2024 아주대학교 G-램프(LAMP) 사업단 워크숍

세션1: 에너지 양자 물질 연구

Minbaek Lee | Department of Physics, Inha University

Triboelectric Energy Harvesters from its Working Principle to Recent Progress

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The issue of the research for self-powered nanosystems is likely to integrate different nano-devices into a stand-alone. Such nanosystem, surely, requires a sustainable power source to make the entire package as self-powered one. In this regard, scavenging energy from the environmental sources can be a possible choice for powering nano-systems. Among the others, there are many of mechanical form of energy (such as body movement, muscle stretching) or vibration energy (such as acoustic/ultrasonic wave) which can be converted into electric energy. In this regard, triboelectric energy harvesting technology can be one of the solutions for that. The presentation will cover a fundamental of electrification and its application to triboelectric energy harvesters. There are many of ongoing developments and demonstrations in this research field, so that it will also cover some recent developments of new materials and improvements of power with surface charges.

Jae-Ung Lee | Department of Physics and Department of Energy Systems Research, Ajou University

Preparing Atomically ThinMaterials for Quantum Applications

Atomically thin materials are promising candidates as host materials for quantum states, offering significant advantages for integration into existing fabrication technologies. Their two-dimensional nature provides distinct opportunities to control their properties. However, realizing useful quantum states in atomically thin materials presents several challenges. Defects, in particular, play a crucial role in determining the properties of these materials. In this presentation, I will discuss ongoing efforts to develop atomically thin materials for use in quantum technologies.

Jun Won Rhim | Department of Physics, Ajou University

Symmetry and Destructive Interference in Two-dimensional Systems

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We investigate the influence of symmetry and destructive interference in two-dimensional systems on electronic structures and transport properties. Building on this analysis, we propose a practical approach to controlling these effects to engineer specific material properties.

[1] Advances Science **2024** 2307288 (2024).
[2] Nano Letters **24** 4885 (2024).
[3] To be appear in ACS Nano (2024)

Sunghun Kim | Department of Physics, Ajou University

Revealing quantum properties of quasi 1D systems by visualizing electronic structure

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Discovery of graphene has greatly boosted intensive and extensive studies on various low-dimensional compounds as a platform for quantum physics based on strong electron correlation and topology. In this regard, various materials stacked by van der Waals force, such as transition-metal dichalcogenides, have become a central issue of recent research. Among a series of van der Waals materials, quasi-one-dimensional compounds can emerge distinct properties with other two- or three-dimensional materials due to stronger electron correlation compared to them based on its limited channels for interaction. Despite the expectation, their simple but unique filamentary structures prevent the advanced study to clarify the detailed physics of those materials.

In this talk, I will introduce recent studies of transition-metal trichalcogenides (TMTCs), which would be a novel platform to study quantum properties based on both strong electron correlation and topology. By virtue of the improved angle-resolved photoemission spectroscopy technique with micro-focused light, we succeeded to identify the electronic structure of transition-metal triselenides and revealed the complexed phase diagram of the system. With our findings, I will further discuss quantum application based on these materials.

