

A Gas Flame at 1,600°F (about 871°C) was applied for 3 hours to a layer of RP46/glass composite 0.15 in. (about 3.8 mm) thick on a 1.62-in. (≈41.2-mm)-diameter copper pipe while a 60-Hz, 110-V alternating potential was applied across the layer. Electrical-insulation failure, effectively defined for the purpose of the test as being manifested by a current ≥ 0.25 A through the insulation, was not observed.

trical-insulation materials in a program directed toward reducing fire hazards and weights in ship electrical systems. To satisfy the requirements of this program, an electrical-insulation material must withstand a 3-hour gas-flame test at 1,600°F (about 871°C). Prior to the development reported here, RP46 was rated for use at temperatures from -150 to +700°F (about -101 to 371°C), and no polymeric product — not even RP46 — was expected to withstand the Navy 3-hour gas-flame test.

A typical process for applying RP46/glass-fiber composite to a wire, pipe, or other electrically conductive object that one seeks to insulate consists of the following steps:

1. The surface to be coated with the composite is prepared by roughening it, then cleaning it using methanol and acetone.
2. The roughened, cleaned surface is wrapped with either a prepreg [glass fabric or one or more layer(s) of glass fibers pre-impregnated with RP46] or

a dry fabric or fiber sleeve or preform to a desired thickness.

3. If a dry sleeve has been wrapped, then at this point, it is infused with a resin solution having a suitable viscosity, by use of a vacuum-assisted resin-transfer molding (VARTM) technique. The VARTM step can be performed at either room temperature or an elevated temperature, depending on the specific resin solution used.
4. The workpiece as processed thus far is placed in an autoclave, wherein the resin is cured at an appropriate elevated temperature and pressure. If the resin has a low and stable melt viscosity, then the cure can be performed in a vacuum bag in an oven.

The figure depicts the Navy gas-flame test being performed on a copper pipe insulated with an RP46/glass-fiber composite. The same test was also performed on a similarly insulated aluminum pipe. The RP46/glass-fiber composite layers unexpectedly passed the tests, retaining their electrical-insulation integrity for more than 3 hours at 1,600±50°F (about 871±28°C). Furthermore, the composite showed remarkably high insulating capability. This was evident from the observation that while the RP46 was exposed to a temperature of 1,667°F (908°C), the temperature of the insulated conductor was only 229°F (109°C).

This work was done by Ruth H. Pater, Peter Vasquez, Richard L. Chattin, Donald L. Smith, Thomas J. Skalski, and Gary S. Johnson of Langley Research Center and Sang-Hyon Chu of the National Institute of Aerospace. Further information is contained in a TSP (see page 1). LAR-17321-1

◆ Nanocomposite Strain Gauges Having Small TCRs

Usefully large gauge factors and acceptably small drifts should also be attainable.

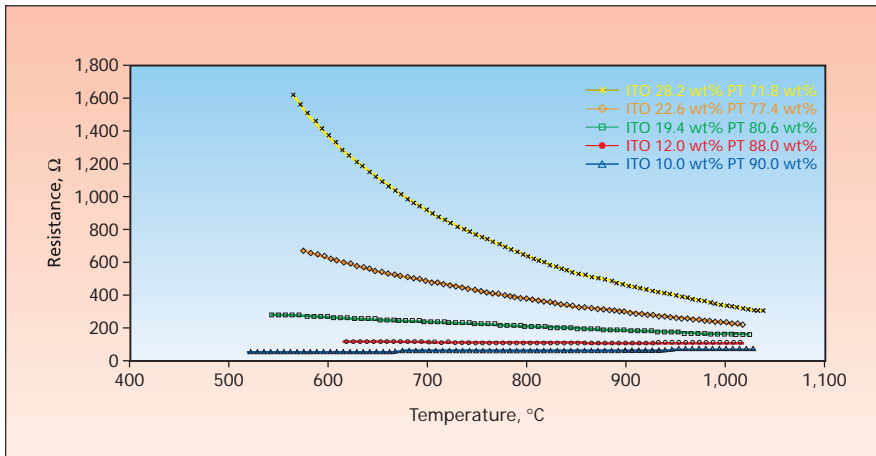
John H. Glenn Research Center, Cleveland, Ohio

Ceramic strain gauges in which the strain-sensitive electrically conductive strips made from nanocomposites of noble metal and indium tin oxide (ITO) are being developed for use in gas turbine engines and other power-generation systems in which gas temperatures can exceed 1,500°F (about 816°C). In general, strain gauges exhibit spurious thermally induced components of response denoted apparent strain. When temperature varies, a strain-gauge material that has a nonzero temperature coefficient of resistance (TCR) exhibits an

undesired change in electrical resistance that can be mistaken for the change in resistance caused by a change in strain. It would be desirable to formulate strain-gauge materials having TCRs as small as possible so as to minimize apparent strain.

Most metals exhibit positive TCRs, while most semiconductors, including ITO, exhibit negative TCRs. The present development is based on the idea of using the negative TCR of ITO to counter the positive TCRs of noble metals and of obtaining the benefit of the

ability of both ITO and noble metals to endure high temperatures. The noble metal used in this development thus far has been platinum. Combinatorial libraries of many ceramic strain gauges containing nanocomposites of various proportions of ITO and platinum were fabricated by reactive co-sputtering from ITO and platinum targets onto alumina- and zirconia-based substrates mounted at various positions between the targets. TCR values of the sensors were determined from measurements made in thermal cycling between room



The TCRs (slopes of electrical resistance versus temperature) of five platinum/ITO nanocomposite films having different compositions ranged from negative to near zero to slightly positive, suggesting that it should be possible to formulate platinum/ITO composites having TCRs very close to zero.

temperature and 1,000°C. Piezoresistive responses of the sensors were measured at strain levels up to 10^{-3} at temperatures from room temperature to 1,200°C.

The chemical compositions of the most promising combinatorial libraries were analyzed by energy-dispersive x-ray spectrometry and scanning electron microscopy. Preliminary results (see fig-

ure) have been interpreted as indicating that TCRs near zero, from room temperature to 1,000°C, could be achieved even in non-optimized platinum/ITO nanocomposite strain gauges containing approximately 12 weight percent of ITO. For one such strain gauge, the gauge factor was found to be relatively large (≈ 26) and the drift rate very low (0.018 percent/h). On the basis of these and similar results, other combinatorial libraries of composites of ITO with Pd, Ni, NiCrAlY alloys, W, and Ir are also under consideration.

This work was done by Otto Gregory and Ximing Chen of the University of Rhode Island for Glenn Research Center. 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-18253-1.