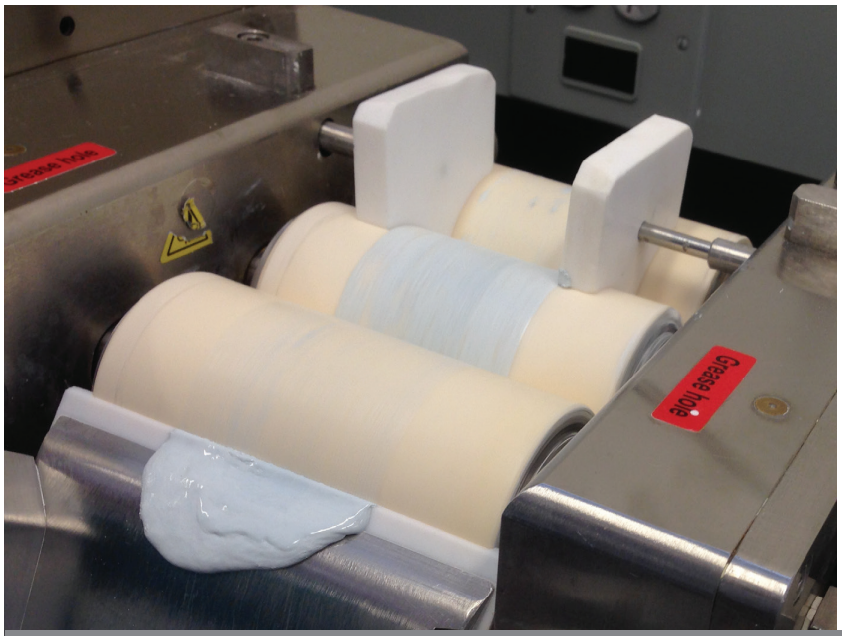

National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

New Dielectric Material for High-Performance, Solid-State Ultracapacitors

Nanoparticle-based formulations enable many novel energy storage devices & manufacturing methods

NASA's Marshall Space Flight Center has developed a high-performance dielectric material in the development of ultracapacitors to replace batteries. This new material, formulated as a composite ink or paste, is based on novel high-permittivity dielectric powders. This dielectric material has performance characteristics of rapid charging; ultra-low leakage; and an extremely high dielectric constant. Furthermore, select compositions can offer battery-like discharge behavior. These attributes make the invention a highly desirable dielectric material for the development and manufacture of novel energy storage devices, including ultracapacitors, batteries, and other devices requiring a high dielectric constant and/or high breakdown voltages. The ceramic material also has the advantage of being completely safe as compared to traditional electrochemical batteries. Targeting potential use for satellite propulsion systems, the invention is undergoing continued development at NASA.

BENEFITS

- Tailorable rheology for use in a range of coating and printing methods, including state-of-the-art aerosol inkjet and direct-write 3D printing systems, as well as traditional thick-film methods
- Ultra-high capacitance and/or breakdown voltage of tailorable, dielectric compositions in either thick or thin layer formats
  - Capacitance range up to 1,000 mF
  - Dielectric breakdown range up to 25 MV/m
- A safe and robust design that eliminates liquid or gel electrolytes used in conventional ultracapacitors or batteries
  - Highly resistant to mechanical shock and vibration
  - Fire- and explosion-resistant, even in extreme thermal environments
  - Nonpolar design provides ease of implementation

THE TECHNOLOGY

NASA's technology is a dielectric materials formulation comprising polymers, organic binders, solvents, and surfactants, formulated together with a ceramic perovskite nanopowder. The ceramic nanopowder can be optimized for the required dielectric properties of capacitance, voltage breakdown, and leakage. This involves the addition of dopants or the use of advanced coatings on the powder particulates, and subsequent thermal treatments.

The rheology of the formulation can be adjusted to work with a variety of coating or printing methods, from conventional thick-film methods to advanced inkjet or direct-write 3D printing methods used for printed electronics. 3D printing provides the ease of printed manufacturing along with the deposition of thinner layers (e.g., 5 microns in thickness vs. 50-100 micron layer via thick-film methods).

Individual devices can then be formed in multilayer arrangements, or stacked and packaged as required for the given device application.

The ink composition is a careful blend of polyimide or polyvinylidene fluoride (PVDF) polymers, solvents, surfactants, and barium titanate nanopowders. Proper ratios are needed for viscosity and processability (e.g., nanopowder wetting and dispersion), along with the optimal ultracapacitor device performance.

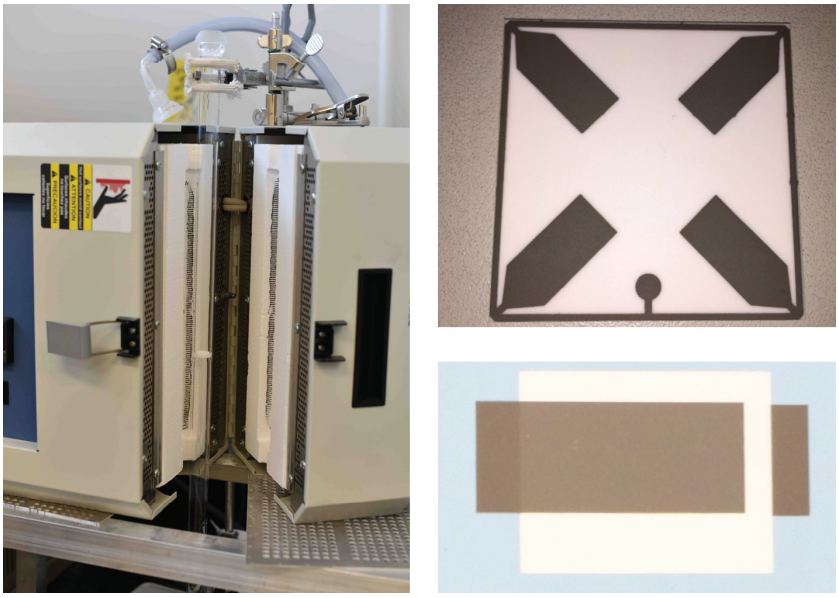

FIGURE Process furnace and test device layouts.

APPLICATIONS

The technology has several potential applications:

- Aerospace: space power and propulsion systems
- Transportation: regenerative braking systems for cars, trucks, buses, and trains; batteries for hybrid and electric cars, as well as fuel cellpowered vehicles
- Energy: smart grid and renewable energy
- Defense: backup power supplies, laser weapons, and railguns
- Health: medical devices

PUBLICATIONS

Patent No: 9,745,481; 10,325,724; 9,881,747

-Cortés-Peña, A. Y., T. D. Rolin, and C. W. Hill. A Novel Solid State Ultracapacitor. No. M17-6033. 2017.

-Zhang, L., Shan, X., Bass, P. et al. Process and Microstructure to Achieve Ultra-high Dielectric Constant in Ceramic-Polymer Composites. Sci Rep 6, 35763. 2016.

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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