

tube surface, or sidewalls, rather than the body, which is shown by the I-V in figure (a).

Electrical conduction via the sidewalls is a necessity for dc NEMS (nanoelectromechanical system) applications, more so than for the field emission applications of such tubes. During the tests, high conductivity was expected, because both probes were shorted to the substrate, as shown by curve 1 in the I-V characteristic in figure (b). When a tube grown on NbTiN was probed, the response was similar to the  $\approx 100$  nA and is represented by

curve 2 in figure (b), which could be cycled and propagated via the tube surface or the sidewalls. However, no measurable currents for the tube grown directly on Si were observed as shown by curve 3 in figure (b), even after testing over a range of samples. This could arise from a dielectric coating on the sidewalls for tubes on Si. As a result of the directional nature of ion bombardment during dc PECVD, Si from the substrate is likely re-sputtered and possibly coats the sidewalls.

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## Nanoparticle/Polymer Nanocomposite Bond Coat or Coating

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This innovation addresses the problem of coatings (meant to reduce gas permeation) applied to polymer matrix composites spalling off in service due to incompatibility with the polymer matrix. A bond coat/coating has been created that uses chemically functionalized nanoparticles (either clay or graphene) to create a barrier film that bonds well to the matrix resin, and provides an outstanding barrier to gas permeation.

There is interest in applying clay nanoparticles as a coating/bond coat to a polymer matrix composite. Often, nanoclays are chemically functionalized with

an organic compound intended to facilitate dispersion of the clay in a matrix. That organic modifier generally degrades at the processing temperature of many high-temperature polymers, rendering the clay useless as a nano-additive to high-temperature polymers. However, this innovation includes the use of organic compounds compatible with high-temperature polymer matrix, and is suitable for nanoclay functionalization, the preparation of that clay into a coating/bondcoat for high-temperature polymers, the use of the clay as a coating for composites that do not have a high-

temperature requirement, and a comparable approach to the preparation of graphene coatings/bond coats for polymer matrix composites.

*This work was done by Sandi G. Miller of Glenn Research Center. Further information is contained in a TSP (see page 1).*

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