Ceramics Composites and Optical Materials Center (CCOMC)

Rutgers University, Rich Haber, 848.445.4931, rhaber1@rci.rutgers.edu

Clemson University, Philip J. Brown, 864.656.6072, pjb@clemson.edu

More Economical Bullet Proof Glass Materials: Crystallization of Magnesium Aluminate Spinel

Magnesium aluminate spinel ($MgAl_2O_4$) is a transparent material that has exceptional ballistic protection performance. The ballistic properties of spinel match those of current laminated glass except this material enables a 2-fold thickness reduction of the transparencies in Humvees. The weight savings reduce fuel consumption, lightens doors, creates more interior space and makes vehicles easier to maneuver. In addition, spinel transparencies can be used in phones, tablets and laptop computers. Furthermore, its transparency enables new types of laser materials and windows for IR lasers and detectors. When transparency is not critical, spinel can be used as a refractory in high temperature furnaces.

Improved bulletproof glass is one application of this technology.

Three technical barriers prevent spinel from realizing this full commercial potential. First, the need to use high-temperature high-pressure densification methods adds tremendous cost to the manufacturing cost of a transparency. Second, manufacturing spinel powder is costly. This is partly because only one commercial manufacturer produces powder suitable for making transparencies. The third barrier arises because the manufacturer uses high temperature processes to make the spinel phase by either melt or solid-state reactions in a high purity production facility. The coarse-grained product is then milled to a particle size suitable for the high temperature-pressure densification step.

It is well known among ceramic engineers that having a smaller particle size and uniform morphology enable reductions in the temperatures and pressures required to make fully dense ceramics that are transparent. To address this challenge, the NSF sponsored Ceramic, Composite, and Optical Materials Center, CCOMC, an I/UCRC at the Department of Materials Science & Engineering at Rutgers University has developed a breakthrough low energy rapid hydrothermal synthesis route for the production of spinel powder.

The process uses inexpensive raw materials similar to those used in traditional high temperature reactions. The overall process-energy requirements are lower than other spinel synthesis techniques. The resulting high purity powder consists of uniform submicron particles that are ideal for transparencies.

The researchers, Daniel Kopp and Richard Riman credit their success to the predictive power of thermodynamics, since it was able to explain why prior attempts to develop a hydrothermal method failed and clearly defined what they had to do to invent a successful process. This new process has also been used to make 10 other new ceramic materials.

> **Economic impact**: This new process has the potential to greatly reduce the cost of spinel powder for several reasons. First, less expensive raw-materials can be used. Second, the reaction conditions employ low temperature and times that are short relative to the current commercial process. Third, the powder does not need any energy intensive milling because sizes and morphologies are controlled by the hydrothermal process. Finally, the capital cost of the reactor is small compared to the capital cost of high temperature furnaces and mills that are currently used to manufacture spinel. Densification of the powder to a transparent state is easier and can be more reliably achieved. This is because the powder has a submicron particle size.

The above benefits collectively allow for a 2- to 5-fold reduction in spinel manufacturing costs. This allows spinel to be an economically viable alternative to laminated- or ion-exchanged-glass for ballistic and display applications, respectively.

For more information, contact Richard Riman at Rutgers University, The State University of New Jersey's School of Engineering, riman@rci.rutgers.edu, Bio http://mse.rutgers.edu/fac/richard-riman, 848-445-4946 or Daniel Kopp, dkopp@scarletmail.rutgers.edu, Bio https://www.linkedin.com/in/dvkopp, 917-848-2749.