G4 : 나노 융합 세라믹스

G4-1 | An efficient synthetic route to metal/metal nitride nanotubes with enhanced electrocatalytic activity for hydrogen evolution reaction

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Exsolution has garnered significant research interest because of its high efficacy in synthesizing metal nanocluster-based composite electrocatalysis. In this study, we report a rationally designed single-step nitridation-exsolution synthetic route to high- performance hydrogen evolution reaction (HER) electrocatalyst. The NH_3 treatment of Ru-substituted oxide nanowires at evaluated temperature induces the exsolution of Ru nanoclusters and also the phase transition to holey metal nitride nanotubes. The obtained Ru exsolved metal nitride nanotube exhibits much higher HER electrocatalytic activity than that of Ru deposited homolog, highlighting the benefit of the nitridation- exsolution approach. The crucial effect of simultaneous nitridation-exsolution process on the HER electrocatalytic activity is attributable to the improved charge transfer kinetics, increased porosity, and the increase of electrocatalytic kinetics. The present study demonstrates that the single-step nitridation-exsolution synthetic strategy can provide an effective means to explore robust composite electrocatalyst materials.

G4-2 | Fe_3O_4@SiO_2 Core-Shell Nanoparticles with controlling the Shell porosity

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The iron oxide core within Fe_3O_4@SiO_2 core/shell-structured nanoparticles have distinct magnetic reactivity, while the silica shell provides surface hydroxyl groups conducive to binding with biomolecules or organic compounds. Due to their combined core/shell properties, these nanoparticles are utilized in tasks such as particle retrieval and targeted transportation. In core-shell nanoparticles where the surface functional groups are significant as previously stated, an increased specific surface area provides more attachment sites for these groups. Therefore, this study focuses on synthesizing Fe_3O_4@SiO_2 nanoparticles with a porous shell using the soft-template method and CTAB to increase these sites. By controlling the quantities of CTAB and TEOS, morphological structure, specific surface area, and magnetic properties of Fe_3O_4@SiO_2 nanoparticles were analyzed according to their content. Consequently, by correlating relevant data, it was investigated whether CTAB serves as a binding site between precursors during shell formation and how TEOS injection influences morphological tendencies.

G4-3 | 나노아키텍처 기반 금속 복합소재의 새로운 강화법칙 도출

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Realizing high strength on a macroscopic scale achieved through the size effect has been an engineering pursuit since size-induced strengthening is solely enabled by the nanoscale regime. Here, we present a new type of metal-matrix nanocomposite reinforced by ceramic nanoarchitected materials. Employing Proximity-field nanopatterning (PnP), which simultaneously enables large production area and high pattern resolution, the inch-scale production of nanoarchitected materials can be produced in a single fabrication step. The resulting three-dimensional (3D) Ni/Al_2O_3/Ni nanocomposite exhibits significantly higher strength, with an approximate 30% increase compared to that predicted by the conventional strengthening theory of composites. This high strength of the 3D MCM nanocomposite is attributed to the extrinsic size effect of the thin ceramic shell, where the mechanical properties of the ceramic increase as the extrinsic dimensions of the specimen decrease. By incorporating size-induced strengthening of ceramics into the conventional strengthening mechanism of composites, a new strengthening model is derived and experimentally demonstrated using the 3D MCM nanocomposite.

G4-4 | 테일러 와류 반응기를 활용한 금속 산화물 미립자의 합성

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테일러 와류 반응기는 concentric cylinder system의 내부 원통을 회전시켜 두 원통 사이의 annulus 영역에 존재하는 유체에 와류를 발생시키고 화학 반응이나 결정화, 살균 등 다양한 실험을 행할 수 있는 유체역학적 장치이다. 테일러 와류는 기존의 교반 기술에 의한 거시적 혼합과는 달리 미시적 수준에서 혼합이 가능하므로, 원료 물질(반응물)의 균일한 혼합을 기대할 수 있다. 이러한 장점을 활용하여 금속 산화물 미립자를 합성할 때 기존 방식에 비해 더욱 균일한 입도 분포를 갖는 시료의 제조가 가능하다. 본 학술 발표에서는 테일러 와류 반응기를 활용하여 스토버 방식에 의해 구형 단분산 실리카 입자를 합성하는 사례 및 실리케이트 원료 물질로부터 실리카 나노 분말을 높은 균일도로 합성하는 연구 결과에 대해 발표하고자 한다. 구형 단분산 실리카 입자는

테일러 와류 반응기를 연속식으로 조업하는 방식으로도 합성이 가능하였으며, 실리카 나노 분말을 산 분위기에서 합성하는 사례는 이산화탄소를 반응물로 활용한 탄산을 적용하는 연구를 수행하였다. 두 경우 모두 기존의 플라스크에서 합성하는 방식에 비해 입도 분포가 상대적으로 낮은 표준 편차를 갖음을 확인하였다.

