater by a clamp, to which is connected the grounding cable of the welding power source.

The anode is a carbon rod 1/8 in. (≈0.3 cm) in diameter. The assembly that holds the anode includes a thumb-knob-driven mechanism for controlling the height of the anode. A small hood is placed over the anode to direct a flow of helium downward from the anode to the cathode during the welding process. A bell-shaped exhaust hood collects the helium and other gases from the process. During the process, as the anode is consumed, the height of the anode is adjusted to maintain an anode-to-cathode gap of 1 mm.

The arc-welding process is continued until the upper end of the anode has been lowered to a specified height above the surface of the water bath. The process causes carbon nanotubes to form in the lowest 2.5 cm of the anode. It also causes a deposit reminiscent of a sandcastle to form on the cathode. The nanotube-containing material is harvested. The cathode and anode can then be cleaned (or the anode is replaced, if necessary) and the process repeated to produce more nanotubes.

Tests have shown that the process results in ≈50-percent yield of carbon nanotubes (mostly of the single-wall type) of various sizes. Whereas the unit cost of purified single-wall carbon nanotubes produced by other process is about $1,000/g in the year 2000, it has been estimated that for the present process, the corresponding cost would be about $10/g.

This work was done by Jeanette M. Benavides and Henning Lidecker of **Goddard Space Flight Center.** *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,114,995). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-14601.

Setup for Visual Observation of Carbon-Nanotube Arc Process

Lyndon B. Johnson Space Center, Houston, Texas

A simple optical setup has been devised to enable safe viewing of the arc and measurement of the interelectrode gap in a process in which carbon nanotubes are produced in an arc between a catalyst-filled carbon anode and a graphite cathode. This setup can be used for visually guided manual positioning of the anode to maintain the interelectrode gap at a desired constant value, possibly as a low-technology alternative to the automatic position/voltage control described in "Automatic Control of Arc Process for Making Carbon Nanotubes" (MSC-23134), *NASA Tech Briefs*, Vol. 28, No. 3 (March 2004), page 51. The optical setup consists mainly of lenses for projecting an image of the arc onto a wall, plus a calibrated grid that is mounted on the wall so that one can measure the superimposed image of the arc. To facilitate determination of the end point of the process, the anode is notched, by use of a file, at the end of the filled portion that is meant to be consumed in the process. As the anode is consumed and the notch comes into view in the scene projected onto the wall, the process operator switches off the arc current.

This work was done by Carl D. Scott of **Johnson Space Center** *and Sivaram Arepalli of GB Tech Inc. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809.*
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