**Prof. Jae-Young Choi**

**WORK ADDRESS**

School of Advanced Materials Science & Engineering

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**EDUCATION**

Ph.D. in Dept. of Mater. Sci. & Eng., KAIST, Daejeon, Korea Mar. 1994 ~ Aug. 1998

• Thesis Topic:Synthesis of perovskite oxide powders under hydrothermal conditions

• Advisor: Prof. Do Kyung Kim

Ms.D. in Dept. of Inorganic Materials, KAIST, Daejeon, Korea Mar. 1992~Feb. 1994

• Thesis Topic: synthesis of monosized spherical SiC, Si3N4, and SiC/Si3N4 composite

powders from gel powders derived from sol-gel process

• Advisor: Prof. Jong Hee Kim

B.D. in Dept. of Mater. Sci. & Eng., POSTECH, Pohang, Korea Mar. 1988~Feb. 1992

**EMPLOYMENT**

- Professor, SKKU, Suwon, Korea Mar. 2015~Present

- **Vice President**, Samsung Electronics, Suwon, Korea Jan. 2011~Feb. 2015

- **Director of Graphene Center**, Samsung Electronics, Suwon, Korea Jan. 2011~Aug. 2013

- **Director of Multi-Functional Device Group**, Samsung Electronics, May. 2008~Dec. 2010

Suwon, Korea

- Project Manager, Samsung Electronics, Suwon, Korea Jan. 2002~May. 2008

- Principal Researcher, Samsung Electronics, Suwon, Korea Dec.1999~Dec. 2001

- **Postdoctoral Research Associate,** Ames lab, Iowa, US Oct. 1998~Sept.1999

• Advisor: Prof. Mufit Akins

**SELECTED ACHIEVEMENT**

◾ **HONORS & AWARDS**

- **2018 World 1% Highly Cited Researchers** **(Nov. 2018)**, Clarivate Analytics

- **Research Achievement Award** **(July 2014)**, Samsung Electronics, Development of new 2D materials for bendable mobile touch screen

- **SAMSUNG Best Paper Award** **(Oct. 2009)**, Samsung Electronics, Gold Award (1st rank in

materials division), Development of large-area graphene growth for electronic applications,

Samsung Journal(2009)

- **World Best Paper Award (Oct. 2009)**, Samsung Electronics, Best paper in SAMSUNG ELECTRONICS of the year, Large-scale pattern growth of graphene films for stretchable transparent electrodes, Nature457 706 (2009)

- **World Best Paper Award** **(July 2008)**, Samsung Electronics, Best paper in SAMSUNG ELECTRONICS of the year, Fermi level engineering of single-walled carbon nanotubes by AuCl3 doping, Journal of American Chemical Society, 130 12757 (2008):

◾ **PUBLICATIONS**

- “Direct growth of graphene on rigid and flexible substrates: progress, applications, and challenges”, ***Chemical Society Reviews*** 2017, 46, 6276-6300. **(# of Citations: 55, Impact factor: 40.443)**

- “Selective Gas Transport Through Few-Layered Graphene and Graphene oxide Membranes”, ***Science*** 2013, 342, 91-95. **(# of Citations: 1056, Impact factor: 41.845)**

- “A stamp for all substrates”, ***Nature Nanotechnology*** 2013, 8, 311-312. **(# of Citations: 40, Impact factor: 31.538)**

- “Probing graphene grain boundary with optical microscopy”, ***Nature*** 2012, 490, 235-239. **(# of Citations: 363, Impact factor: 42.778)**

- “High-mobility and low-power thin-film transistors based on multilayer MoS2 crystals”, ***Nature Communications*** 2012, 3, 1011. **(# of Citations: 1386, Impact factor: 12.121)**

- “A role for graphene in silicon-based semiconductor devices”, ***Nature*** 2011, 479, 338-344. **(# of Citations: 688, Impact factor: 42.778)**

- “Large-scale pattern growth of graphene films for stretchable transparent electrodes”, ***Nature*** 2009, 457, 706-710. **(# of Citations: 10999, Impact factor: 42.778)**

- “Carbon nanotube network structuring using two-dimensional colloidal crystal templates”, ***Advanced Materials*** 2008, 20, 457-461. **(# of Citations: 59, Impact factor: 27.398)**

- “Fermi Level Engineering of Single-Walled Carbon Nanotubes by AuCl3 Doping”, ***Journal of American Chemical Society*** 2008, 130, 12757-12761. **(# of Citations: 239, Impact factor: 14.612)**

