Ultrathin Bipolar Plates for Fuel Cells

Modified Conductive Compounds Make It Possible to Manufacture Bipolar Plates from a Bipolar Film Coil

Bipolar plates are one of the key components of fuel cells and redox flow batteries. They consist of plastics compounds highly filled with electrically conductive materials. To save space, cut costs, and reduce weight, there is increasing demand for the production of thinner plates without compromising robustness and service life. This can be achieved using modified polymers. With a new technology, bipolar plate films based on these modified polymers can be processed as coils.

The modified polymers enable films to be processed as coils © Eisenhuth

Fig. 1. By modifying the highly filled plastics, considerably thinner bipolar plate films can be produced than was previously the case © Eisenhuth

Sustainable energy sources are of vital importance for society's future power supply. Since wind and solar power are subject to fluctuation due to changing weather conditions, the generated energy must be held in medium or long-term buffer storage. The ideal solution for this task is provided by so-called redox flow batteries. These generally take the form of 40-ft containers which, as electrochemical converters, can store and deliver large amounts of energy. Another possibility is fuel cells that convert fuels such as hydrogen into electrical energy. This technology is becoming increasingly popular for mobile and portable applications and is already being used for trucks, cars, trains, boats, domestic energy supply (cogeneration), and independent power supply units, e.g. for data centers.

For these technologies to become established in the market, further development of bipolar plates, as the central functional elements of fuel cells and redox flow batteries is necessary. Bipolar plates are a key component of fuel cells and redox flow batteries. Conventional carbon-containing bipolar plates usually consist of thermoplastic or

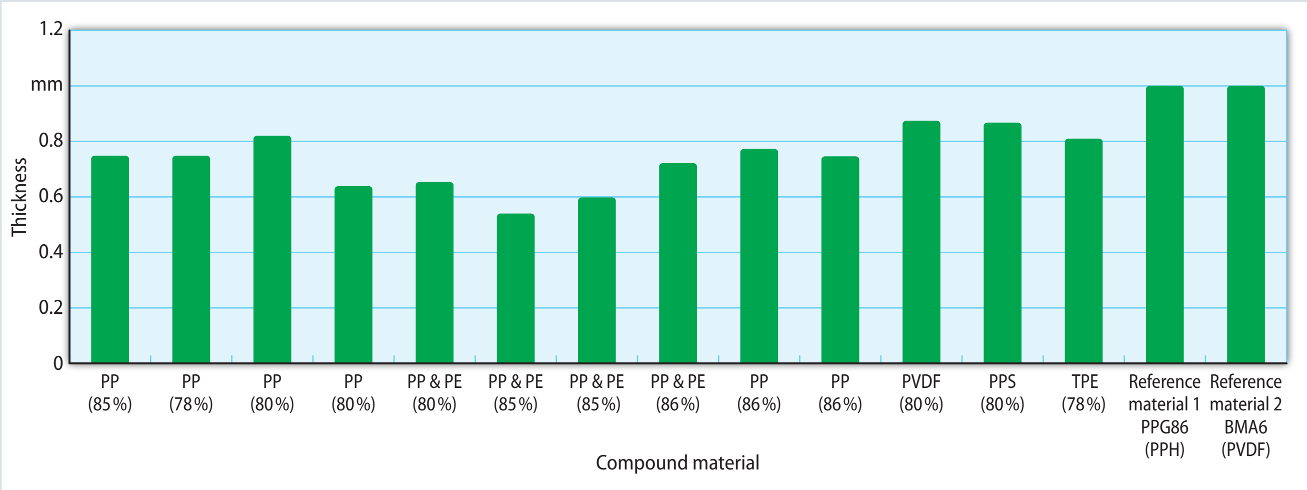

Fig. 2. Film thickness of the processed compounds and comparison with reference materials (filling degrees in brackets): the thickness of the plates ranges between about 0.5 and 1 mm Source: Eisenhuth; graphic: © Hanser

thermoset matrix materials with a high content of conductive fillers such as graphite, carbon black or carbon nanotubes. Although made from plastics, bipolar plates must have very good electrical and thermal conductivity. To achieve suitably high conductivity, the plastic must be filled with up to 80 or 90 wt.% conductive material. Here, the binding polymer plays a crucial role in preventing the compound from becoming brittle and ensuring optimum processability, although it only makes up 10 to 20 wt.% of the compound. For long and economical use of bipolar plates, high electrical conductivity, resistance to degradation, and mechanical stability under load are required.

