

## 전기화학 프로세스에 의한 Carbon 특성

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### Electric Properties of Carbon Using Electrochemical Process

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Electro-deposition of carbon film on silicon substrate in methanol solution was carried out with various current density, solution temperature and electrode spacing between anode and cathode. The carbon films with smooth surface morphology and high electrical resistance were formed when the distance between electrode was relatively wider. The electrical resistance of the carbon films were independent of both current density and solution temperature.

**Key Words** : memory effect, superconducting bar

#### 1. 서론

Diamond like carbon (DLC) films have attractive attention's for their properties such as high temperature semiconductivity and chemical stability[1]. Several techniques to deposit DLC films have been developed like pulsed laser deposition, ion beam deposition, vapor deposition [2,3]. Experiment shows that the deposition from the vapor phase can be also prepared in liquid phase and vice versa [4]. Recently, Suzuki et al[5], successfully deposited carbon films by electrolysis of a water ethylene glycol solution. The carbon film analyzed Raman spectroscopy was graphite carbon. Engineering point of view, the ethylene glycol solution is so viscous and harmful that it has a problem to clean substrate after deposition. Hence, the objectives of this study is to prepare DLC in methanol solution and characterize the final deposited film.

#### 2. 실험

Fig.1 is a schematic diagram of the deposition system. Analytically pure methanol (99.5%) was used as electrolyte. A silicon (100) substrate with a size of  $15 \times 20 \times 0.3\text{mm}^3$  was mounted on the negative electrode. Before deposition the substrate was in the mixture of dilute  $\text{HNO}_3$ -HF solution for a few minutes

and cleaned by ultrasonic treatment. The initial distance between the substrate and positive electrode was set to 10mm. The potential applied to the substrate was controlled from 0 to 5000 V under a constant temperature. Electric resistivity and surface morphology of deposited films were determined by four point probe method and scanning electron microscopy (JEOL 35C), respectively.

#### 3. 결과 및 고찰

Carbon films less than 2000 thick was fabricated by electro-deposition in methanol liquid. The carbon quality formed by electro-deposition influenced by process parameters like applied voltage, current density, distance between electrodes and solution temperature. Fig.2 is the D.C. voltage change at a constant current density of  $30\text{mA}/\text{cm}^2$  with distance between Si and graphite electrode. As shown in Fig.2, the resistance of the carbon film more than 20 Mwas observed at each electrode distance such as 3, 10, 15 and 20 mm, respectively. Low resistance of the carbon film, marked L in figure, was observed at the electrode distance of 5 mm. Since the current density was kept constant during the measurement of resistance, the voltage showed be increased with

deposition time. One of interesting points in Fig.2, the tendency of voltage increasing depends on the resistance. For example, low resistance with 5 mm electrode distance shows moderate increasing of the voltage, whereas, high resistance with different electrode distance like 3, 10, 15 and 20 mm shows steep increasing of the voltage. The moderate increasing of the voltage means that the final carbon film has low resistance. The high increasing of the resistance is resulted to the dopants in the carbon film with high resistance on the silicon substrate. From the Fig.2, it is clear that its voltage change during electro-deposition can be as one of the parameters to evaluate the final deposit. Fig.3 is the resistance change with current density and solution temperature at a constant electrode distance. Solid and open circles in the Fig.3 are carbon film with high and low resistances, respectively. As shown in Fig.3, the carbon film with low resistance was well deposited than the carbon film with high resistance. As the electrode of distance became wider from 10 to 20 mm, the carbon film with high resistance was tended to be formed. Especially, the carbon film with high resistance was well formed at the range of current density of  $20 \sim 40 \text{ mA/cm}^2$  and the temperature of  $30 \sim 50^\circ\text{C}$ . The surface of the carbon film is usually smoother than that of diamond film. The smoothness is one of important factors for the application of electronic device since the smoothness influences the effect of electric field emission, it is important to enhance the smoothness of the electronic field emitter. Fig.4, Fig.5 and Fig.6 are surface morphology observed by scanning electron microscopy, respectively. As shown in Fig.4, rough carbon surface was observed at the current density of  $20 \text{ mA/cm}^2$  and a constant electrode distance of 5 mm. The surface roughness was decreased with increasing electrode distance from 10 to 20 mm. As shown in Fig.5 and 6, the smooth surface was also observed at constant current density of  $30 \sim 40 \text{ mA/cm}^2$ . This means that the surface roughness was increased with decreasing electrode distance, resultantly, the carbon film with low resistance was formed. However, the surface roughness was decreased with increasing electrode distance, resultantly, the carbon film with high resistance was formed. A narrow electrode distance less than micro scale with high current density made electric spark so that it increases the solution temperature. The high solution temperature by the electric spark changes the electro-deposition condition which results in decreasing surface smoothness and forming the carbon film with low resistance.

#### 4. 결론

Carbon films were electro-deposited on Si substrates in methanol solution. The carbon films with high electrical resistance and smooth surface were formed when the distance between the electrodes was relatively wider. Surface roughness was decreased with increasing electrode distance, which tended to form the carbon film with high resistance. The electrical resistance of the films was independent of both current density and methanol liquid temperature.

#### 참고 문헌

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