SW7 : 국립대 육성 세라믹/융합소재 젊은 과학자 연구 토론 세션

SW7-1 | 2차원 전이금속 탄화물 $Ti_3C_2T_x$ MXene의 제조공정, 특성 및 전기화학적 응용

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2차원 전이금속 탄화물 $Ti_3C_2T_x$ MXene은 $M_{N+1}X_NT_x$의 조성을 갖는 무기 화합물로, 최근 가장 주목받고 있는 2차원 소재 중 하나이다. 여기서 M은 전이 금속이고, X는 C 또는 N이며, T는 표면 기능기(예: -OH, -F, =O)을 나타낸다. $Ti_3C_2T_x$ MXene은 높은 전기전도성, 친수성, 넓은 비표면적 및 우수한 기계적 강도와 같은 고유한 재료 특성으로 인해 에너지 저장 및 변환 분야에서 큰 관심을 받고 있다. 본 연구에서는 $Ti_3C_2T_x$ MXene 기반의 다양한 구조체 전극을 제조하고 배터리, 슈퍼커패시터 및 수전해 촉매 응용 가능성에 대해 논의하고자 한다. 또한, $Ti_3C_2T_x$ MXene이 에너지 저장 및 변환 응용 분야에서 특성을 어떻게 향상시킬 수 있는지와 전기화학적 성능 향상 메커니즘에 대해 논의하고자 한다. 이러한 연구는 $Ti_3C_2T_x$ MXene과 같은 2차원 소재를 활용한 차세대 에너지 저장 및 변환 기술 개발에 새로운 가능성을 제시할 수 있을 것으로 기대된다.

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SW7-2 | 열전 및 압전 기반의 플렉서블/웨어러블 에너지 하베스터

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Thermoelectric and piezoelectric hybrid generators (TPHGs) are attractive candidates for powering wearable body sensor networks continuously and permanently owing to their excellent access to human-generated energy. First, to achieve the enhanced piezoelectricity of flexible piezoelectric composites-based films, we have demonstrated the flexoelectric-boosted electromechanical properties of piezoelectric nanoparticles using an induced built-in strain gradient in heterogeneous core-shell nanostructure for enhancing the intrinsic piezoelectricity of pure $BaTiO_3$ nanoparticles. We have also demonstrated the enhanced poling efficiency in nanocomposite made of P(VDF-TrFE) and porous $BaTiO_3$ nanofibers. Moreover, we have developed the high-temperature workable f-PEH comprising the high Tc KNN-based ceramics and a thermally stable polyimide (PI) matrix which can be a promising candidate for developing f-PEH and self-powered sensors working in high-temperature environments. Next, to realize the flexible thermoelectric energy harvesting technology, we have fabricated the tailorable f-TEHs based on thermoelectric films and papers made by dispersing the Bi_2Te_3 particles inside polymeric and cellulose matrices, respectively. Finally, the hybrid generator was assembled through simple drop-casting and gravitational settling effect, for the first time. The film layer sedimented with the conductive thermoelectric particles simultaneously served as an electrode and a bottom substrate for piezoelectric energy harvesting. The proposed design concept for f-TPHGs can aid in the development of high-performance multisource energy harvesting devices for wearable sensors.

SW7-3 | 아세톤의 선택적 감지를 위한 강유전성 ε-WO_3

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Acetone is one of the major byproducts of lipolysis, which is excreted via exhaled breath due to its high volatility. Accordingly, exhaled breath acetone analysis using portable sensors could be a non-invasive, always accessible technique to in-situ monitor fat burning during exercise and dieting. However, implementing this technology remains a great challenge due to the lack of sensing materials that can detect acetone selectively in complex gas mixtures like human breath. Herein, we suggest ferroelectric ε-WO_3 nanomaterials as a novel sensing material for ultraselective and sensitive detection of acetone. Acetone is a polar gas with a high dipole moment of 2.88 D. Thus, the key idea is to facilitate a strong interaction of polar acetone to the sensing surface using polarized ferroelectric domains. The ferroelectric ε-WO_3 was prepared by doping Nb and Ti into γ-WO_3 via the ultrasonic spray pyrolysis method. The acetone selectivity of the ε-WO_3 sensors was significantly higher than any other values reported in the literature, and the acetone response was also sufficiently high to monitor breath acetone at ppb levels. The correlation between the ferroelectric properties and gas sensing characteristics was investigated by measuring the spontaneous polarization, and the acetone adsorption ability of the ε-WO_3 nanomaterials was evaluated using thermal desorption spectroscopy. This work will provide a novel strategy for designing highly selective oxide semiconductors and facilitate the development of a new class of portable breath acetone sensors for monitoring fat burn efficiency.

SW7-4 | 자기-기계-전기변환 소자의 제작과 응용

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Magneto-mechano-electric (MME) composites are promising candidate for not only sensing of ultralow magnetic field for biomedical applications but also harvesting electric energy for standalone-powered IoT systems. To date, MME generators have been demonstrated by composite structures with various energy conversion components such as piezoelectric, magnetostrictive, triboelectric, and magnet materials to primarily convert an AC magnetic field into mechanical vibration by a magnetostriction effect or magnetic force, which is subsequently transduced into electricity by a piezoelectric or triboelectric effect. This presentation includes demonstrations of world-best performance MME magnetic field sensor as well as MME generator. Firstly, it includes demonstration of an ultra-sensitive MME magnetic field sensor which can detect alternating current (AC) magnetic field below 1 pT. Secondly, it includes demonstration of a hybrid type MME generator which can generate root-mean-square (RMS) output power of 60 mW.