- “Design of dispersants for the dispersion of carbon nanotubes in an organic solvent”, ***Advanced Functional Materials*** 2007, 17, 1775-1783. **(# of Citations: 95, Impact factor: 16.836)**

* **PATENT**

- **Issued the world’s first original patent of graphene growth in 2007 at Samsung** (Korean patent; Graphene sheet and process of preparing the same, 10-2009-0026568, Filed Sept. 10. 2007, US patent; Graphene sheet and process of preparing the same, US8,075,864 B2, Filed Jul. 7. 2008)

- **Ranked as #1 in the worldwide ranking of inventors by number of graphene patent** filed according to the report of Nature Materials, 11, 2-5 (2012).

**DETAIL LIST UP IN CAREER**

◾ **HONORS & AWARDS**

- **2018 Highly Cited Researchers** **(Nov. 2018),** Clarivate Analytics

- **Research Achievement Award (July 2014),** Samsung Electronics, Development of new 2D materials for bendable mobile touch screen

- **SAMSUNG Best Paper Award** **(Oct. 2009),** Samsung Electronics, Gold Award (1st rank in

materials division), Development of large-area graphene growth for electronic applications,

Samsung Journal(2009)

- **World Best Paper Award (Oct. 2009),** Samsung Electronics, Best paper in SAMSUNG ELECTRONICS of the year, Large-scale pattern growth of graphene films for stretchable transparent electrodes, Nature457 706 (2009)

- **World Best Paper Award** **(July 2008),** Samsung Electronics, Best paper in SAMSUNG ELECTRONICS of the year, Fermi level engineering of single-walled carbon nanotubes by AuCl3 doping, Journal of American Chemical Society, 130 12757 (2008):

- **SAMSUNG Best Paper Award (Dec. 2006),** Samsung Electronics, Silver Award (2nd rank in materials division), Development of nanoparticle array technology for NAND flash memory applications, Samsung Journal (2006)

- **Research Achievement Award for 20th Anniversary of SAMSUNG ELECTRONICS (Oct. 2006),** SAMSUNG ELECTRONICS, Technology transfer to Samsung Electronics, Development of selectively emitting keypad for mobile phone

- **Excellent Researcher (Jan. 2005)**, SAMSUNG ELECTRONICS, Best researcher of the

year

- **Knowledge Management Award (Dec. 2004)**, SAMSUNG ELECTRONICS, Best practice of knowledge management in project management

- **Research Achievement Award (Dec. 2004)**, SAMSUNG ELECTRONICS, Best achievement of project, Development of mass production technology of nickel nano particle for MLCC

- **Honorable Samsung Award (자랑스런 삼성인상) (Jan. 2004)**, Samsung Group, Best technology development achievement of Samsung Group, Development of nickel nano particle for MLCC

- **Customer Value Award (Oct. 2003)**, Technology transfer to Samsung Electromechanics, Synthesis technology of nickel nano particle for MLCC

**- Knowledge Management Award (Sept. 2003)**, Best practice of knowledge management

**- Breakthrough Award (July 2003)**, SAMSUNG ELECTRONICS, Best research achievement in SAMSUNG ELECTRONICS, Synthesis technology of nickel nanoparticle for MLCC

- **Breakthrough Award (Feb. 2003)**, SAMSUNG ELECTRONICS, Best research achievement in SAMSUNG ELECTRONICS, Coating technology of nickel nanoparticle for MLCC

- **Customer Value Award (Feb. 2002)**, SAMSUNG ELECTRONICS, Technology transfer to Samsung Electromechanics, Coating technology of nano particle for MLCC

- **Management Breakthrough Award (Jan. 2001)**, SAMSUNG ELECTRONICS, Best

practice of TRIZ

- **Customer Value Award (July 2000)**, SAMSUNG ELECTRONICS, Technology transfer to Samsung SDI, Dispersion technology of electrode materials of secondary battery

◾ **SPECIAL DETAILS IN CAREER (Technology transfer, Mass production etc.)**

- **Technology transfer of graphene supercapacitor to Samsung Corning (Dec. 2012)**: Graphene-based nano electrode structure was developed to overcome the limit of energy density of conventional supercapacitor and transferred to Samsung Corning

- **Establishment of Samsung Graphene Center (Jan. 2011)**: Samsung graphene center was established to find the opportunity of graphene-based new business creation in Samsung. I built the development strategy of graphene materials and device applications with Samsung branch companies (SAMSUNG ELECTRONICS, Samsung Electronics, Samsung SDI, Samsung Techwin, and Samsung Corning) and established Samsung Graphene Center to have a role of director.