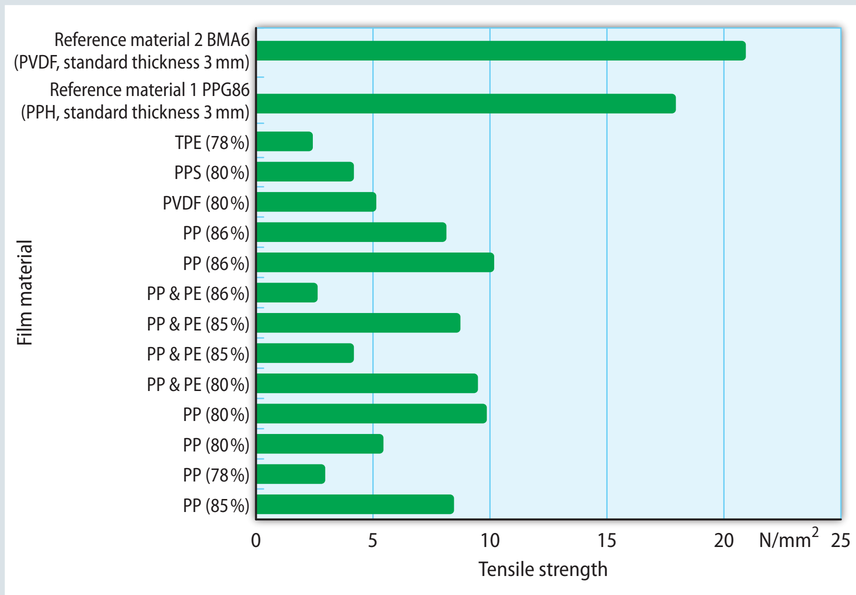

Fig. 3. The tensile strength of the different films is lower than that of the reference materials. However, the reference materials are also considerably thicker (3 mm) Source: Eisenhuth; graphic: © Hanser

Challenge: Thin but Durable

Polypropylene (PP) and polyolefins in general are frequently used as the polymers for bipolar plates. But for special requirements, other materials such as polyphenylene sulphide (PPS), polyvinylidene fluoride (PVDF), and phenolic resins are also used. Although highly filled graphite bipolar plates based on PP, polyethylene (PE), PVDF, and PPS offer high durability and can be manufactured economically, users are also increasingly demanding thinner, weight-optimized components to save space, reduce weight, and cut material costs. Low thickness and high durability are very conflicting requirements for such high conductive-filler loadings and make the achievement of this goal even more challenging.

By modifying the plastics used in bipolar plates such as PP, PE, PVDF, and PPS, their mechanical properties can, at least within certain limits, be adapted to the required specification and, through impact strength improvement, for example, be made more flexible or ductile. This is essential for the manufacture of thin plates. By using special impact modifiers, Eisenhuth GmbH & Co. KG has been able to produce thin, highly filled, very conductive bipolar plate films as coils in a continuous process (**Fig. 1**). In this process, polyolefin block copolymers additionally containing ethylene-propylene-diene-monomer rubber (EPDM) were produced with varying graphite content.

The starting point was the production of highly filled compounds. Compounding was carried out on twin screw extruders from Collin, Leistritz, and Battenfeld. On these machines, various modified PP, PE, PVDF, and PPS compounds with a carbon content of about 80 wt.% were produced and pre-conditioned for the shaping process. The next important step comprised processing them into thin films on a suitable continuous production unit.

Modified Films Achieve the Required Values

The average thickness of the films was well below 1 mm and for the most part between 0.5 and 0.8 mm (**Fig. 2**). Dur- »