SW7-5 | 소각산란을 활용한 이차전지 소재 정량 기공분석

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소각산란(small angle scattering) 기술은 X선 혹은 중성자선이 시료를 투과하며 발생하는 소각 영역의 산란패턴을 관찰하여 시료 내에 존재하는 1-300 nm 정도의 크기를 갖는 조성 혹은 밀도의 불균일성을 비파괴적으로 분석하는 기술이다. 특히 빔이 투과한 거시적인 체적 내의 통계적인 나노구조에 대한 정보를 제공하므로, 시료 내 닫힌기공(closed pore)을 포함한 모든 기공에 대한 분석이 가능하며, 무엇보다 산란강도의 적절한 절대값화(absolute calibration)를 통해 기공크기분포, 총 기공도를 포함하는 정량적인 분석이 가능하기 때문에 시료 내 나노크기의 기공 분석에 매우 적합하다. 따라서, 본 연구에서는 X선소각산란(SAXS)과 중성자소각산란(SANS)을 상보적으로 활용하여 이차전지의 전극소재로 활용되는 하드카본과 Ni-rich NCM 소재의 기공을 정량 분석한 연구 결과에 대해 소개하고자 한다.

SW7-6 | 생체 움직임의 실시간 측정을 위한 자가발전형 웨어러블 센

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In the forthcoming era of the Internet of Things (IoT), considerable attention has been directed towards wearable and self-sustaining intelligent devices, which hold promise as potential channels for emerging human-machine interfaces (HMIs) in the realm of information and communication. Self-sustaining technologies designed for sensors are pivotal in enabling the continuous functioning of extensive integrated devices, as they obviate the need for external power sources to supply electricity. To achieve the realization of such self-sustaining sensors, several research teams have been actively engaged in the development of sensors using commonly employed piezoelectric materials and the triboelectric effect. During this presentation, I will provide an overview of recent advancements in the field of self-sustaining and wearable sensors. The initial segment will delve into displays and sensors rooted in the triboelectric effect, while the subsequent portion will detail the creation of wearable electronic skin tailored for real-time healthcare monitoring, accomplished through the utilization of piezoelectric materials.

SW7-7 | Selective Laser Heat Treatment: A Novel Method for Direct Synthesis of 2D Nanomaterial on Arbitrary Substrates

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Transition metal dichalcogenides (TMDs) have attracted significant interest as one of the key materials in future electronics such as logic devices, optoelectrical devices, and wearable electronics. However, a complicated synthesis method and multistep processes for device fabrication pose major hurdles for their practical applications. Here, we introduce a direct and rapid method for layer-selective synthesis of MoS_2 and WS_2 structures in wafer-scale using a pulsed laser annealing system (λ = 1.06 μm, pulse duration ~100 ps) in ambient conditions. The precursor layer of each TMD, which has at least 3 orders of magnitude higher absorption coefficient than those of neighboring layers, rigorously absorbed the incoming energy of the laser pulse and rapidly pyrolyzed in a few nanoseconds, enabling the generation of a MoS_2 or WS_2 layer without damaging the adjacent layers of SiO_2 or polymer substrate. Through experimental and theoretical studies, we establish the underlying principles of selective synthesis and optimize the laser annealing conditions, such as laser wavelength, output power, and scribing speed, under ambient conditions. As a result, individual homostructures of patterned MoS_2 and WS_2 layers were directly synthesized on a 4-in. wafer. Moreover, a consecutive synthesis of the second layer on top of the first synthesized layer realized a vertically stacked WS_2/MoS_2 heterojunction structure, which can be treated as a cornerstone of electronic devices. As a proof of concept, we demonstrated

the behavior of a MoS_2-based field-effect transistor, a skin-attachable motion sensor, and a MoS_2/WS_2-based heterojunction diode in this study. The ultrafast and selective synthesis of the TMDs suggests an approach to the large-area/mass production of functional heterostructure-based electronics.

SW7-8 | 유전체 소재의 연구와 교육 융합 사례

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Among wide range of dielectric materials, ferroelectric materials are tremendously important because of its piezoelectric and pyroelectric (electrocaloric) effects for various useful applications such as sensors, transducers, actuators and generators. It is also crucial for electrostatic energy storage devices (capacitors) due to its high dielectric constants. Moreover, it is directly related to the critical electrical device, multi-layered ceramic capacitor (MLCC). Unfortunately, normal ferroelectric physics is not good for capacitors since it has large energy loss generally when we are faced with its polarization-electric field (P-E) hysteresis curves. This is the reason why many people are interested in and develop a myriad of compositions for specific ferroelectric materials such as relaxor ferroelectric, antiferroelectric, pseudo-linear dielectric, and even superparaelectric materials for the applications, although many parts of their fundamental physics are still veiled. In this talk, up-to-date research about both ferroelectric ceramics and polymers will be reviewed within his research topics. Some of them shows abnormal characteristics, ambiguous mechanisms or device applications.