SW5 : 나노복합소재 기술연구회

SW5-1 | Amperometric immunoassays based on microelectrodes

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A band-type microelectrode was made using a parylene-N film as a passivation layer. A circular-type, mm-scale electrode with the same diameter as the band-type microelectrode was also made with an electrode area that was 5,000 times larger than the band-type microelectrode. By comparing the amperometric signals of 3,5,3',5'-tetramethylbenzidine samples at different optical density values, the band-type microelectrode was determined to be 9 times more sensitive than the circular-type electrode. The properties of the circular-type and the band-type electrodes (e.g., the shape of their cyclic voltammograms, the type of diffusion layer used, and the diffusion layer thickness per unit electrode area) were characterized according to their electrode area using the FEM simulation. From these simulations, the band-type electrode was estimated to have the conventional microelectrode properties, even when the electrode area was 100 times larger than a conventional circular-type electrode. These results show that both the geometry and the area of an electrode can influence the properties of the electrode. Finally, amperometric analysis based on a band-type electrode was applied to commercial ELISA kits to analyze human hepatitis B surface antigen (hHBsAg) and human immunodeficiency virus (HIV) antibodies.

SW5-2 | 용액공정을 통한 주석 셀레나이드(SnSe) 열전 박막 소재 합성

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Tin selenide (SnSe) is one of the most highlighted thermoelectric materials with the record high efficiency since its discovery in 2014. However, weak mechanical properties and relatively low performance at a low-to-mid temperature range of SnSe limit its practical application. To address these issues, we developed the solution-processed fabrication of highly textured polycrystalline SnSe thin films with the desirable crystallographic orientation. The precursor ink solution for the solution process was synthesized by the alkahest-based route, which further undergoes purification and composition control to achieve an optimized ink solution. Moreover, the highly textured crystallographic structure was realized by a systematically controlled heat treatment process. The synthesized molecular-sized precursor of $Sn_2Se_6^{4-}$ decomposed to form $SnSe_2$ as an intermediate phase, where Se further evaporated to form the final SnSe phase. The structural analyses revealed its high degree of orientation in the b-c plane, which achieved the remarkable electrical properties of the SnSe thin films that yield a maximum power factor of 4.27 $\mu W\ cm^{-1}\ K^{-2}$ at 550 K. We also studied Ag doping of the SnSe thin film by the solution process, using a modified process of the synthetic chemistry for the SnSe precursor. Ag-doped SnSe thin film show significantly improved electrical properties at a near-room temperature range but also exhibited an enhancement in the crystallographic orientation. The crystallographic structure and the mechanism of the texturing were thoroughly investigated by X-ray diffraction (XRD) analyses, in which secondary phases of $SnSe_2$ and $AgSnSe_2$ were observed in the Ag-doped SnSe thin films. Accordingly, we proposed that the presence of the Ag intercalated in the intermediate $SnSe_2$ phase improves the thermal stability of $SnSe_2$ during the heat treatment, thus providing a longer duration for grain growth of the $SnSe_2$ and finally intensifying the texturing in the SnSe thin film The thermoelectric properties of the Ag-doped SnSe thin film reflected its crystallographic structure, where the maximum power factor of 11.97 $\mu W\ cm^{-1}\ K^{-2}$ at 300 K was achieved. To precisely evaluate the in-plane thermal conductivity of the thin films, the room temperature thermal conductivities were measured using a microfabricated thermoelectric measurement platform, and temperature-dependent thermal conductivity was theoretically estimated. As a result, the 2% Ag-doped thin film exhibited the highest ZT value of 0.46 at 300 K and was estimated to have a maximum ZT value of 0.93 at 550 K. Thin film wrinkling and photolithography is employed in the fabrication of stretchable and patterned devices, where the maximum power density of 58.28 $mW\ cm^{-2}$ was obtained at a temperature difference of 147.7 K.

SW5-3 | Co-doped NiFe(oxy)hydroxide as anode for solar-powered anion exchange membrane water electrolyzer : an electrochemical activation energy aspect

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Anion exchange membrane water electrolysis (AEMWE) employing non-platinum group metals (PGMs) is gaining attention as an advanced and environmental technology for producing hydrogen fuel. However, achieving high-efficiency AEMWE is delayed due to the low performance of non-PGMs-based electrocatalysts, especially the anode involved in the oxygen evolution reaction (OER). In this study, we developed cobalt-nickel-iron-(oxy)hydroxide (NiFeCo-OOH) by introducing cobalt to nickel-iron-(oxy)hydroxide (NiFe-OOH) to enhance OER activity. The introduction of Co induced a change in the chemical state of Ni, which reduced the activation energy barrier and the onset potential for OER. The AEMWE single-cell employing NiFeCo-OOH as the anode demonstrated enhanced performance not only compared to the AEMWE single-cell employing NiFe-OOH but also outperformed AEMWE single-cells employing RuO_2. Additionally, we established an integrated system that combines AEMWE single-cell with commercially available silicon solar cells, realizing the production of hydrogen fuel from renewable energy sources.

SW5-4 | 에너지 촉매 제작을 위한 원자층 증착 장비 기술

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원자층 증착 기술(Atomic Layer Deposition, ALD)은 복잡한 구조를 가진 반도체 소자 내에 고품질의 균일한 박막을 형성하는데 가장 많이 활용되어 왔다. 최근에는 ALD 기술의 우수한 특성으로 인해 고표면적 다공성 물질의 촉매 제조에 적용하는 연구가 증가하고 있다. 촉매 분야에 적용하기 위한 ALD의 장점은 매우 얇은 막 (1~2 nm)이나 나노 입자 형태의 물질 담지에 있어서 매우 적합하다는 것이다. 그럼에도 불구하고, 다공성 표면에 ALD 기술을 적용하기 위해서는 느린 프리커서/반응체 확산 및 낮은 수율 문제를 극복해야 하기 때문에 새로운 접근 방식의 ALD 장비를 설계해야 한다.
따라서, 빠른 확산 및 대량 생산을 위한 개조된 원자층 증착법 기술이 연구 되었다. 고온 개질 촉매를 제작하기 위한 dual-heating zone 펌프를 가진 ALD 장비를 설계하였다. 이를 이용하여 페로브스카이트 지지체에 페로브스카이트 박막을 형성하여 촉매를 제작하고, "Intelligent 촉매"를 대량 생산하였다. 또한, 유동층 반응기를 ALD에 도입하여 고표면적 지지체에 백금 나노 입자를 형성하고 TiO_2을 덮어 연료전지용 촉매의 내구성을 높히는 연구를 진행하였다. 이러한 연구는 촉매 제조 분야에서 상당한 의의를 갖고 있으며, 다공성 표면에 대한 ALD 기술 개선과 상용화를 위한 장비 설계 개발에 이바지할 것이다.