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(onsite and online)

Unconventional Piezoelectric Effects from Ceramic Nanoparticles to Biopolymer Nanofibers for Energy Harvesting

Date: 15 November, 2023 (Wednesday)
Time: 4:00 p.m. (HKT)
Venue: Room 7-34 and 7-35
Haking Wong Building
HKU

Speaker: Prof. Chang Kyu Jeong
Division of Advanced Materials Engineering
Jeonbuk National University
Republic of Korea

Join Zoom Meeting:

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Abstract:
In the first topic, we demonstrate the flexoelectric-boosted electromechanical properties of piezoelectric nanoparticles using an induced built-in strain gradient in heterogeneous core-shell nanostructure. The composition-graded core-shell structure of BaTiO3@SrTiO3 nanoparticles enables a significant increment of the effective piezoelectric charge coefficient *via* the chemical heterogeneities-induced lattice strain gradient. Through the combinations of *ab-initio* calculation and multiphysics simulations, the origin of the strain distribution over nanoparticles is theoretically interpreted with accompanying phase balance and diffusion criteria. In addition, our designed core-shell nanoparticles-based energy harvesting devices generate highly efficient and flexoelectric-boosted piezoelectric output signals. Individual core-shell nanoparticles and related elastomeric nanocomposites reported in this work represent state-of-the-art electromechanical properties compared to previously reported piezoelectric nanoparticles and composites.

In the second topic, the concept for the morphotropic phase boundary (MPB), which has been exclusive in the field of high-performance piezoelectric ceramics, has been surprisingly confirmed in P(VDF-TrFE) piezoelectric copolymers by the groups. This study demonstrates the exceptional behaviors reminiscent of MPB and relaxor ferroelectrics in the feature of widely utilized electrospun P(VDF-TrFE) nanofibers. Consequently, an energy harvesting device that exceeds

the performance limitation of the existing P(VDF-TrFE) materials is developed. Even the unpoled MPB-based P(VDF-TrFE) nanofibers show higher output than the electrically poled normal P(VDF-TrFE) nanofibers. This study is the first step toward the manufacture of a new generation of piezoelectric polymers with practical applications.

In the third topic, electrospun silk nanofiber mat was soaked into ethanol (EtOH) for 2 h. Through the EtOH treatment, a phase transition from α-helix phase to β-sheet phase is observed. The molecular phase transition from α-helix to β-sheet induced the reorganization of silk fibroin's phase structure, which influence the dipole moment of molecular hydrogen bonds. The electrospun- silk biodegradable piezoelectric generators were fabricated with as-spun and EtOH-immersed silk mat respectively. The output of EtOH treated device was 10 times higher (up to ~7 V and 150 nA) than the device fabricated with as-spun silk mat. To specify the relationship between piezoresponse property and molecular hydrogen bonding, electrical poling was applied to both as-spun and EtOH treated piezoelectric generators. Contrary to the general case of ferroelectric polymer, electrical output of both E-SBPGs were decreased when the high voltage was applied. We defined this result as a 'quasi-piezoelectricity'. Due to the breaking of hydrogen bonds, dipole moment of hydrogen bonds is deteriorated, and it leads to decline of piezoelectric output. Finally, the EtOH-immersed E-SBPG attached to the different body parts to utilized as a self-powered motion detecting sensor.

***Keywords** : core-shell nanoparticles, flexoelectric, P(VDF-TrFE), morphotropic phase boundary (MPB), relaxor, energy harvesting, piezoelectric, biomaterials, electrospinning*

Biography:

Chang Kyu Jeong is a professor in the Major of Electronic Materials Engineering within the Division of Advanced Materials Engineering at Jeonbuk National University. He received his B.S. degree from Hanyang University and his M.S. and Ph.D. degrees from Korea Advanced Institute of Science and Technology (KAIST), respectively, in Materials Science and Engineering. After working on a postdoctoral research fellow in Institute for NanoCentury (KINC), he was employed as a postdoctoral scholar in Pennsylvania State University. From 2018 Spring, he has worked on Jeonbuk National University, Korea.

His basic research field is dielectric/piezoelectric/ferroelectric materials and devices. More recently, his research has focused on the electromechanical coupling phenomena (piezoelectricity, flexoelectricity, electrostriction, ion migration, electrostatic, triboelectrification, etc.) of biomaterials as well as bioinspired/biomimetic materials and structures. Surely, his original research topics have been also performed such as dielectric/piezoelectric/ferroelectric ceramics, polymers, and composites toward crucial applications including energy harvesting and sensor devices. Recently, he is also interested in magnetic materials as well as multilayer ceramic capacitors (MLCC).

He has contributed to the editorial board of *Nano Convergence* (IF = 10.038) and *Sensors* (IF = 3.847) since 2019. He has given invited talks in various international conferences including Materials Research Society (MRS). He is the member of both MRS, Electrochemical Society (ECS) and European Materials Research Society (E-MRS) internationally. As the Korean domestic academics, he is the committee and/or member of Korean Ceramic Society, Korean Dielectrics Society, Materials Research Society of Korea (MRS-K), Polymer Society of Korea, Korean Sensors Society, Korean Institute of Electrical and Electronic Material Engineers, and so on. He has reviewed many academic papers in various prestigious journals such as *Science, Joule, Advanced Materials, Advanced Functional Materials, Nano Energy, ACS Nano, ACS Energy Letters, Matter, Materials Today, Journal of Material Chemistry A ~ C, Chemistry of Materials,*

ACS Applied Materials & Interfaces, Composites Part B, Energy, Applied Energy, IEEE Transaction on Ferroelectrics, Applied Surface Science, Scientific Reports, Sensors and Actuators A, Advanced Materials Technologies, ACS Applied Energy Materials, Langmuir, Dalton Transactions, Ceramics International, Journal of Alloys and Compounds, Journal of Materiomics, etc.

Recent Selected Papers (Corresponding authorship)

1. "Uncertainty and irreproducibility of triboelectricity based on interface mechanochemistry" ***Physical Review Letters***, accepted

2. "Generating electricity from molecular bonding-correlated piezoresponse of biodegradable silk nanofibers", ***Nano Energy***, 2022, 103, 107844

3. "Ferroelectric Polymer Nanofibers Reminiscent of Morphotropic Phase Boundary Behavior for Improved Piezoelectric Energy Harvesting", ***Small***, 2022, 18(15), 2104472

4. "Conformably Skin-Adherent Piezoelectric Patch with Bioinspired Hierarchically-Arrayed Microsuckers Enables Physical Energy Amplification", ***ACS Energy Letters***, 2022, 7(5), 1820–1827

5. "Flexoelectric-boosted piezoelectricity of BaTiO3@SrTiO3 core-shell nanostructure determined by multiscale simulations for flexible energy harvesters" ***Nano Energy***, 2021, 89, 106469

6. "Triboelectrification: Backflow and Stuck Charges are Key" ***ACS Energy Letters***, 2021, 6(8), 2792–2799

7. "Hydrogel Ionic Diodes toward Harvesting Ultra-Low-Frequency Mechanical Energy" ***Advanced Materials***, 2021, 33(36), 2103056

8. "Laser-directed synthesis of strain-induced crumpled MoS2 structures for enhanced triboelectrification toward haptic sensors" ***Nano Energy***, 2020, 78, 105266

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For further information, please contact Dr. D.M. Shin at 3917 8061.