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Development of High-Productivity Manufacturing Technology for Fuel Cell Separators Using Carbon-Based Resin Composites

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Toward the realization of a hydrogen society, fuel cells are expected to be deployed in diverse mobility fields, and their widespread dissemination requires high performance, high durability, and low cost. Separators are major components of fuel cell stacks and are used in the hundreds per fuel cell stack; therefore, improving productivity is a key issue for cost reduction. Although metal separators are currently mainstream, separators made of composite resin materials containing conductive fillers such as graphite and carbon fibers (carbon-based resin composites) can be advantageous in certain applications from the viewpoints of lightweight design and durability. Carbon-based resin composite separators must achieve both low electrical resistance and high mechanical strength. Because an electrically insulating resin acts as a binder, conductivity must be ensured while maintaining sufficient strength to prevent hydrogen leakage caused by deformation or cracking. In addition, composite molding requires heating and cooling, leading to longer cycle times than those of metal separators; thus, shortening molding time is an important challenge. In this study, material development and process development were pursued with a target of molding cycle time comparable to that of metal separators.

In the material development stage, resin materials are generally classified into thermosetting resins and thermoplastic resins. In this study, thermoplastic resins were adopted in consideration of processability and future recyclability. Because molding of carbon-based resin composite materials requires heating and cooling cycles, selecting resins with a small difference between the molding temperature and the demolding temperature is important for reducing the molding cycle time. Therefore, among the many available thermoplastic resins, multiple candidate resins were screened, and a resin favorable for shortening the molding cycle time was selected, although a decrease in mechanical strength was confirmed. Next, graphite content was optimized to impart conductivity, identifying a range in which resistance decreases markedly, while excessive graphite reduced strength. Carbon fibers were then introduced as reinforcement, and the optimum formulation was determined by balancing mechanical strength and moldability. As a result, a formulation enabling short molding time together with low electrical resistance and high mechanical strength was established.

In the process development stage, mold structure and hot-press molding conditions were examined to shorten heating and cooling time. Conventional heating-cooling molds employ independent heating and cooling circuits, which tend to prolong cooling time. In contrast, this study proposed a mold structure that alternately supplies the same oil medium at different temperatures through shared flow paths near the molding surface, enabling heating and cooling close to the material and accurate, uniform temperature control.

Verification of the combined effects showed that molding cycle time was reduced from 15.0 s/sheet to 8.0 s/sheet through material optimization and further reduced to 2.0 s/sheet by applying the developed mold structure (Fig.1). Continuous molding, including material charging and product removal, was demonstrated at 2.0 s/sheet. Furthermore, by placing two molds in a single press and performing simultaneous molding, productivity equivalent to 1.0 s/sheet, comparable to that of metal separators, was demonstrated to be achievable.

Electrical resistance and mechanical strength were evaluated under the shortened cycle. Melt compounding was used to mix and disperse the resin, graphite, and carbon fibers, and compounding and hot-press conditions were optimized to suppress filler grinding and to promote graphite-graphite contacts, ensuring a stable conductive network. As a result, both electrical resistance and mechanical strength satisfied the target values even under short-cycle conditions.

As future work, scale-up verification is required, and countermeasures against warpage, waviness, and cracking are needed through improvements in material flowability and heating/cooling uniformity. Further reduction of electrical resistance is expected by optimizing compounding and filler dispersion to increase strength, reduce resin content, and enable higher graphite loading. Overall, the knowledge obtained regarding material design and molding processes provides a valuable foundation for establishing mass-production processes of fuel cell separators and contributing to lower fuel cell production costs.

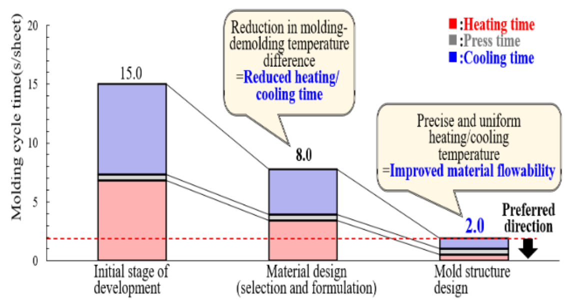

Fig.1 Verification results for molding cycle time reduction achieved through the combined effects of material design and mold structure design.