JAEHYUN LEE

Date of Birth : December 10, 1985
Major : Organic Chemistry
Position : Postdoctoral Researcher, Institute for Chemical Research, Kyoto University
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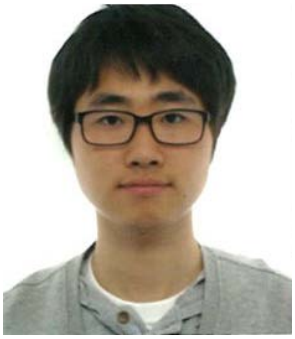

EDUCATION

Mar. 2016 – Present : Postdoctoral Fellow
- Kyoto University
- Institute for Chemical Research
- Prof. Atsushi Wakamiya

Sep. 2015 – Feb. 2016 : Researcher Scholar
- Kyoto University
- Institute for Chemical Research
- Prof. Atsushi Wakamiya

Mar. 2013 – Feb. 2016 : Doctor of Philosophy
- Catholic University of Korea
- Department of Chemistry
- Advisor : Prof. Jongwook Park
- Thesis Title : A Study on Organic Functional Materials Based on Novel Core Groups
- GPA: 4.45/4.5

Feb. 2013 : Master of Science
- Catholic University of Korea
- Department of Chemistry
- Advisor : Prof. Jongwook Park
- Thesis Title : A Study on Organic Light Emitting Diode (OLED) Property of Various Organic Semiconducting Compounds
- GPA: 4.45/4.5

Feb. 2011 : Bachelor of Science (w/military service 2 years)
- Catholic University of Korea
- Double Major, Department of Physics and Department of Chemistry
- GPA: 4.10/4.5 (Summa cum laude from Department of Physics)

JAEHYUN LEE

AWARDS

1. **Sep. 2016** : Japan Society for Promotion of Sciences (JSPS) Fellowship
2. **May 2015** : Excellent Presentation Award of The Korean Society of Industrial and Engineering Chemistry (Spring Meeting)
3. **Feb. 2015** : 12th Scholarship Award of Catholic University of Korea
4. **Nov. 2014** : Excellent Presentation Award of The Korean Society of Industrial and Engineering Chemistry (Fall Meeting)
5. **Feb. 2011** : Summa cum laude from Department of Physics, Catholic University of Korea

PUBLICATIONS

1. Jaehyun Lee, Hyocheol Jung, Hwangyu Shin, Joonghan Kim, Daisuke Yokoyama, Hidetaka Nishimura, Atsushi Wakamiya, and Jongwook Park, "Excimer Emission Based on Control of Molecular Structure and Intermolecular Interactions", *J. Mater. Chem. C* 4, 2784-2792, 2016 (Back Cover)
2. Jaehyun Lee, Hwangyu Shin and Jongwook Park, "Solution Processable White Organic Light-emitting Diodes Using New Blue Host Material Including Substituent Group", *J. Nanosci. Nanotechnol.* 16, 2101-2104, 2016
3. Jaehyun Lee, Beomjin Kim, Jongwook Park, "Excimer Formation Promoted by Steric Hindrance in Dual Core Chromophore for OLED Emitters", *J. Nanosci. Nanotechnol.* 16, 8854-8857, 2016
4. Mina Jung, Jaehyun Lee, Hyocheol Jung, and Jongwook Park, "Synthesis and Physical Properties of New Pyrene Derivative with Bulky Side Groups for Blue Emission", *J. Nanosci. Nanotechnol.* 16, 8796-8799, 2016
5. Hwangyu Shin, Hyocheol Jung, Beomjin Kim, Jaehyun Lee, Jiwon Moon, Joonghan Kim, and Jongwook Park, "Highly Efficient Emitters of Ultra-Deep-Blue Light Made from Chrysene Chromophores", *J. Mater. Chem. C* 4, 3833-3842, 2016
6. Seungho Kim, Beomjin Kim, Jaehyun Lee, Hwangyu Shin, Young-Il Park, Jongwook Park, "Design of Fluorescent Blue Light-Emitting Materials Based on Analyses of Chemical Structures and Their Effects", *Materials Science and Engineering R.* 99, 1-22, 2016
7. Garam Yang, Hayoon Lee, Hwangyu Shin, Jaehyun Lee, Jongwook Park, "Synthesis and Luminescent Properties of Poly (9-(3-Vinyl-phenyl)-phenanthrene)", *J. Nanosci. Nanotechnol.* 16, 1748-1751, 2016