- **Technology transfer of CNT-based transparent electrode to Samsung LCD (Dec. 2010)**: CNT-based transparent electrode was developed to replace expensive ITO material. CNT dispersion and doping technology to improve sheet resistance of CNT electrode was developed for an application of LCD touch panel. CNT electrode was applied to pixel electrode of LCD and demonstrated on 25” LCD touch panel with Samsung LCD. My role was project manager

- **Technology transfer of phosphor dispersion system to Samsung SDI (May, 2008)**: Dispersion of phosphor particle slurry and control of its rheological behavior for slurry injection process was developed for the PDP fabrication process. The resulting dispersion system was applied to mass production line of PDP, SDI. My role was project manager

- **Technology transfer of selectively emitting keypad of mobile phone to Samsung Electronics (Dec. 2006)**: New keypad system of mobile phone was developed where button of the keypad emits at selective position with different service mode. For the development, phosphor material emitting at blue light LED was chosen and dispersed with selective light absorption materials to make a film to be used for selectively emitting keypad. The resulting technology was demonstrated in Galaxy mobile phone and transferred to Samsung Electronics. My role was project manager.

- **Technology transfer of dispersion design methodology to Samsung Electromechanics (Dec. 2005)**: I developed diagnosis methodology of dispersion elements (particle, dispersant, binder, and solvent) and design method of optimal dispersion system from the each dispersion element. This dispersion design technology was transferred for the basic methodology for the development of MLCC of Samsung Electromechanics. My role was project manager.

- **Technology transfer of nickel nano particle mass-production technology to Samsung Electromechanics (Dec, 2004):** After successful development of nickel nano particle in lab scale, scale-up development of nickel nano particle synthesis and coating technology was conducted and demonstrated in a pilot production facility of Samsung Electromechanics. My role was project manager.

- **Technology transfer of nickel nano particle coating technology to Samsung Electromechanics (Feb. 2002):** Nickel nanoparticle for the electrode of MLCC needed the ceramic coating on the particle for the shrinkage matching between electrode (nickel) and dielectric (barium titanate) layers during sintering process. Large-scale solution coating technology of barium titanate as well as graphite on nickel particle was developed and transferred to Samsung Electromechanics. My role was project manager.

**- Technology transfer of dispersion technology of electrode materials in Li ion battery to Samsung SDI (July 2000):** Stable dispersion of electrode materials in Li ion battery was needed to produce uniform and dense electrode layer for the high energy density of the battery. Pilot-scale dispersion technology of electrode material was developed and transferred to Samsung SDI. This activity was my individual activity for the support of Li ion battery business section, SDI.

* **RESEARCH EXPERIENCES**

- **Synthesis of new 2D materials and device application (Jan.2011~Present)**

2D materials in addition to graphene are also attracting materials due to their high fracture strain, semiconducting property, and insulating property for future device application. I studied large-area uniform growth of monolayer boron nitride (insulator) by the CVD method by suppressing the formation of impurity particles with surface treatment of copper substrate and demonstrated possibility to be applied as a substrate material of the graphene device. As the second step, the growth of boron nitride on nonmetallic substrate was studied for the easy application of the material to electronic application. Growth technology of boron nitride on nano carbon layer was successfully developed by using the nano carbon as a nucleation site.

Another 2D material, molybdenum disulfide (MoS2) was studied for finding the possibility as a channel material of thin film transistor. In this study, I made monolayer molybdenum disulfide sheet by mechanical exfoliation and my coworker fabricated the thin film transistor using the molybdenum disulfide to demonstrate the possibility of low power transistor application (**Nature Communications** 3 1011 (2012)). In the present, I am studying the new 2D materials that overcome the property limits of current 2D materials (graphene, boron nitride, and molybdenum disulfide) because the current 2D material have inferior electronic properties compared with their counter competing current materials (copper as a conductor, SiO2 as a insulator, Si as a semiconductor)

• CVD growth of boron nitride

• Mechanical exfoliation of molybdenum disulfide (MoS2)