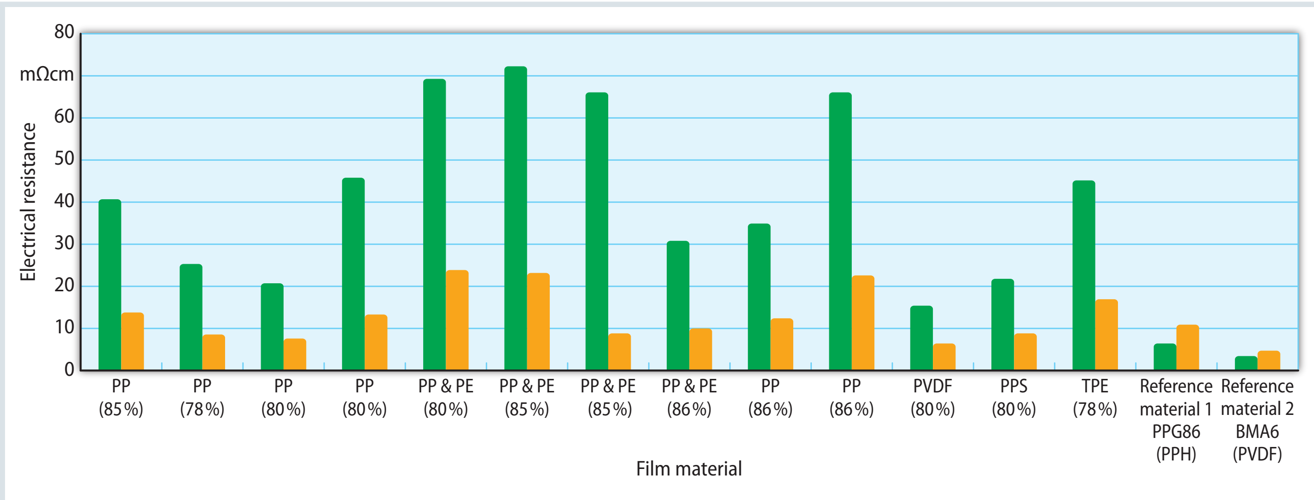

Fig. 4. The electrical resistance of the compounds (filling degrees in brackets) is higher than that of the reference materials. However, this is compensated for by the lower thickness of the films Source: Eisenhuth; graphic: © Hanser

ing production, however, the film can be precisely adjusted to the specification so that the required thickness can be ensured to a tenth of a millimeter in serial production. The tensile strength of the plates produced was between 4 and 11 N/mm^2 (**Fig. 3**), which is lower than that of the reference material. It should be remembered, however, that the measurements were not carried out on a standard test bar but on the film itself, which is only about 0.6 mm thick. Further trials to improve tensile strength are currently in progress. The electrical resistivity values of the different material types are higher than those of the reference material (**Fig. 4**). However, it should be borne in mind that thinner plates compensate for the somewhat poorer electrical conductivity.

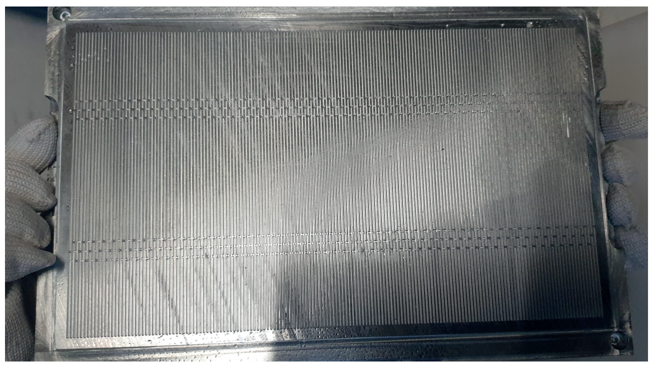

Fig. 5. Stamped graphite compound film: the bipolar plate is produced by the stamping/bending process © Eisenhuth

The films also open up new processing options. Until now, suitable shaping methods for producing bipolar plates have been hot pressing and injection molding. In these processes, the preconditioned material is generally fed into a heated compression or injection mold. In the case of compounds with a thermoset matrix, a chemical curing reaction under heat must take place before the plate can be removed from the cavity. With thermoplastic matrices, on the other hand, the compound must first be melted and then brought below the melting or glass transition temperature of the particular plastic before demolding. In hot pressing or injection molding, the technically challenging options consist in directly shaping the required structures or producing unstructured sheet blanks instead.

Coil Processing Is Possible

With the latest technology, graphite compound films can now be processed as coils (**Title figure**). In a similar way to stamping, the films are drawn down from a coil and processed by stamping/bending to produce the final structured plate (**Fig. 5**).

The new technology represents a further important step in automated manufacture of conductive compound films to achieve the economy of scale effect. In this way, the overall costs of fuel cell or battery systems can be significantly reduced. The mechanical properties obtained are comparable with those of graphite-filled, pressed or injection molded bipolar plates. Electrical conductivity, too, lies within a range that is suitable for the application. In view of the current legal framework conditions specified in particular by the EU Commission, there is an ever more pressing need for action to make mobility emission-free. The films described can make an important contribution towards greater acceptance of fuel cell technology. ■

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