8. **Jaehyun Lee** and Jongwook Park, "Synthesis and Electroluminescence of Novel Pyrene-Fused Chromophores", *Org. Lett.* 17, 3960-3963, 2015
9. **Jaehyun Lee**, Seungho Kim, Jee-Hwan Kim, and Jongwook Park, "A New Anthracene Derivative Containing t-Butyl Group for Solution Process OLEDs", *J. Nanosci. Nanotechnol.* 15, 8285-8288, 2015
10. **Jaehyun Lee**, Seungho Kim and Jongwook Park, "New Blue-Light Emitting Materials in White OLED Based on Solution and Vacuum Methods", *Mol. Cryst. Liq. Cryst.* 618, 74-79, 2015
11. **Jaehyun Lee**, Yao Liang, Hwangyu Shin, Yuguang Ma and Jongwook Park, "White OLED Using Highly Efficient Green Dopant via Solution Process", *Mol. Cryst. Liq. Cryst.* 621, 26-30, 2015
12. Sunmi Lee, Seungho Kim, **Jaehyun Lee**, Beomjin Kim, and Jongwook Park, "New Approach Way Using Substituent Group at Core Chromophore for Solution Process Blue Emitter", *J. Nanosci. Nanotechnol.* 15, 1850-1854, 2015
13. Sunmi Lee, Hwangyu Shin, Beom-Soo Michael Park, **Jaehyun Lee**, and Jongwook Park, "Synthesis and Luminescent Property of Poly(9-(3-vinyl-phenyl)-anthracene)", *J. Nanosci. Nanotechnol.* 15, 5438-5441, 2015
14. Seungho Kim, Beomjin Kim, **Jaehyun Lee**, Young-Jun Yu, and Jongwook Park, "Highly Efficient White Organic Light Emitting Diodes Using New Blue Fluorescence Emitter", *J. Nanosci. Nanotechnol.* 15, 5442-5445, 2015
15. Hwangyu Shin, Hyeonmi Kang, Jong-Hyung Kim, Yun-Fan Wang, Hayoon Lee, Garam Yang, **Jaehyun Lee**, Beomjin Kim, Kwang-Yol Kay and Jongwook Park, "Synthesis and Electroluminescence Property of New Hexaphenyl Benzene Derivatives Including Emitting Materials for OLED", *Mol. Cryst. Liq. Cryst.* 618, 38-46, 2015
16. Seungho Kim, Kyung Jin Lee, **Jaehyun Lee**, Hwangyu Shin, Kwang-Yol Kay, and Jongwook Park, "New Amino Methyl Coumarin Derivative for OLED Blue Emitter", *Mol. Cryst. Liq. Cryst.* 620, 139-146, 2015
17. Hyocheol Jeong, Hwangyu Shin, **Jaehyun Lee**, Beomjin Kim, Young-Il Park, Kyoung Soo Yook, Byeong-Kwan An, Jongwook Park, "Recent Progress in the Use of Fluorescent and Phosphorescent Organic Compounds for OLED Lighting", *Journal of Photonics for Energy* 5, 057608, 2015
18. Hwangyu Shin, Seungho Kim, **Jaehyun Lee**, Hayoon Lee, Hyocheol Jeong, Jongwook Park, "Research Trends in Organic Light Emitting Diode", *Appl. Chem. Eng.* 26, 381, 2015
19. **Jaehyun Lee**, Beomjin Kim, Ji Eon Kwon, Joonghan Kim, Daisuke Yokoyama, Katsuaki Suzuki, Hidetaka Nishimura, Atsushi Wakamiya, Soo Young Park and Jongwook Park, "Excimer formation in organic emitter films associated with a molecular orientation promoted by steric hindrance", *Chem. Commun.* 50, 14145-14148, 2014

