Clean interfaces: Research could usher in next generation of batteries, fuel cells

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Scientists from South Carolina's leading public universities—the University of South Carolina and Clemson University—have made a discovery that could dramatically improve the efficiency of batteries and fuel cells.

The research, which is published in the journal *Nature Communications*, involves improving the transport of oxygen ions, a key component in converting chemical reactions into electricity. The team studied a well-known material, gadolinium doped ceria (GDC), which transports oxygen ions and is currently in use as a solid oxide fuel cell electrolyte. Through the use of additives and a "smart" chemical reaction, they demonstrated a greatly enhanced conductivity in GDC. The result is a faster and more efficient conversion into electricity.

"This breakthrough will pave the path to fabricate next generation energy conversion and storage devices with significantly enhanced performance, increasing energy efficiency and making energy environmentally benign and sustainable," said Fanglin (Frank) Chen, a chemical engineering professor at the University of South Carolina.

"The origin of the low grain boundary conductivity is known to be segregation of gadolinium (Gd) in the grain boundary which leads to a built-in charge at the interface referred to as the space charge effect," Chen said. "This built in charge serves as a barrier for ion transport at the interface. The challenge is how to effectively avoid the segregation of Gd in the grain boundary. The grain boundary is extremely narrow, on the order of a few nano-meters. Therefore, it is extremely difficult to characterize and rationally control the amount of Gd in such a narrow region."

"In order to make 'clean' grain boundaries and avoid the segregation of Gd at the interface we have added an electronic conductor cobalt iron spinel (CFO), resulting in a composite structure," said Kyle Brinkman, a professor at Clemson University and co-author of the work. "The CFO reacts with the excess Gd present in the grain boundary of GDC to form a third phase. It was found that this new phase could also serve as an excellent oxygen ionic conductor. We further investigated the atomic microstructure around the grain boundary through a series of high resolution characterization techniques and found that Gd segregation in the grain boundary had been eliminated, leading to dramatic improvement in the grain boundary oxygen ionic conductivity of GDC."

The improved oxygen ionic conductivity of GDC has been demonstrated in an oxygen permeation experiment where the elevated oxygen ion transport was used to separate pure oxygen from air at elevated temperatures. The approach of targeting emergent phases resulting in clean interfaces can be applied to a number of essential materials for energy conversion and storage devices used in handheld electronics, vehicles, and power plants, making them more cost-effective, efficient and environmentally friendly.

Currently, ceramic composites consisting of ionic and electronic conductive components like those in this study are under consideration for membrane separation devices that provide oxygen for enhanced conversion of coal and natural gas, as well as for membrane reactors used in natural gas conversion and recovery.

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