METALLIC BIPOLAR PLATES – COMPACT, LOW COST, LONG-TERM STABLE

THE TASK

The use of renewable energies frequently entails questions regarding energy storage options. Hydrogen production from energy surpluses and the storage thereof could provide a solution. Hydrogen could be directly used for the propulsion of vehicles thereby speeding up the further development of electric mobility, rather be stored or transformed into natural gas in ongoing procedures.

In a fuel cell, hydrogen and oxygen are converted to water, and the electrical energy produced is used for propulsion (Fig. 1). The current driving range of vehicles with fuel cells is approximately 600 km. The fuelling procedure is like that used for a conventional car. A special filling station network would not be needed.

A membrane electrode assembly and a bipolar plate (BIP) are key fuel cell components. The BIP is responsible for hydrogen and oxygen supply, removal of water and cooling. On the hydrogen, the BIP gathers the emitted electrons and transfers them to the oxygen side after they have performed work in moving the vehicle. Thus the BIP material must have excellent electrical conductivity that also does not significantly decrease under the electrochemical conditions in the fuel cell.

The task is to develop a compact, low-cost BIP suitable for mass markets and stable in the long term.

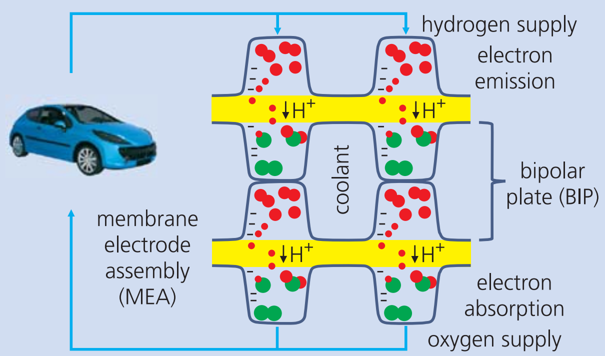
OUR SOLUTION

Graphite is used as the BIP material in applications with sufficient available installation space, whereas deep drawn stainless steel sheets with a thickness of approximately 0.1 mm are preferred in the automotive industry due to reduced installation space and high cost pressure. As a default, these steel sheets have until now been gold plated, because the natural passive coating of the stainless steel is a poor current conductor. At the Dortmund Surface Center (DOC), a branch office of the Fraunhofer IWS Dresden, two alternative coating systems were developed and tested in the miniBIP project, registered under 03ET045A and funded by the Federal Ministry of Education and Research BMBF:

- PNC (plasma-nitrocarburized coatings)
- GLC (graphitic carbon coatings)

The contact resistances of the coatings has to be similar to those of gold. The coating must also adhere sufficiently so that ready coated plain sheets can be formed into BIPs without damage.

Diagram of a fuel cell



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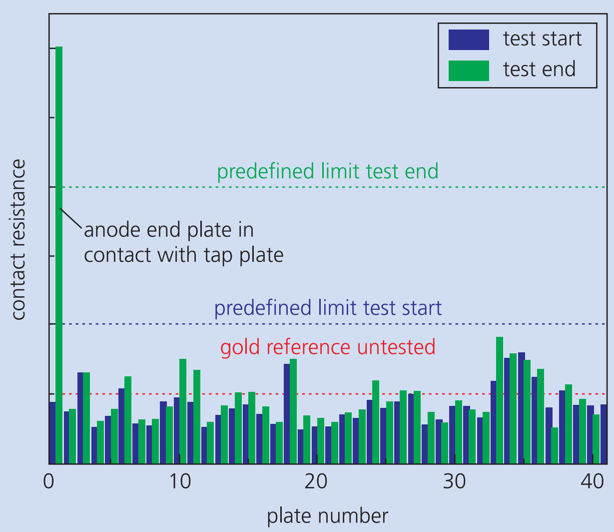
RESULTS

In the project, both surface modification techniques were optimized on various stainless steels in terms of high corrosion resistance and low contact resistance (Fig. 2). Both coating systems achieved the contact resistance of the gold coated sheets. Significantly improved anti-corrosion characteristics in comparison with those of the uncoated material were demonstrated.

The best results for the contact resistance were achieved by GLC coatings of less than 100 nm thickness. They were deposited with pulsed vacuum arc evaporation by twofold substrate rotation within a minute. Similar values could be achieved by sequential plasma-nitrocarburizing in about 15 minutes.

Contact resistance values of the BIP after PNC-treatment, fuel stack with 40 cells, after 1000 test hours (test results of the Daimler AG)



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The thickness of the surface zones enriched with nitrogen and carbon is below 5 µm. Both techniques also offer mass market potential in strip coating machines.

At the end of the project, the project partner Daimler AG assembled a fuel cell stack consisting of 40 cells. Figure 3 elucidates the results before and after the operation of the stack. Apart from the faulty anode plate, the contact resistance values of all BIPs before and after the test lay in the range of the unstressed gold reference. They were 300 percent below the requirements after the end of the test. In tests with former test geometry, GLC coatings proved to be about 200 percent below the required limit at the end of the test.

The requirements could also be achieved for both surface modifications at the end of the stack tests, in which the test sheets were first surface-coated and then formed, as well as locally damaged in a scratch test. The test specimens showed no corrosion, even on damaged surfaces.

2 Pattern part with forming elements of a metallic bipolar plate

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