Advancement in Electrolyte Materials for Solid Oxide Fuel Cells

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Abstract

Solid oxide fuel cell (SOFC) electrolytes has advanced from conventional oxide-ion conductors such as YSZ to sophisticated proton-conducting and co-ionic systems. This review synthesises progress across oxide-, proton- and dual-ion-conducting families within a harmonised 500–800 °C window, using mainly a single cell-level reporting schema. By centring the comparison at the cell level, we assemble state-of-the-art demonstrations and map them onto a durability framework that makes performance limits and degradation risks explicit. Tables 7 and 8 convert materials insights into stack-relevant guidance, enabling like-for-like benchmarking that is reproducible and decision-oriented. Three messages emerge where oxide-ion systems are the most mature and stack-ready, yet ≤ 650 °C operation is constrained by residual ohmic losses and cathode surface-exchange kinetics, even with sub-micrometre membranes. Protonic cells deliver high conductivity and competitive power at 500–650 °C but require chemical robustness against CO_2/H_2O to stabilise Ba-containing perovskites. Dual-ion electrolytes spanning engineered semiconductor-ionic heterostructures and composite co-ionic designs achieve attractive outputs near 500–550 °C, although long-term stability is constrained by secondary-phase volatility, coarsening and interfacial drift. Architecture and processing are decisive levers: dense ultrathin electrolytes with targeted interlayers, bilayer/multilayer stacks, space-charge/strain-engineered heterostructures and thin-film routes complement scalable tape-casting, screen printing, extrusion and micro-tubular formats. We prioritise chemically robust protonics; stabilised co-ionic systems with engineered interfaces; cathode-electrolyte pairings qualified under realistic fuels and humidities; and standardised reporting that ties electrochemical diagnostics and post-mortem analysis to fade metrics. This framework provides decision-oriented evidence to guide device design, operating policy and scale-up from record single cells to stacks.

Author keywords

Electrolyte materials; Oxide-conducting, proton-conducting and dual ion-conducting; SOFC

Indexed keywords

Engineering controlled terms

Barium compounds; Cathodes; Composite films; Film preparation; Ion exchange; Ion exchange membranes; Ionic conduction in solids; Perovskite; Perovskite solar cells; Screen printing; Solid electrolytes

Engineering uncontrolled terms

Electrolyte material; Fuel cell electrolytes; Ion-conducting; Ionic systems; Oxide ion conductors; Oxide-conducting, proton-conducting and dual ion-conducting; Proton conducting; Protonic; Single-cell level; Solid-oxide fuel cell

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Author keywords