SW11 : 나노 신소자 용 세라믹 소재 및 공정

SW11-1 | 뉴로모픽 하드웨어 용 알칼리 이온 기반 시냅스 소자

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Nanoscale memristive systems are emerging as an alternative platform to conventional silicon transistors for energy-efficient hardware implementation of neuromorphic computing. The memristor (ionic memristor) is referred to as the fourth circuit element, which the resistance can be changed gradually by the electric pulse signals that have been applied to it. Moreover, the stored resistance state in a memristor is non-volatile, and their large on/off ratio with analog resistive memory characteristics makes this system appealing as a circuit element for neuromorphic computing devices. Their gradual resistance change characteristics induced by ion-migration depend on the magnitude, duration, and number of programming pulses, with the resulting synaptic response mimicking the synaptic function of biological neurons. However, the stochastic nature of defect-induced switching coupled with limited control over intrinsic materials defects have been identified as the primary factors undermining the reliability of memristors in scaled crossbar-array architecture.

In this talk, I will present a Na-doped TiO_2 memristor that uses high-mobility sodium cations instead of oxygen anions (oxygen vacancies) as the main agent for resistive switching. In this manner, reversible switching is achieved even under rectifying characteristics involving more than three orders of magnitude smaller current than a forward-biased memristor. We adopted TiO_2 as the matrix material since it can be controllably grown by atomic layer deposition (ALD) and acts as an effective host for Na-ion migration. Therefore, unlike conventional memristors based on oxygen anions, the high mobility of Na ions can be expected to produce memristive behavior regardless of the underlying oxygen vacancy concentration and even under a low electrical current.

SW11-2 | Electronic-Grade van der Waals Thin-Films

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Two-dimensional (2D) materials have been considered as potential building blocks for use in fundamental elements of electronic applications, because of their diverse and remarkable properties. However, such fundamental approaches cannot directly be applied practically because of issues such as precise alignment/positioning and large-quantity material production. I will demonstrate wafer-scale vdW heterostructures by exploiting the lateral and vertical assembly of solution-processed 2D vdW materials. The high exfoliation yield of the molecular intercalation-assisted approach enables the production of micron-sized nanosheets in large quantities and its lateral assembly in a wafer-scale via vdW interactions. Subsequently, the laterally assembled vdW thin-films were vertically assembled to demonstrate various electronic device applications, such as transistors and photodetectors. Furthermore, multi-dimensional vdW heterostructures were demonstrated by integrating one-dimensional carbon nanotubes as a p-type semiconductor to fabricate p–n diodes and complementary logic gates. Lastly, electronic devices were fabricated via various printing technologies as a lithography-free manner based on the stable nanomaterial dispersions.

SW11-3 | Atomic layer deposition of oxides thin films for future capacitors

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DRAM의 스케일링 추세에 따라 셀 면적이 줄어들고 있으며, 이로 인해 DRAM 소자 동작에 필요한 최소 커패시터 정전용량 확보가 어려워지고 있다. 따라서 필요 정전용량에 도달하기 위해 높은 종횡비를 가진 3차원 구조의 도입이 필수적이며, 얇은 두께의 박막을 균일하게 피복하기 위해 원자층증착법(atomic layer deposition, ALD)이 핵심 박막 증착 공정이다. 최근에는 유전막 두께를 줄이기 위해 커패시터의 절연 특성을 향상시키는 다양한 방법이 시도되고 있으며, 셀 크기 감소로 인한 필연적인 종횡비 감소로 인해 높은 유전율의 유전막 연구가 진행되고 있다. 특히 고유전율 박막은 3차원 DRAM 제품 출시시 현재의 ZrO_2 기반 유전막을 대체하며 필요성이 확대될 것으로 예상된다. 본 연구에서는 ZrO_2 (k~30)나 TiO_2 (k~80)보다 높은 유전율을 가진 $SrTiO_3$ 삼성분계 박막의 ALD 공정을 개발하였으며, 양이온 조성 제어와 전기적 특성 확보 결과에 대해 논의하고, 커패시터의 전기적 특성 향상을 위한 전략에 대해 소개할 예정이다.