20. **Jaehyun Lee**, Beomjin Kim, Youngil Park, Seungho Kim, and Jongwook Park, "Fluorine Effects in New Indenofluorenedione Derivatives for Electron Transporting Layer in OLED Devices", *J. Nanosci. Nanotechnol.* 14, 6431-6434, 2014
21. **Jaehyun Lee**, Soo-Kang Kim, Hwangyu Shin, and Jongwook Park, "Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes", *Mol. Cryst. Liq. Cryst.* 599, 139-144, 2014
22. Hayoon Lee, Beomjin Kim, Seungho Kim, Joonghan Kim, **Jaehyun Lee**, Hwangyu Shin, Ji-Hoon Lee and Jongwook Park, "Synthesis and electroluminescence properties of highly efficient dual core chromophores with side groups for blue emission", *J. Mater. Chem. C* 2, 4737-4747, 2014
23. Beomjin Kim, **Jaehyun Lee**, Youngil Park, Changjun Lee, and Jong Wook Park, "Highly Efficient New Hole Injection Materials for OLEDs Base on Phenothiazine Derivatives", *J. Nanosci. Nanotechnol.* 14, 6404-6408, 2014
24. Seungho Kim, Beomjin Kim, **Jaehyun Lee**, and Jongwook Park, "A Comparative Study on the Optical Properties of Single-Layered White OLED Based on Multi-Host, Dopant System", *Mol. Cryst. Liq. Cryst.* 597, 107-113, 2014
25. **Jaehyun Lee**, Se Hun Kim, Woosung Lee, Jiwon Lee, Byeong-Kwan An, Se Young Oh, Jae Pil Kim, and Jongwook Park, "Electrochemical and Optical Characterization of Cobalt, Copper and Zinc Phthalocyanine Complexes", *J. Nanosci. Nanotechnol.* 13, 4338-4341, 2013
26. Beomjin Kim, Youngil Park, **Jaehyun Lee**, Daisuke Yokoyama, Ji-Hoon Lee, Junji Kido and Jongwook Park, "Synthesis and Electroluminescence Properties of Highly Efficient Blue Fluorescence Emitters Using Dual Core Chromophores", *J. Mater. Chem. C* 1, 432-440, 2013 (Back Cover)
27. Seungho Kim, Kyung Jin Lee, Beomjin Kim, **Jaehyun Lee**, Kwang-Yol Kay and Jongwook Park, "New Ambipolar Blue Emitting Materials Based on Amino Coumarin Derivatives with High Efficiency for OLEDs", *J. Nanosci. Nanotechnol.* 13, 8020-8024, 2013
28. Hwangyu Shin, Yun-Fan Wang, Jong-Hyung Kim, **Jaehyun Lee**, Kwang-Yol Kay, Jongwook Park, "Synthesis and Electroluminescence Property of New Hexaphenyl Benzene Derivatives Including Amine Group for Blue Emitters", *Nanoscale Research Letters* 8, 421-429, 2013
29. Youngil Park, Beomjin Kim, Changjun Lee, **Jaehyun Lee**, Ji-Hoon Lee and Jongwook Park, "High Efficiency New Hole Injection Materials for Organic Light Emitting Diodes Based on Dimeric Phenothiazine and Phenoxazine Moiety Derivatives", *J. Nanosci. Nanotechnol.* 12, 4356-4360, 2012
30. Young-Il Park, Joong Suk Lee, Beom Joon Kim, Beomjin Kim, **Jaehyun Lee**, Do Hwan Kim, Se-Young Oh, Jeong Ho Cho, Jong-Wook Park,

"High-Performance Stable n-Type Indenofluorenedione Field-Effect Transistors", *Chem. Mater.* 23, 4038-4044, 2011

