Graphite 복합재료를 이용한 연료전지 Bipolar Plate

◆ 개요:
Graphite를 90 wt%까지 고분자 (페놀수지, 에폭시수지, 폴리이미드수지 등)에 혼합하여 높은 전기전도도 (300 S/cm 이상)와 기체차단성을 갖는 연료전지용 bipolar plate를 제조하는 기술.
Graphite와 수지의 표면에너지를 각각 조절하여 wetting 특성을 높여야만 복합재료 성형이 가능하며 높은 전기전도도와 우수한 기계적 물성을 얻을 수 있다.

◆ 응용분야:
연료전지, 높은 전기전도성 및 열전도성 복합재료 전극

◆ 참고문헌:
Electrical Conductivity of Conductive Fillers

- Container volume: Crosshead displacement
- Effective stress: Loadcell
- Electric resistance: Multimeter
- Data logging: PC

Equation of electrical conductivity

\[
\text{Conductivity}(S/cm) = \text{Resistivity}(\Omega) \times \frac{\text{Area}}{\text{Height}}
\]

Equation of fiber(powder) volume fraction

\[
V_{f,\text{powder}} = \frac{V_{\text{graphite}}}{V_{\text{Cylinder(Container)}}}
\]

Where, \(V_{\text{cylinder}}\) decreases as displacement increases
The contact angle values of phenolic resin and methyl alcohol are 72.3 ° and 9.7 °. The contact angles of mixing solutions with the volume ratios of phenolic resin to methyl alcohol as 1:1, 2:1, and 3:1 are 11.2 °, 19.6 °, and 31.5 °.

**Equation of contact angle**

\[ \gamma_S = \gamma_L \cos \theta + \gamma_{SL} \]

Where \( \gamma_S \), \( \gamma_L \), and \( \gamma_{SL} \) are the surface free energy of the solid, the surface tension of the liquid and interfacial energy between the solid and liquid. \( \theta \) is the contact angle.
The electrical conductivities of KS75 (75 µm) and KS150 (150 µm) are 74 S/cm and 20 S/cm at volume fraction 65%. The reason may be that with the graphite powder size is smaller, the chances of contact between two graphite particles are increased.

SEM morphology of graphite powder before molding of graphite KS75-A, B, C, graphite KS150-D, E, and F.  the graphite powder size is smaller KS75 (A, B, and C) than KS150 (D, E, and F). The graphite powders inhibit plate shapes.
Electric conductivity of bipolar plate

The conductivity of the composite was increased up to 379 S/cm at 90 wt% of graphite bipolar plate.

Equation of electrical conductivity

$$\sigma(S/cm) = \frac{\log(2)}{PI} \times \frac{1}{\text{Resistivity(}\Omega\text{)}} \times \frac{1}{\text{Thickness}}$$

The graphite loading content was increased from 60 to 90 wt% by using appropriate amount of methanol in mixing stage, which was effectively eliminated by a degassing steps in compression molding. The graphite-polymer wettability was controlled by using an appropriate solvent ensuring the highly-loading content and void-free morphology in phenolic bipolar plates.
The flexural strength of the composite bipolar plate to decreases with the increased content of graphite. The flexural strength of the composite bipolar plate non-post-cured KS 150-graphite 80 wt% is 20.79 MPa, but the flexural strength of the composite bipolar plate post-cured KS 150-graphite 80 wt% at 210 °C for 10 min is 41.86 MPa.

The flexural strength of KS 75-graphite 60 wt% is 56 MPa and KS 150-graphite 60 wt% is 46 MPa in cure condition at 200 °C for 60 min.

Equation of flexural strength

\[ S = \frac{3PL}{2bd^2} \]
Bipolar Plate Morphology

Optical microscopy photographs of bipolar plate composites of
(A) graphite KS150 65 wt%,
(B) graphite KS150 70 wt%, and
(C) graphite KS150 80 wt% (×200)

Black portion in micrograph is due to void of phenolic resin and graphite bipolar plate.