Samarium Doped Ceria: A Key Player in Solid Oxide Fuel Cell (SOFC)

Student Editorial Board from Universiti Tun Hussein Onn Malaysia

Introduction

Utilizing materials with high oxygen ion conductivity is essential for energy conversion, energy storage, and catalytic processes. Due to their remarkable ability to efficiently convert chemical energy into electrical energy through electrochemical processes, solid oxide fuel cells (SOFCs) have garnered significant attention as a potential source for the generation of electrical power. Conventional SOFCs that employ yttria-stabilized zirconia (YSZ) as an electrolyte material typically operating at approximately 1000°C [1–3]. However, operating at such high temperatures causes material deterioration as well as additional technological and economic challenges. As a result, new electrolyte materials for SOFCs that function at lower temperatures are required. In this context, ceria-based materials (Figure 1) offer considerable potential as electrolytes for low-temperature SOFCs [4–7].

Figure 1: *Samarium-Doped Ceria (SDC) Powder [12]*

In numerous fields, including chemistry, physics, material science, and biology, rare earth metal oxides are essential. Since they have such a wide range of uses, including as UV absorbers and blockers, SOFCs, optics, antibacterial agents, gas sensors, and three-way catalysts for automotive emission control, ceria nanoparticles have attracted a great deal of attention in the most cutting-edge research. Ceria, commonly known as cerium oxide (CeO_2), is a versatile material recognized for its strong oxygen ion conductivity and great temperature stability. The oxygen vacancies formed by doping rare earth cations into the ceria lattice greatly boost the ionic conductivity of ceria. The ionic conductivity of doped ceria at 750°C is comparable to that of YSZ at 1000°C [8]. Sm^{3+}, Dy^{3+}, and Gd^{3+} are among the dopants that are effective in increasing ionic conductivity [9,10]. Doping ceria with samarium ions results in the transformation into samarium doped ceria (SDC), a solid electrolyte material exhibiting heightened ionic conductivity. This enhanced conductivity is crucial for SOFCs as it facilitates the effective transport of oxygen ions between the cathode and anode.

Properties of SDC

SDC has numerous important features that are critical for improving SOFCs technology. First and foremost, it possesses elevated oxygen ion conductivity, an important factor in enhancing SOFCs performance. This property facilitates the efficient movement of oxygen ions between the cathode and anode, thereby assisting the electrochemical processes that generate electricity [3,11].

Ceria nanoparticles have a great deal of potential as antibacterial agents against bacteria. The antibacterial potential of ceria oxide (CeO_2) is also increased by an oxygen vacancy in the crystal lattice. Different mechanisms are used by the antibacterial activity of metal/metal oxide nanoparticles to interact with microbial cells. Furthermore, SDC with a cubic fluorite crystal structure (Figure 2) has exceptional thermal stability, allowing it to endure the high working temperatures necessary for SOFCs, which generally range from 800°C to 1000°C. This intrinsic stability enables SOFCs' long-term dependability and longevity, which is critical for practical applications. Furthermore, SDC's compatibility with multiple electrolyte configurations adds to its versatility, allowing it to be used as both a thick electrolyte material and an electrolyte-supported cell, allowing it to accommodate a wide range of SOFC designs.