31. **Jaehyun Lee**, Seungho Kim, Hyocheol Jung, and Jongwook Park, "New Anthracene Derivative Including t-Butyl Group as Blue Emitter in Solution Process OLED", *J. Nanosci. Nanotechnol.* in press
32. Seungho Kim, **Jaehyun Lee**, Hayoon Lee, Hyocheol Jeong, Youngil Park, and Jongwook Park, "Synthesis and Electroluminescent Properties of New Polyindenopyrazine Derivatives for OLEDs", *J. Nanosci. Nanotechnol.* in press

PATENTS

1. Atsushi Wakamiya, Hidetaka Nishimura, Naoki Maruyama, Anesh Gopal, **Jaehyun Lee**, Alwani I. Rafieh, Yasujiro Murata, "Perovskite Solar Cell for Hole Transporting Material", Japan Patent, Submission No. JP 2016-013870, 2016
2. Jongwook Park, **Jaehyun Lee**, Beomjin Kim, "Triple or Multiple Core-based Compound for Organoelectroluminescent Device and Organoelectroluminescent Device Employing the Same", Korea Patent, Submission No. 10-2013-0004064, 2013, Registration No. 10-1554693, 2015
3. Jongwook Park, **Jaehyun Lee**, "Organic Compound Including Fused Core Moiety, Organic Optoelectric Device Including the Same and Display" WO 2016/039510 A1, PCT/KR2015/000395, 2015
4. Jongwook Park, **Jaehyun Lee**, "Organic Compound Including Fused Core Moiety, Organic Optoelectric Device Including the Same and Display", Korea Patent, Submission No. 10-2014-0121222, 2014
5. Jongwook Park, Garam Yang, Sunmi Lee, Hayoon Lee, Hwangyu Shin, Beom-Soo Michael Park, **Jaehyun Lee**, "Polymer for Organic Optoelectronic Device and Organic Optoelectronic Device Including the Same", Korea Patent, Submission No. 10-2014-0150561, 2014

PRESENTATIONS

- International Conference -

1. **Jaehyun Lee**, Hayoon Lee, Hyocheol Jung, Minjin Jo, and Jongwook Park, "Electroluminescence Properties of Novel Pyrene-Fused Chromophores", SID, 2016, P-156
2. **Jaehyun Lee**, Seungho Kim, Hwangyu Shin, Hayoon Lee, Hyocheol Jung and Jongwook Park, "Novel core chromophores based on specific chemical structures and their effects", Pacifichem, 2015, MTLS 525