• Fabrication of MoS2 thin film transistor

• Structure design of new 2D material

- **Synthesis of graphene and device application (Jan. 2007~Present)**

I developed world’s first growth technology of large-area monolayer graphene by CVD. This work was done together with coworkers (Prof. Yong Hee Lee, SKKU and Prof. Byung Hee Hong, SNU). Original growth idea was created by me and my researchers of SAMSUNG ELECTRONICS in 2007. During the synthesis of nickel nano particle for MLCC in 2003, ceramic coating on nickel nano particle was required for the shrinkage matching between electrode (nickel) and dielectric (barium titanate) layers during sintering process. At that time, we developed large-scale coating technology of thin graphite layer on nickel particle but did not know the importance of the result. In 2007, we realized that the thin graphite layer was a few layer graphene fomed on nickel surface and could establish growth strategy from the result in SAMSUNG ELECTRONICS and conducted growth experiment with the coworkers. We issued the world’s first original patent of graphene growth in 2007 at Samsung (Korean patent: Graphene sheet and process of preparing the same, 10-2009-0026568, Filed Sept. 10. 2007, US patent: Graphene sheet and process of preparing the same, US8,075,864 B2, Filed Jul. 7. 2008) and reported world’s first paper of large-area monolayer graphene growth on nickel substrate with the coworkers in 2009 (**Nature** 457 706 (2009)). Owing to pioneering research on grpahene growth and applications, I was ranked as #1 in the worldwide ranking of inventors by number of graphene patent filed according to the report of **Nature Materials**, 11, 2-5 (2012).

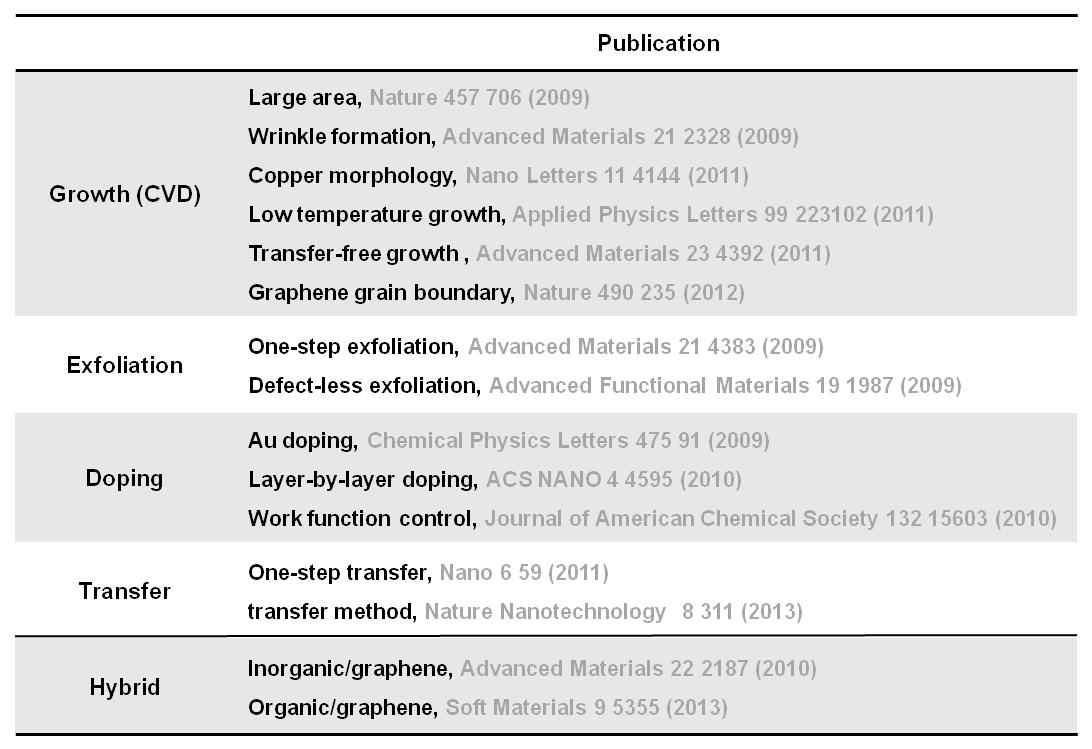
Table 1 shows the summarized list of material research activities and publications in my graphene research. I developed 2 kinds of graphene synthesis technology; CVD growth for large-area electronic applications and exfoliation method for graphene ink-based applications. In the case of CVD method, I developed CVD growth of monolayer graphene on nickel substrate where graphene should be transferred to device substrate by transfer process. As the second step, new growth concept was applied to develop transfer process-free growth method where self-assembled molecules were pyrolized and converted to graphene directly on device substrate. Regarding with exfoliation technology, one-step exfoliation method and defect-less exfoliation method were studied.

