Faster, more efficient technique for creating high-density ceramics

North Carolina State University

A researcher from North Carolina State University has developed a technique for creating high-density ceramic materials that requires far lower temperatures than current techniques – and takes less than a second, as opposed to hours. Ceramics are used in a wide variety of technologies, including body armor, fuel cells, spark plugs, nuclear rods and superconductors.

At issue is a process known as “sintering,” which is when ceramic powders (such as zirconia) are compressed into a desired shape and exposed to high heat until the powder particles are bound together into a solid, but slightly porous, material. But new research from Dr. Jay Narayan, John C. Fan Distinguished Chair Professor of Materials Science and Engineering at NC State, may revolutionize the sintering process.

Narayan’s new technique, selective-melt sintering, allows sintering of yttria-stabilized zirconia at 800 degrees Celsius (C) – instead of the conventional 1450 C. In addition, using the selective-melt sintering technique, it is possible to sinter zirconia at 800 C in less than a second, and create a material with no porosity at all. In contrast, traditional sintering techniques take four to five hours at 1450 C.

“This technique allows you to achieve ‘theoretical density,’ meaning it eliminates all of the porosity in the material,” Narayan says. “This increases the strength of the ceramic, as well as improving its optical, magnetic and other properties.”

The key to Narayan’s approach is the application of an electric field, at approximately 100 volts per centimeter, to the material. When this field is applied, it creates subtle changes in the material’s “grain boundaries” – where atoms from different crystals meet in the material. Namely, the field draws “defects” to the grain boundary. These defects consist of vacancies (missing atoms) which can carry charges. The defects are negatively charged and draw current from the electric field to the area – which raises the temperature along the grain boundary.

Raising the temperature along the grain boundary means that the material can be sintered at a much lower temperature, because sintering is done by selectively melting the grain boundaries to fuse the crystals together.

Normally you would have to apply enough heat to raise the mass of all the material to the melting point, even though you only need to melt the grain boundary. “Pre-heating” the grain boundary with an electric field is what allowed Narayan to lower the sintering temperature from 1450 C to 800 C and sinter the material much more quickly.

An invited viewpoint paper describing the work, “New mechanism for field-assisted processing and flash sintering of materials,” is published online in Scripta Materialia. Narayan is the sole author.

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