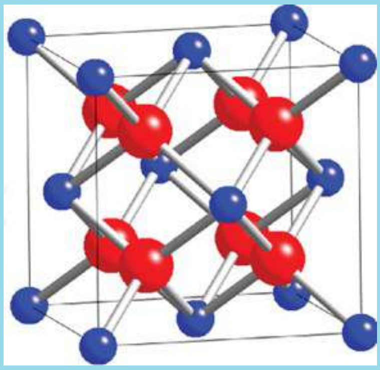

Figure 2: *Schematic of a cubic fluorite structure of SDC [13]*

Applications of SDC in SOFCs Technology

A SOFCs is an electrochemical device that directly converts chemical energy from a fuel into electrical energy, resulting in high electrical efficiency. The SOFCs comprises three primary components: the anode, electrolyte, and cathode. The electrolyte serves to connect the anode and cathode, closing the circuit by transporting negatively charged oxygen ions. The anode undergoes electrochemical oxidation of the fuel, while the cathode undergoes electrochemical reduction of the oxidant (O_2 from the air). The electrolyte's high conductivity is essential for lowering ohmic resistances within the cell. SDC serves multiple crucial roles in SOFCs technology. To begin with, it is commonly employed as an electrolyte material in SOFCs, establishing a reliable ionic conduction pathway for oxygen ions between the cathode and anode. Given the critical role this function plays in achieving high cell performance, SDC stands as an indispensable component in the design of efficient SOFCs [9,10].

Furthermore, as a mixed ionic-electronic conductor (MIEC), SDC allows for the simultaneous movement of oxygen ions and electrons within the cell. This distinct characteristic improves electrode kinetics and overall cell efficiency, further enhancing the performance of SOFCs. SDC also functions as an electrolyte support structure in certain SOFC setups. In this role, it offers mechanical support to the cell while keeping its ionic conductivity, hence contributing to the structural integrity and performance of the SOFCs system [3,9,12].

Benefits of SDC in SOFCs Technology

SDC offers several notable advantages that enhance the performance and viability of SOFCs. Initially, its strong ionic conductivity and mixed-conduction capabilities play a pivotal role in elevating the overall efficiency of SOFCs. These features allow for efficient transit of oxygen ions and electrons inside the cell, resulting in better power production for a given fuel input. This increased efficiency is a substantial benefit, making SOFCs with SDC electrolytes appealing for a variety of energy-generating applications.

Furthermore, SDC helps SOFCs fuel flexibility. SOFCs that use SDC electrolytes may run on a variety of fuels, including hydrogen, natural gas, and even biofuels. This versatility makes them adaptable energy conversion devices suited for a wide range of energy sources, contributing to their potential for meeting a wide range of energy demands. Higher oxygen ion conductivity, fewer interfacial losses with cathode and anode, extended stack lifetime, and cheaper overall cost are benefits of employing doped ceria as a material for SOFCs. Finally, the durability of SDC is noteworthy. Because of its thermal stability and resistance to chemical degradation, SOFCs have prolonged operating lifespans, reducing maintenance needs and enhancing the overall reliability of these clean energy systems [2,6,11].

Challenges and Future Prospects

While SDC provides considerable benefits in SOFCs technology, challenges persist in addressing issues like reducing manufacturing costs and improving electrode performance. Elevated temperatures can lead to the coarsening of the electro-catalyst nickel in the anode, inducing thermal stress on the cell structure, which may result in physical flaws and potentially drive-up manufacturing costs. Researchers are continuing to investigate different SDC compositions and manufacturing procedures to solve these difficulties and improve SOFCs efficiency and cost-effectiveness [1,11].

Conclusion

SDC plays a critical role in advancing SOFCs technology. The connectivity improves as the SDC content grows. More channels will be made available for the conduction of oxygen ions in the electrode once the SDC particles are linked. Because of its strong ionic conductivity, thermal stability, and compatibility with diverse cell layouts, it is an important material for increasing SOFCs performance and expanding their applications. SDC-based SOFCs are positioned to contribute to a sustainable and clean energy future as research and development activities continue.

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Zolhafizi Bin Jaidi (PhD)
Faculty of Mechanical & Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM)

Muhammad Zul Idzham Bin Abdul Ghani (Master)
Faculty of Mechanical & Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM)

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INSTITUTE OF MATERIALS, MALAYSIA

Suite 1006, Level 10, Block A, Kelana Centre Point,
No. 3 Jalan SS 7/19, 47301 Petaling Jaya, Selangor.
Tel: 03-76611591
03-76611592

secretariat@iomm.org.my
www.iomm.org.my
+60 18-911 3480
Institute of Materials, Malaysia