Doping technology was needed in order to improve electrical conductivity of graphene for the application to flexible transparent electrode. Various types of chemical structure were surveyed from the inventory of oxidant and reductant chemicals and could be listed according to their redox potentials. Relative difference of redox potential between dopants and graphene could control doping types (n-type or p-type) and carrier density by Fermi-level shift of graphene.

Graphene was grown on nickel or copper substrate in CVD method and should be transferred to device substrate. However the transfer process generates various types of defects such as tearing, folding, and polymer residuals. Thus clean and simple transfer process is needed. Simple one-step transfer process was developed by using polymer glue and demonstrated in 40” flexible touch panel film at Samsung Tech Fair in 2009.

New types of graphene hybrid interfaces; inorganic/grpahene and organic/graphene were also studied. Hexagonal ZnO (0001) nanowire grows epitaxially on grpahene (0001). From this hybrid structure, flexible nanogenerator could be fabricated. P3HT polymer assembles on graphene with face-to-face stacking due to the π-π interaction between π electrons in thiophene of P3HT and π electrons in benzene of graphene. This face-to-face stacking was demonstrated to improve electrical transport in OTFT structure.

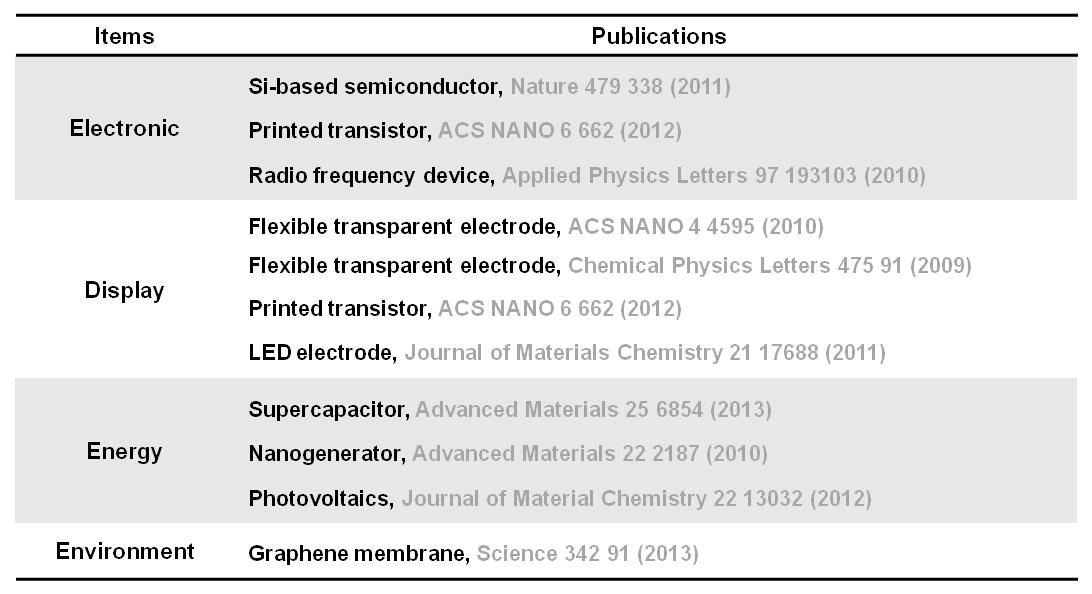
Table 1



Application of graphene to devices was studied in areas of electronic, display, energy, and environment. Table 2 shows summarized list of device research activities and publications. Large-area graphene grown by CVD process was applied to electronic, display, energy applications such as transistor, radio frequency device, flexible display, LED, flexible nanogenerator, and flexible photovoltaics. From various researches on device applications, I published prospective paper about future device application of large-area graphene (**Nature** 479 338 (2011)).

Flake-type graphene ink was studied for the application of energy and environment such as super capacitor and gas selection membrane. Well stacked grpahene film with CNT spacers produced the super capacitor having high volume as well as mass energy density. Another application of graphene flake was gas selection membrane. Interlayer gap between grpahene sheets was used as a gas separation channel in membrane structure and world’s highest hydrogen/carbon dioxide selectivity was obtained (**Science** 342 91 (2013)).