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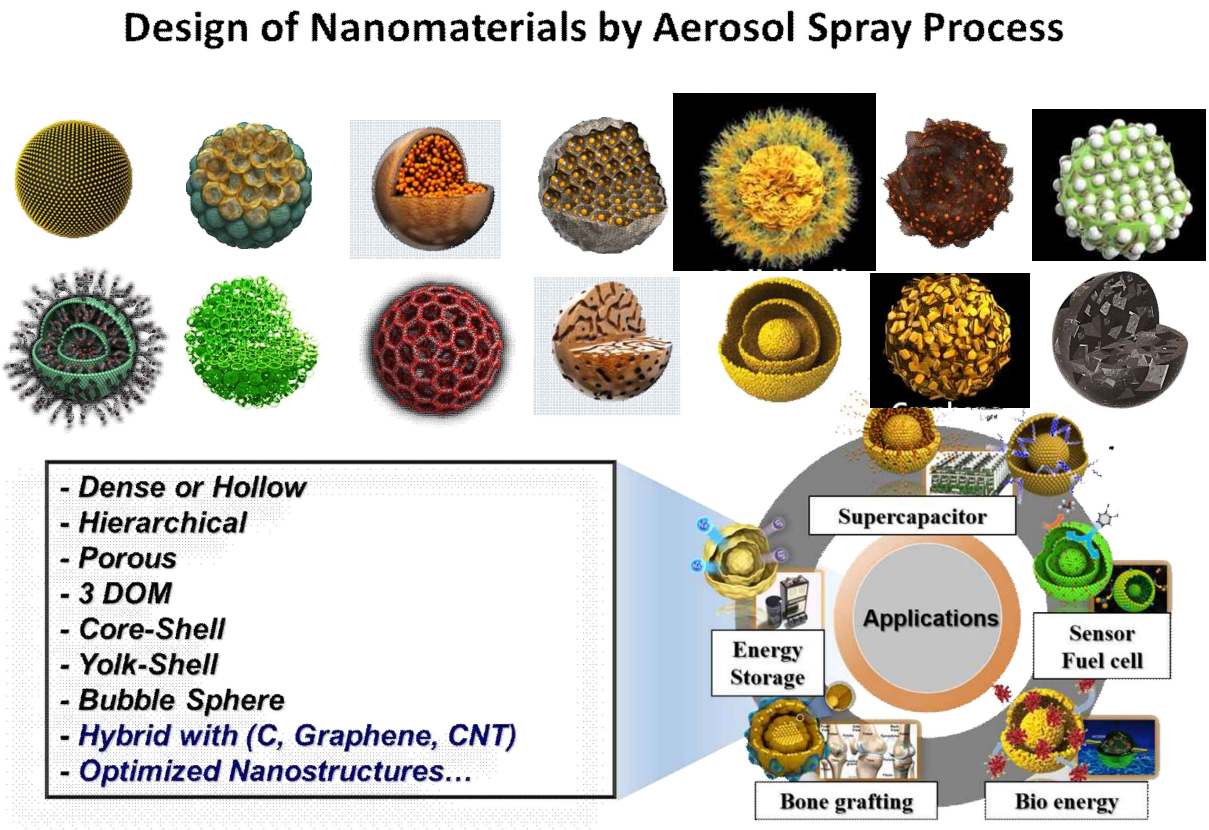
세션2: 에너지 저장 기술

박승근 I 중앙대학교 첨단소재공학과

분무 공정을 활용한 에너지 저장 및 변환용 나노구조체 개발

나노구조체는 고유의 물리화학적 특성으로 인해 에너지 저장 및 변환분야에서의 활용 가능성이 매우 큰 소재로 주목받고 있다. 2000년도부터 이러한 나노구조체 제조를 위한 합성법들이 다양하게 제안되었지만, 현재까지도 구조체 설계가 용이하고 제조 신뢰성 높아 대량생산이 가능한 제조법을 개발하는 것은 매우 도전적인 일이다.

본 세미나에서는 분무 공정을 통해 나노구조체를 제조하는 몇 가지 전략과 구체적인 연구 사례에 대해 소개하고, 해당 공정이 가지는 장점과 특징을 주로 다룰 것이다. 특히, 분무 공정을 통해 제조된 나노구조체를 에너지 저장 및 변환분야로 응용한 사례를 살펴봄으로써 향후 해당 공정기술의 발전가능성과 전망을 공유하고자 한다.



Jongkook Hwang | Department of Chemical Engineering, Ajou University

Impact of Pore Structure on Potassium Storage Behavior of Hard Carbon Anode materials for Potassium-Ion Hybrid Capacitors

Potassium Ion Hybrid Supercapacitors (PIHCs) are increasingly recognized for their low r edox potential of K^+/K and the abundance and cost-effectiveness of potassium resources. De spite their potential, the enhancement of high-power PIHCs is often constrained by the slow kinetics of K^+ storage in traditional battery-type carbon anode materials.
Pore structure engineering has emerged as a promising solution to augment the electrochemi cal performance of these materials. Although various studies have explored the relationship between pore structures and K^+storage behavior, a definitive consensus on the impact of spe cific pore sizes has yet to be reached. This is largely due to the challenges associated with fabricating model carbon materials with precisely controlled porous structures and a limited understanding of how these structures affect capacitive an ddiffusion-controlled K^+ storage.

