

rials that have high strengths and other tailorable properties as described below.

The ceramic component of a material in this family consists of hollow ceramic spheres that have been formulated to be lightweight ( $0.5 \text{ g/cm}^3$ ) and have high crush strength [40–80 ksi ( $\approx 276$ – $552$  MPa)]. The hollow spheres are coated with a metal to enhance a specific performance — such as shielding against radiation (cosmic rays or x rays) or against electromagnetic interference at radio and lower frequencies, or a material to reduce the coefficient of thermal expansion (CTE) of the final composite material, and/or materials to mitigate any mismatch between the spheres and

the matrix metal. Because of the high crush strength of the spheres, the initial composite workpiece can be forged or extruded into a high-strength part. The total time taken in processing from the raw ingredients to a finished part is typically 10 to 14 days depending on machining required.

For purposes of further processing, the material behaves like a metal: It can be processed by conventional machining (including formation of threads) or electrical-discharge machining, and pieces of the material can be joined by techniques commonly used to join metal pieces. The material is also receptive to coating materials and exhibits highly variable thermal conductivity from

metal to ceramic depending on loading.

Typical mechanical properties of such a material include a density less than that of beryllium (ranging from  $1.2$ – $17 \text{ g/cm}^3$  while the density of beryllium is  $1.85 \text{ g/cm}^3$ ) and modulus as high as 25 Msi ( $\approx 170$  GPa). In contrast, the modulus of aluminum is generally 14 Msi ( $\approx 97$  GPa). The CTE, the thermal conductivity, and the specific heat can be tailored, through the formulation of the ceramic and metal matrix ingredients of the composite.

*This work was done by Dean M. Baker of Advanced Powder Solutions, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15348-1*

## Piezoelectrically Enhanced Photocathodes

**Attributes would include stability, high efficiency, and relative ease of fabrication.**

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Doping of photocathodes with materials that have large piezoelectric coefficients has been proposed as an alternative means of increasing the desired photoemission of electrons. Treating cathode materials to increase emission of electrons is called “activation” in the art. It has been common practice to activate photocathodes by depositing thin layers of suitable metals (usually, cesium). Because cesium is unstable in air, fabrication of cesiated photocathodes and devices that contain them must be performed in sealed tubes under vacuum. It is difficult and costly to perform fabrication processes in enclosed, evacuated spaces. The proposed piezoelectrically enhanced photocathodes would have electron-emission properties similar to those of cesiated photocathodes but would be stable in air, and therefore could be fabricated more easily and at lower cost.

Candidate photocathodes include nitrides of elements in column III of the periodic table — especially compounds of the general formula  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  (where  $0 \leq x \leq 1$ ). These compounds have high piezoelectric coefficients and are suitable for obtaining response to ultraviolet light. Fabrication of a photocathode according to the proposal would include inducement of strain in cathode layers during growth of the layers on a substrate. The strain would be induced by exploiting structural mismatches among the various constituent materials of the cathode. Because of the piezoelectric effect in this material, the strain would give rise to strong electric fields that, in turn, would give rise to a high concentration of charge near the surface.

Examples of devices in which piezoelectrically enhanced photocathodes could be used include microchannel plates, electron-bombarded charge-coupled devices,

image tubes, and night-vision goggles. Piezoelectrically enhanced photocathode materials could also be used in making highly efficient monolithic photodetectors. Highly efficient and stable piezoelectrically enhanced, ultraviolet-sensitive photocathodes and photodetectors could be fabricated by use of novel techniques for growing piezoelectrically enhanced layers, in conjunction with thinning and dopant-selective etching techniques.

*This work was done by Robert A. Beach, Shouleh Nikzad, Lloyd Douglas Bell, and Robert Strittmatter of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office—JPL. Refer to NPO-40407.*

## Iridium-Doped Ruthenium Oxide Catalyst for Oxygen Evolution

**Possible applications of this catalyst include fabrication of water electrolysis units in hydrogen generators.**

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NASA requires a durable and efficient catalyst for the electrolysis of water in a polymer-electrolyte-membrane (PEM) cell. Ruthenium oxide in a slightly reduced form is known to be a very effi-

cient catalyst for the anodic oxidation of water to oxygen, but it degrades rapidly, reducing efficiency. To combat this tendency of ruthenium oxide to change oxidation states, it is combined with irid-

ium, which has a tendency to stabilize ruthenium oxide at oxygen evolution potentials. The novel oxygen evolution catalyst was fabricated under flowing argon in order to allow the iridium to