High Performance
Graphite-Coated Titanium Separator
for Polymer Electrolyte Fuel Cells (PEFC)

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KOBE STEEL TITANIUM
KOBE STEEL, LTD.
Polymer electrolyte fuel cell

Fuel cells generate electric energy using H₂ gas and O₂ gas.

Polymer electrolyte fuel cells are one variety of fuel cells.

As polymer electrolyte fuel cell systems are compact and have high output, they are expected to be used in fuel cell cars to solve global environmental and energy problems.
What are separators?

Roles of separators

- to serve as a flow path for fuel, which is $H_2$ gas and $O_2$ gas
- to collect generated electricity
- to work as heat exchangers

The name “separator” comes from separating the $H_2$ gas flow from the $O_2$ gas flow.

Structure of a polymer electrolyte fuel cell

Polymer electrolyte membrane

$H_2$ gas

Coolant

Coolant

Coolant

O$_2$ gas

Coolant

Many flow paths for $H_2$ gas and $O_2$ gas
Usefulness of titanium separators

Conventional required characteristics of separators
- Electrical conductivity
- Corrosion resistance to acidic environments resulting from trace dissolution of polymer electrolyte membranes
- Light weight
- Low cost

For fuel cell cars
- Downsizing is indispensable.
- Additional properties are required.
  -- High strength
  -- High toughness
  -- Ease in forming thin sheets
  -- Possibility of forming flow passes by press forming

Conventional material for separators
- Graphite sheet (~2mm)
- Flow paths are made by milling work.

These properties can result in metal separators
- Stainless steel sheet
- Titanium sheet

From the viewpoint of corrosion resistance, titanium is the most promising material for metal separators in fuel cell cars.
## Demand forecast for titanium separators

- The production of FC units for cars is forecast to reach about 1 million units in 2025.
- The total weight of titanium separators per unit is about 40 kg.
- Demand for titanium separators in 2025 is forecast to be about 8,500 metric tons.

### Production of FC units for cars (thousands)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2013</th>
<th>2015</th>
<th>2018</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>185</td>
<td>1,530</td>
<td>10,520</td>
<td>33,700</td>
<td>146,700</td>
<td>1,058,000</td>
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</tbody>
</table>

### Estimated number of FC units using titanium separators

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2013</th>
<th>2015</th>
<th>2018</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37</td>
<td>306</td>
<td>2,104</td>
<td>6,740</td>
<td>29,340</td>
<td>211,600</td>
</tr>
</tbody>
</table>

### Total weight of titanium separators (in metric tons.)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
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<th>2015</th>
<th>2018</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>12</td>
<td>84</td>
<td>270</td>
<td>1,174</td>
<td>8,464</td>
</tr>
</tbody>
</table>

*1. Source: Fuji Keizai Co., LTD. (2011)
2. It is estimated that 20% of FC units uses titanium separators.
3. Total weight of titanium separators per unit is about 40kg.
One of the technical problems of titanium separators

- Lack of endurance of contact conductivity
  -- The contact conductivity of titanium separators easily increases during use because of its ease of passivation.

- Therefore, noble metal coatings (Pd, Pt, Au, etc.) have been studied for titanium separators.

  Titanium substrate

  Noble metal coating

  However, the use of noble metal coatings leads to higher costs.

- On the other hand, graphite is an inexpensive material and also has as good conductivity as noble metals.

- In addition, graphite has been used in conventional separators.

- As a result, we believe graphite may be a suitable coating material for titanium separators.
New surface treatment process for titanium separators

- For these situations, we developed graphite-coated titanium for separators.

Titanium substrate

Thin graphite surface layer

Surface treatment process → Very simple method

Graphite powder applied on titanium → Roll pressing → Heat treatment
Surface layer structure of graphite-coated titanium

Cross-sectional SEM image of graphite coated titanium

Cross-sectional TEM image of interlayer between thin graphite layer and titanium substrate

There is an interlayer.
Long-term stability of contact conductivity is expected due to the above-mentioned properties.
Appearance of graphite-coated titanium sheets

Untreated titanium (0.1t)  Graphite-coated titanium (0.1t)

Gray surface
Appearance of graphite-coated titanium coil

Graphite-coated titanium coils can be produced as well as graphite-coated titanium sheets.

0.1mm\(^t\) × 200mm\(^W\) × 60000mm\(^L\)
The graphite-coated titanium has very low contact resistance, which is almost the same as that of graphite.

High contact resistance due to existence of its surface passivation film

→ Not good for a separator material

Decrease due to existence of graphite coat on titanium

Almost the same

Practical level
-Immersion in a pH2 H₂SO₄ solution for 500 hours
-Acceleration test

-Untreated titanium

-Low contact resistance was maintained during the immersion.
-Consequently, the graphite-coated titanium is considered to have high endurance in the environment inside fuel cells.
Press forming test result

Appearance of graphite-coated titanium after press forming test

There was no peeling of the graphite layer in the press forming test.
The graphite-coated titanium will be used after press forming.

- Immersion in a pH2 H₂SO₄ solution for 100 hours
- Acceleration test

Endurance test
80°C, pH2, H₂SO₄
0.65V vs SCE applied

- Low contact resistance is maintained during the immersion even after the press forming.
- As a result, the graphite coated titanium is considered to be one of the practical materials for separators.
Conclusions

Graphite-coated titanium has the following advantages.

- Low contact resistance is maintained in the environments inside fuel cells, so high endurance of conductivity is expected.

The graphite-coated titanium is expected to be suitable for fuel cell separators.

Future research

- Optimization of process conditions
  [Evaluation tests]
  -- Electric power generation tests
  -- Endurance tests
  -- Press forming tests
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