Table2



- **CNT dispersion and doping for electronic applications (Jan.2005~Dec.2006)**

I developed the dispersion and doping technology of CNT for the application of a flexible transparent electrode and a transistor in LCD, OLED, and TFT. First thing to do for the application of CNT to the devices was the preparation of CNT ink. Design of dispersant chemical structure was conducted to produce stable CNT ink solution. Structure of dispersant is composed of head group and tail group. The head group was designed to be strongly absorbed to CNT surface and the tail group was designed to be soluble and repulsive in the solvent. From this design strategy, Fluoro-based dispersant for aqueous system and thiophene-based dispersant for nonaqueous system were developed.

Doping technology was developed in order to improve sheet resistance of CNT transparent electrode for flexible display. Lewis acid/base concept used for the design of dispersant structure was firstly introduced to design dopant materials for CNT. Relative differences in redox potential between dopant materials and CNTs determined the types of dopant (p-type or n-type) and carrier concentration of CNT. In the case of p-dopant, 4 types of new chemical structure such as inorganic acid, halogen oxoanion, gold trichloride, and aromatic solvent were developed. For the development of n-type dopant, chemicals to donate electrons to CNT were studied and 2 kinds of new n-dopant structure such as neutral viologen and nicotineamide adenine dinucleotide (NADH) were developed. By using the developed new dispersants and dopants, electro-optical properties of CNT transparent electrodes were optimized to be world best value of 95 ohm/sq @ 90%.

• Design of dispersant structure for CNT ink

• Design of p-dopant structure for CNT doping

• Design of n-dopant structure for CNT doping

• CNT-based flexible transparent electrode

- **Dispersion technology and its device application (Jan. 2005~Dec. 2006)**

Nano materials have important roles in many device applications. In order to effectively apply nano materials to device, the nano materials should be properly arrayed or coated in the device structure. For proper array or coating of nano materials in device structure, dispersion technology to produce stable ink solution should be seriously developed. In this study, I focused on the design of dispersant structure to optimize dispersion properties of nano materials and established the design methodology of dispersant chemical structure. Structure of dispersant is composed of head group and tail group. Head group was designed to strongly absorbed to particle surface by strong Lewis acid/base reaction. Tail group was designed to be hindered each other by miscibility and repulsive action in solvent. Using the developed design methodology of dispersant structure, various nano materials were applied to practical devices in Samsung branch companies; dielectric particles in binder for PDP and phosphor particles in binder for PDP, Quantum dot in epoxy for color filter of LCD, ZrO2 particle in Si-polymer for high refractive index encapsulation material of LED, and emitting particles for selective emitting keypad of cell phone.

• Establishment of design methodology for dispersant structure

• Dispersion of phosphor particle in binder for PDP

• Dispersion of phosphor particle in binder for PDP

• Dispersion of quantum dot in epoxy for color filter of LCD

• Dispersion of ZrO2 in Si-polymer for high refractive index encapsulation for LED

• Dispersion of emitting material for selective emitting key pad for cell phone

- **Synthesis and coating of nickel nano particle for MLCC application (Dec. 1999~Dec. 2004)**

80 nm of nickel nano particle was required for high capacitance and down sizing of multi layer ceramic capacitor (MLCC) where dielectric layer (barium titanate) and metal layer (nickel) staked. I successfully developed the synthesis technology of nickel nano particles by hydrazine solution method and scaled-up the method for pilot line production. Another technology required for nickel nano particle of MLCC is ceramic coating on nickel nano particle for the shrinkage matching between electrode (nickel) and dielectric (barium titinate) layers during sintering process. Large-scale solution coating method of barium titinate as well as graphite on nickel particle was developed and transferred to Samsung Electromechanics. My role was project manager. Owing to the successful commercial development of nickel nano particle, I got “Honorable Samsung Award” (Jan. 2004), biggest prize in Samsung Group. In the technological point of view, graphite coating on nickel particle, which was realized to be few layer graphene on nickel surface, was a seed technology for world’s first growth of large-area graphene on nickel substrate in 2007.