In this presentation, I will highlight the recent advancements made by our research group in investigating the influence of pore structures on the K+ storage behavior of hard carbon anode materials. We have developed carbon materials with specifically controlled pore sizes: micropore-dominated, ultramicropore/mesopore-mixed, and mesopore-dominated. Our findings indicate a positive correlation between the volume of ultramicropores and the capacitive K+ storage capacity. Furthermore, we synthesized mesoporous carbon spheres with a controlled degree of mesopore openings and identified that prominently exposed mesopores significantly enhance the capacitive K+ storage capacity. This research advances our fundamental understanding of pore structure design and its critical role in enhancing capacitive K+ storage in carbon anode materials for high-power PIHCs.

Chung-Yul Yoo | Department of Chemistry, Ajou University

Investigation on the chloroaluminate anions intercalation in graphene-based materials for rechargeable aluminum-ion batteries

Development of energy storage systems with high energy and power density, high safety, long cycle life, and low cost is crucial for various applications, including portable electronics and grid storage of renewable energies. Among various battery technologies, rechargeable aluminum ion batteries are particularly attractive due to the abundance, low cost, and safety of aluminum. However, unlike lithium ion batteries, many aspects of the fundamental intercalation processes and dynamics in these aluminum-based battery systems remain unresolved.

In this study, we investigate the intercalation of chloroaluminate ions in atomically thin carbon cathodes using mesoscopic devices for charge transport and operando optical microscopy. These measurements provide insights into the energetics and dynamics of intercalation processes in atomically thin samples. We compare the atomically thin single crystal measurements to the cycling response of a high-performance rechargeable aluminum ion battery consisting of a few-layer graphene–multiwall carbon nanotube composite cathode. Our findings show that these nano-composites exhibit a high specific capacity and cyclic stability at high current densities, with a ~3-fold improvement in overall ion diffusivity in the aluminum ion battery. However, the battery cells still exhibit chloroaluminate diffusivities less than ~1% of those in mesoscopic single crystals. Our results highlight the distinction between intrinsic and ensemble electrochemical behavior in aluminum-based batteries and demonstrate that engineering ion transport to enhance diffusivity in these devices can lead to significant improvements in battery performance.

Jin-Sung Park | Department of Materials Science and Engineering, Ajou University

Pitch-derived carbon coated Si-based microspheres for achieving Li-battery anodes with high cycle stability

As the demand for large-scale storage solutions, such as electric vehicles and energy storage systems, continues to grow, the need for lithium-ion batteries (LIBs) with higher energy density becomes more critical.Graphite is commonly used as the anode material in lithium-ion batteries (LIBs); however, its theoretical capacity of 372 mAh g^{-1} is not sufficient for meeting the demands of large-scale energy storage needed for future applications. In contrast, silicon has garnered significant research interest due to its nearly tenfold higher theoretical capacity compared to graphite. However, silicon faces challenges such as low electrical conductivity and significant volume expansion (300-400%) during cycling. This expansion can lead to electrode pulverization, delamination of the electrode material from the current collector, and rapid capacity degradation. Additionally, the formation of a thick and unstable solid-electrolyte interphase (SEI) layer results in lithium-ion loss, leading to high irreversible capacity and low Coulombic efficiency. To tackle the issues mentioned above, various strategies have been employed to enhance both the cycle stability and electrical conductivity of silicon-based anode materials. Pitch, an inexpensive carbon material sourced from petroleum, has been proposed as a coating on the surface of silicon particles. Conductive carbon derived from pitch is uniformly applied both internally and externally to the nanostructured particles. The pitch-derived carbon fills the pores within the nanostructured framework and creates a stable coating on the surface, enhancing the structural integrity of the microspheres during charge and discharge cycles. This presentation In this presentation, two cases where pitch-derived carbon is applied to Si-based anodes are to be explained in detail.