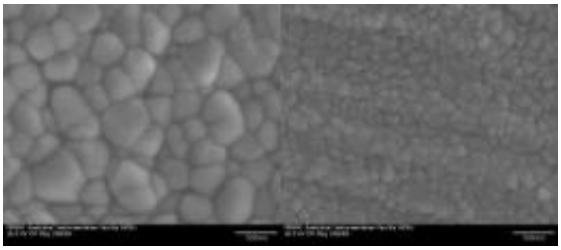
Electric fields make ceramic production quicker, cheaper, better

June 1 2010



By applying a 60 Hertz alternating current field, researchers were able to reduce the grain size of ceramics by 63 percent -- and eliminated porosity at 1,250 degrees Celsius, as opposed to the 1,500 degrees Celsius needed without the electric field. Credit: Dr. Hans Conrad, North Carolina State University

Researchers from North Carolina State University have found that applying a small electric field results in faster formation of ceramic products during manufacture at lower temperatures, and enhances the strength of the ceramic itself.

At issue is a process called sintering, which is how most ceramic products are made. The process involves taking fine ceramic powder, compressing it into the desired shape of the final product, and heating it. Under high heat, the atoms of the powder material bond by diffusion - meaning the atoms of different powder grains move around, bonding the fine powder particles together. Sintering eliminates porosity in the ceramic product, which significantly strengthens the material.

"By applying a 60 Hertz alternating current (AC) field, we were able to eliminate porosity at 1,250 degrees Celsius - as opposed to the 1,500 degrees Celsius needed without the electric field," says Dr. Hans Conrad, emeritus professor of materials science and engineering at NC State and co-author of the study. In addition, the researchers were able to reduce the grain size of the ceramic by 63 percent - creating grains with a diameter of 134 nanometers (nm), as opposed to the 360 nm diameter grains produced using conventional sintering methods. Smaller grain size makes a ceramic stronger, because the larger a grain is, the easier it is for cracks to both form and spread.

Ceramics make up significant components of an array of products, including insulators, spark plugs, fuel cells, body armor, gas turbines, nuclear rods, high temperature ball bearings, high temperature structural materials and heat shields.

The researchers were able to achieve similar, but less significant, results using an electric field created by direct current (DC). Porosity was eliminated at 1,400 degrees Celsius using DC, and grain size was reduced to a diameter of 217 nm - both still dramatic improvements over current sintering techniques. The field used for both AC and DC fields was 13.9 volts/cm.

"We found that the use of a small electric field - with a current of only six-tenths to eight-tenths of an amp per centimeter squared - can result in improved sintering rates with much finer grain size," Conrad says. In other words, ceramics manufacturers can make their products more quickly and cheaply by using an inexpensive electric field - and make their product stronger as well.

"You don't use much energy, and you put it right at the atomic site where it is needed - rather than using more energy to create higher temperatures in a kiln, which is less efficient," Conrad says. "If you want

to make a strong ceramic, you want to eliminate porosity and keep the grain size as small as possible. And you want to do it at the lowest cost - which means using the smallest amount of energy and doing it at the lowest temperature at the fastest rate possible. Using an electric field achieves all of these goals."

The research is described in "Enhanced sintering rate of zirconia (3Y-TZP) by application of a small AC electric field," which will be published in a forthcoming issue of *Scripta Materialia*. The lead author of the paper is Dr. Di Yang, a senior research associate at NC State. This research stemmed from previous work by Yang and Conrad that was funded by the U.S. Army Research Office.

Conrad and Yang are currently working to determine the effects of the frequency and strength of the electric field and to investigate other ceramic materials.

Provided by North Carolina State University