• Synthesis of 80 nickel nano particle by solution method

• Coating of barium titanate on nickel particle

• Coating of few layer graphene on nickel particle

• Scale-up of synthesis process for the mass production line

- **Synthesis of monodisperse ceramic particle (Mar. 1992~Aug.1998)**

Monodisperse ceramic nano particles are required to make dense, uniform, and thus high quality ceramics through sintering process. Synthesis methods of mono disperse particle were studied for the structural ceramics and electro ceramics. For the structural ceramic particle (SiC and Si3N4), monodisperse precursor particles were prepared by sol-gel method and converted to monodisperse SiC, Si3N4, and a mixture of SiC and Si3N4 particles by pyrolysis and heat-treatment process. In the case of electoceramic particle (perovskite compositions), precursor gel particle was synthesized by alcohol-aqueous mixture solution method and converted to monodisperse perovskite particles by hydrothermal method. The demonstrated compositions were BaTiO3, SrTiO3, PbTiO3, PbZrO3, Pb(Z 0.5,Ti0.5)O3, and Ba(Zr0.5,Ti0.5)O3.

• Synthesis of monodisperse precursor particle by sol-gel method

• Pyrolysis and heat-treatment to convert the precursor to SiC and Si3N4 particles

• Synthesis of monodisperse precursor particle by alcohol-aqueous mixture method

• Hydrthemal transformation to convert the precursor to perovskite particle

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| **RECORDS of ACADEMIC RESEARCHES**  **◾ Summary**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Journal | | | | | |  | Domestic | | International | | |  | SCI | Non SCI | SCI | Non SCI | |  | 1 | 3 | 152 | 0 | | Total | 156 | | | | | NSC | **# of papers about nanomaterials and device applications: 156**  **# of papers about carbon-based (CNT, Graphene) materials: 66**  ◾ ***Chemical Society Reviews*** 2017, 46, 6276-6300. **(# of Citations: 55, Impact factor: 40.443)**  ◾ ***Science*** 2013, 342, 91-95. **(# of Citations: 1056, Impact factor: 41.845)**  ◾ ***Nature Nanotechnology*** 2013, 8, 311-312. **(# of Citations: 40, Impact factor: 31.538)**  ◾ ***Nature*** 2012, 490, 235-239. **(# of Citations: 363, Impact factor: 42.778)**  ◾ ***Nature Communications*** 2012, 3, 1011. **(# of Citations: 1386, Impact factor: 12.121)**  ◾ ***Nature*** 2011, 479, 338-344. **(# of Citations: 688, Impact factor: 42.778)**  ◾ ***Nature*** 2009, 457, 706-710. **(# of Citations: 10999, Impact factor: 42.778)** | | | |   **◾ International Journal Paper (Corresponding authors are underlined)**  156. K. H. Choi, J. Jeon, S. Oh, S. Chae, B. J. Jeong, S. O. Yoon, C. Woo, X. Dong, A. Ghulam, C. Lim, M. Seo, T. Y. Kim, Z. Liu, C. Wang, A. Junaid, J.-H, Lee, H. K. Yu, and **J.-Y. Choi**, Family of low dimensional materials with ternary elements Ta2NixSey: Growth strategy for Ta2NiSe5 and Ta2NiSe7, **Journal of Alloys and Compounds**, 867, 159054, (2021)  155. K. H. Choi, S. Oh, S. Chae, B. J. Jeong, B. J. Kim, J. Jeon, S. H. Lee, S. O. Yoon, C. Woo, X. Dong, A. Ghulam, C. Lim, Z. Liu, C. Wang, A. Junaid, J.-H, Lee, H. K. Yu, and **J.-Y. Choi**, Transition metal thiophosphates Nb4P2S21: New kind of 2D materials for multi-functional sensors, **Journal of Alloys and Compounds**, 864, 158811, (2021)  154. W.-G. Lee, D. Sung, J. Lee, Y. K. Chung, B. J. Kim, K. H. Choi, S. H. Lee, B. J. Jeong, **J.-Y. Choi**, and J. Huh, Tuning the electronic properties of highly anisotropic 2D dangling-bond-free sheets from 1D V2Se9 chain structures, **Nanotechnology**, 32, 9, (2020)  153. S. J. Kim, **J. Y. Choi**, H. Moon, H. R. Choi, and J. C. Koo, Biomometic Hybrid Tactile Sensor with Ridged Structure That Mimics Human Fingerprints to Acquire Surface Texture Information, **Sensors and Materials**, 32, 3787, (2020)  152. C. McKay, C. Park, J. Chang, M. Brackbill, **J.