SW11-4 | 치밀 프로톤 전도성 산화물 제작을 위한 소결 공정

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Proton conducting oxides exhibit notable ion-conducting property at intermediate temperatures around 500°C, thus being actively adopted as an electrolyte to various devices. While they require high-temperature sintering above 1600°C to gain full density owing to their refractory nature, it has been observed that the temperature can be significantly reduced below 1500°C

when they are sintered on Ni-based electrode. However, a consistent explanation on the mechanisms is yet been established owing to difficulties in identifying and tracing the transient phases responsible for the accelerated sintering behavior during such high-temperature process. Here, we present the fuel electrode-assisted facile densification of a proton-conducting electrolyte on a (NiO)-(proton conducting electrolyte) composite support. It will be shown that an internal supply of sintering aid from the electrode to the electrolyte enables the full densification of electrolyte at relatively lower temperature. The probable mechanism of this behavior will be suggested and the newly designed approach for the further decrease of sintering temperature will be discussed.

SW11-5 | 표면 구조와 특성 제어를 위한 맥신 소재의 합성법

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The recent emergence of MXene, a new class of 2-dimensional materials composed of transition metal carbides, nitrides, or carbonitrides, offers promising opportunities for their versatile applications in energy harvesting and storage, optoelectronic devices, electromagnetic interference shielding, and more. However, the limited range of synthetic pathways, mostly confined to aqueous HF, has been a significant bottleneck hindering the widespread utilization of MXene materials. In this presentation, we introduce novel pathways for synthesizing MXene from MAX phases: anhydrous HF etchants to remove water, and a halogen-free hydrothermal reaction. On one hand, a water-free environment minimizes the presence of surface terminal groups (-OH and -O-) on MXene flakes, which strongly influence their physical properties and overall performance, including colloidal dispersion behavior, hydrophilicity, mechanical strength, and others. On the other hand, the hydrothermal method produces MXene nanoflakes with no halogen terminations but hydroxyl and oxygen-terminated surfaces. Halogen-free MXene holds particular promise in biomedicine and electronic industries due to the absence of halogen species, which can be released into the surroundings spontaneously or upon oxidative degradation of MXenes. Halogen species are known for their causticity and cytotoxicity. These studies highlight the importance of fine-tuning the process-structure-function relationships, allowing researchers to select the most suitable MXene preparation method based on the requirements of specific applications.

SW11-6 | 웨어러블 플랫폼 응용을 위한 신축/유연 페로브스카이트 광전소자 기술

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Despite drastic advances in the performance of halide perovskite-based optoelectronics, operational stability still remains a challenge towards commercialization. Among various encapsulation strategies reported to date, glass-based encapsulation serves as one of the only solutions, which provides operational stability against the damp heat test. However, glass-based encapsulation lacks the ability to contain lead upon physical impact and does not offer flexibility/stretchability, significantly limiting the application of halide perovskite-based optoelectronics.

Here, we devise a multi-functional encapsulation scheme utilizing hydrogen bond-based self-healing polymers as a simple platform to guarantee operational stability, lead sequestration, and flexibility/stretchability. Utilizing self-healing polymer-based encapsulation, a long-term operational stability of over 1,000 h under 50 °C/50% RH was achieved in halide perovskite-based solar cells. More importantly, Pb in physically damaged halide perovskite-based optoelectronic devices were completely contained within the self-healing encapsulation as indicated by in vitro cytotoxicity tests. In stark contrast to glass encapsulated devices, self-healing polymer encapsulated devices were able to accommodate casual bending and stretching flexibility while maintaining their original performance. Finally, we demonstrate the concept of user-defined scalable modular optoelectronics (akin to building LEGO blocks) based on self-healing polymer encapsulated halide perovskite-based solar cells and light emitting diodes.

We expect this versatile encapsulation platform to provide a simple, but practical solution to resolving the multi-faceted challenge in the field of halide perovskites.