G4-5 | Engineering of Powder Materials Enabled by Atomic Layer Deposition

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It has been proven that atomic layer deposition (ALD) can provide highly uniform film growth on the wide area of substrate, conformal growth on the nanostructures with complicated shapes, and controllability of thickness and composition; atomic craft of materials enabled by ALD has indeed attracted a lot of attention from many industrial and research fields. Therefore, ALD is expanding its territory to diverse fields, such as energy and biology. By controlling the reactivity of the surface, either homogeneous or inhomogeneous coating on the shell of nano-structured powder could be enabled by ALD process. In this presentation, ALD technology will be introduced, which has been used for functionalizing the surface of powder materials for efficient energy conversion and other convergence research such as refractory metal alloys.

G4-6 | 광센서와 태양전지를 위한 할라이드 페로브스카이트 조성 엔지니어링

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Halide perovskites have garnered significant attention as promising light absorption and emission materials for photovoltaics and optoelectronic applications, because of their outstanding properties and merits, such as strong light absorption, long carrier diffusion length, tunable optical bandgap, ease of processing and low cost. In this presentation, I will discuss my recent research focusing on the compositional exploration of halide perovskites, considering their structural and optical properties of halide perovskites (ABX_3: A = Cs^+, methylammonium (MA^+) and formamidinium (FA^+); B = Sn^{2+} and Pb^{2+}; X = Cl^-, Br^- and I^-). Ternary diagrams illustrating phase and optical properties will be presented for several halide systems, such as $MAPbX_3$, $CsPbX_3$, and $ASn_{0.6}Pb_{0.4}I_3$. Our approach proves valuable for the tailored design of halide perovskites for diverse applications. First, a high performance, self-powered, color-filter-free blue photodetector is developed by engineering the A-site monovalent cations of wide-bandgap perovskites. The blue photodetector exhibits a high external quantum efficiency of 84.9%, which is the highest reported EQE in blue photodetectors. Next, a high efficiency monolithic perovskite-perovskite tandem solar cell is achieved by carefully tuning the monovalent cations in narrow-bandgap perovskites and the halide ions in wide-bandgap perovskites. The single-junction devices, with both narrow and wide bandgap perovskites, demonstrate remarkable efficiencies exceeding 22% and 18%, respectively. Furthermore, the double-junction tandem device achieves an impressive efficiency of over 27.5%.

G4-7 | An effective way of optimizing the photocatalytic functionality of semiconductor using noble-metal-free conductive oxide nanosheets

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Hybridization with conductive 2D nanosheets has evoked intense research activities because of their effectiveness for optimizing the photocatalyst performance of diverse semiconductors. To circumvent the high price and limited electronic coupling of previously-reported graphene and/or RuO_2 nanosheets, here we suggest the synthesis of economically-feasible noble-metal-free conductive nanosheets via the fine-control of chemical composition and defect structure. The diversification of cationic composition of multimetallic oxide nanosheet enables to finely tailor anion vacancy and surface bond polarity, leading to a strong interfacial electronic coupling with hybridized species and thus an improvement of charge/mass transfer. The composition-optimized multimetallic oxide nanosheets can function as superior hybridization matrices for enhancing visible light (λ〉 420 nm) photocatalytic activities over graphene and noble metal-based RuO_2 nanosheet. The present study highlights the high efficiency of composition-controlled multimetallic oxide nanosheets as hybridization matrices for photocatalysts.

G4-8 | 1마이크로 이하의 구상형 h-BN 합성을 위한 새로운 전략

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Nowadays, there has been a trend towards miniaturization and densification in the semiconductor process. They have confronted the technical barriers from quantum

tunneling in front-end and have prompted efforts to overcome these challenges through advanced packaging. Nonetheless, challenges in thermal management persist within advanced packaging, requiring the development of new materials and optimization technologies. Hexagonal boron nitride (h-BN), a two-dimensional layered material, exhibits remarkable properties such as thermal stability, high thermal conductivity, and electrical insulation. It minimizes electrical interference and fulfills heat dissipation requirements, making it a suitable candidate for thermal management applications. However, the plate-like structure of h-BN introduces issues such as heat transfer anisotropy and poor fluidity. Thus, it is necessary to fabricate h-BN into a spherical shape to preserve its advantages while addressing limitations. In this study, we propose a novel strategy for synthesizing submicron spherical h-BN by manipulating the morphology of BN precursor. This spherical BN was robust and crystalline, so it had high thermal conductivity like conventional h-BN. Moreover, when mixed with polymers, it exhibited improved fluidity, leading to uniform dispersion and making it highly suitable for bonding or packaging applications. This novel strategy for spherical BN will accelerate the technological advancement in multi-micron scale packaging processes, including 3D stacking and hybrid bonding.