-Y. Choi**, J. H. Lee, and S. H. Kim. Systematic Review and Meta-analysis of Pharmacist-Leg Transitions of Care Services on the 30-Day All-Cause Readmission Rate of Patients with Congestive Heart Failure, **Clinical Drug Investigation**, 39, 703, (2019)  151. I. J. Choi, B. J. Kim, S. H. Lee, B. J. Jeong, T. Nasir, Y. S. Cho, N. Kim, J.-H. Lee, H. K. Yu, and **J.-Y. Choi**, Fabrication of a room-temperature NO2 gas sensor using morphology controlled CVD-grown tellurium nanostructures, **Sensors and Actuators: B. Chemical**, 333, 128891, (2021)  150. T. Nasir, B. J. Kim, M. Hassnain, S. H. Lee, B. J. Jeong, I. J. Choi, Y. Kim, H. K. Yu, and **J.-Y. Choi**, Plasticized Polystyrene by Addition of –Diene Based Molecules for Defect-Less CVD Graphene Transfer, **polymers**, 12, 1839, (2020)  149. Y. Kim, S. H. Lee, S. Jeong, B. J. Kim, **J.-Y. Choi**, and H. K. Yu, Conversion of WO3 thin films into self-crosllinked nanorods for large-scale ultraviolet detection, **RSC Advances** 10, 14147, (2020)  148. J. W. Lee, W.-Y. Im, S. Y. Song, **J.-Y. Choi**, and S. J. Kim, Analysis of early failure rate and its risk factor with 2157 total ankle replacements, **Scientific Reports**, 11, 1901, (2021)  147. S. Chae, S. Oh, K. H. Choi, J. W. Lee, J. Jeon, Z. Liu, C. Wang, C. Woo, L. Shi, J. Kang, S. Y. Song, S. J. Kim, J. H. Lee, H. K. Yu, and **J.-Y. Choi**, Aqueous dispersion of 1D van der Waals Mo6S3I6 crystal using biocompatible tri-block copolymer, **Ceramics International**, 47, 11935, (2021)  146. S. Chae, S. Oh, K. H. Choi, J. W. Lee, J. Jeon, Z. Liu, C. Wang, C. Lim, X. Dong, C. Woo, A. Ghulam, L. Shi, J. Kang, S. J. Kim, S. Y. Song, J. 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| Patent | | |
|  | Domestic | International |
|  | 194 | 219 |
| Total | 413 | |
| Comments | **# of papers about nanomaterials and device applications: 413**  **# of papers about carbon-based (CNT, Graphene) materials: 124**   1. **Graphene**   ◾ Issued the world’s first original patent of graphene growth in 2007 at Samsung (Korean patent; Graphene sheet and process of preparing the same, 10-2009-0026568, Filed Sept. 10. 2007, US patent; Graphene sheet and process of preparing the same, US8,075,864 B2, Filed Jul. 7. 2008)  ◾ Ranked as #1 in the worldwide ranking of inventors by number of graphene patent filed according to the report of **Nature Materials**, 11, 2-5 (2012).  ◾ **Jae Young Choi**, Hyeon Jin Shin, Seon Mi Yoon, Jae Yong Han, Single crystalline graphene sheet and process of preparing the same, China Application 200810169624.0  ◾ **Jae Young Choi**, Graphene sheet comprising intercalation compound and process of preparing the same, US Application 707,213  ◾ **Jae Young Choi**, Keun Soo Kim, Byung Hee Hong, Method for removing a carbonization catalyst from a graphene sheet and method for transferring the graphene sheet, EU Application 09167413.5   1. **CNT**   ◾ **Jae Young Choi**, Seong Jae Choi, Hyeon Jin Shin, Seon Mi Yoon, Dispersan for carbon nanotubes and corbon nanotube composition comprising the same, US Application 829,620  ◾ **Jae Young Choi**, Chan Ho Pak, Seok Gwang Doo, Jeong Hee Lee, Young Hee Lee, Kay Hyeok An, Sung Jin Kim, Carbon nanotube, support catalyst, method of preparing the support catalyst and a fuel cell comprising the support catalyst, US Application 897,144  ◾ **Jae Young Choi**, Hyeon Jin Shin, Seon Mi Yoon, Bo Ram Kang, Young Hee Lee, Un Jung Kim, Carbon nanotube n-doping material, carbon nanotube n-doping method and device using the same, US Application 350,558  ◾ **Jae Young Choi**, Woo Jong Yu, Un Jeong Kim, Young Hee Lee, Method of doping transistor comprising carbon nanotube, method of controlling position of doping ion, and transistors using the same, US Application 232,958  ◾ **Jae Young Choi**, Hyeon Jin Shin, Seon Mi Yoon, Carbon nano-tube(CNT) light emitting device and method of manufacturing the same, US Application 961,577 | |

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