3. Jaehyun Lee, Seungho Kim, Hwangyu shin, Hayoon Lee, Hyocheol Jung, and Jongwook Park, “Excimer formation in organic emitter films associated with a molecular orientation promoted by steric hinderance”, SID, 2015, P.124
4. Jaehyun Lee, Beomjin Kim, and Jongwook Park, “Excimer Formation Promoted by Steric Hindrance in Dual Core Chromophore for OLED Emitters”, ME&D, 2015, NS-28
5. Mina Jung, Jaehyun Lee, Hyocheol Jung, and Jongwook Park, “Synthesis and Physical Properties of New Pyrene Derivative with Bulky Side Groups for Blue Emission”, ME&D, 2015, NS-36
6. Jaehyun Lee, Seungho Kim, Hyocheol Jeong, and Jongwook Park, “New Anthracene Derivative Including t-Butyl Group as Blue Emitter in Solution Process OLED”, Nano Korea, 2015, P1503_430
7. Seungho Kim, Hwangyu Shin, Jaehyun Lee, Hyocheol Jeong, Youngil Park, and Jongwook Park, “Synthesis and Electroluminescent Properties of New Polyindenopyrazine Derivatives for OLEDs”, Nano Korea, 2015, P1501_435
8. Jongwook Park, Hayoon Lee, Beomjin Kim, Seungho Kim, Joonghan Kim, Jaehyun Lee, Hwangyu Shin, “Synthesis and electroluminescence properties of highly efficient dual core chromophores with side groups for blue emission”, SPIE, 2014, 9183-8, Invited Paper
9. Beomjin Kim, Young-Il Park, Jaehyun Lee, Ji-Hoon Lee, Jongwook Park, and Hsing-Lin Wang, “Synthesis and electroluminescence properties of highly efficient dual core chromophores”, ACS, 2014, ORGN 170
10. Hwangyu Shin, Hayoon Lee, Jaehyun Lee, Seungho Kim, Kwang-Yol Kay, and Jongwook Park, “Synthesis and Electroluminescence Property of New Hexaphenyl Benzene Derivatives Including Amine Group for OLED”, ICEL, 2014, P-2.102
11. Jongwook Park, Jaehyun Lee, Seungho Kim, Hwangyu Shin, Hayoon Lee, “New blue emitting materials in white OLED using hybrid process based on solution and vacuum methods”, ENGE, 2014, S13-0573
12. Jaehyun Lee, Beomjin Kim, Youngil Park, Seungho Kim, and Jongwook Park, “New Indenofluorenedione Derivatives Including Fluorine for Electron Transporting Layer”, IMID, 2014, P2-113
13. Seungho Kim, Beomjin Kim, Youngil Park, Jaehyun Lee, and Jongwook Park, “Synthesis and Electroluminescent Properties of New Polyindenopyrazine Derivatives for OLEDs”, ME&D, 2014, PP-16-36
14. Garam Yang, Hayoon Lee, Hwangyu Shin, Jaehyun Lee, and Jongwook Park, “Synthesis and Luminescent Properties of Poly(9-(3-Vinyl-phenyl)-phenanthrene)”, ME&D, 2014, PP-16-31

15. **Jaehyun Lee**, Seungho Kim, Sookang Kim, and Jongwook Park, "A New Anthracene Derivative Containing t-Butyl Group for Solution Process OLEDs", Nano Korea, 2014, TS03
16. **Jaehyun Lee**, Seungho Kim, and Jongwook Park, "New Blue Emitting Materials in White OLED Based on Solution and Vacuum Methods", ADMD, 2014, PL03, Invited Paper
17. **Jaehyun Lee**, Yao Liang, Hwangyu Shin, Yuguang Ma, and Jongwook Park, "White OLEDs Using Highly Efficient Green Dopant in Solution Process", KJF, 2014, PB054
18. Garam Yang, Yoojin Lee, Hayoon Lee, **Jaehyun Lee**, and Jongwook Park, "Synthesis and Luminescent Properties of Poly(9-(3-vinyl-phenyl)-pyrene)", KJF, 2014, PB057
19. **Jaehyun Lee**, Hwangyu Shin, and Jongwook Park, "White Organic Light-Emitting Diodes Using New Blue Host Material Including Substituent Group Based on Solution Process", ICNST, 2014, P1-7
20. Garam Yang, Hayoon Lee, Hwangyu Shin, **Jaehyun Lee**, and Jongwook Park, "Synthesis and Luminescent Properties of Poly(9-(3-vinyl-phenyl)-phenanthrene)", ICNST, 2014, NM3_1041
21. Beomjin Kim, Seungho Kim, **Jaehyun Lee**, Hwangyu Shin, Daisuke Yokoyama, Junji Kido, and Jongwook Park, "Highly Efficient New Emitting Materials Based on Daul Core Concepts for Blue Fluorescence OLEDs", SPIE, 2013, 8829-3
22. Beomjin Kim, Seungho Kim, **Jaehyun Lee**, Hwangyu Shin, and Jongwook Park, "New Blue Emitter System for OLEDs", MRS Spring Meeting, 2013, JJ13.79
23. Jongwook Park, Beomjin Kim, Seungho Kim, Hwangyu Shin, **Jaehyun Lee**, "Novel Blue Fluorescence Emitters Using Dual Core Chromophores", MRS Fall Meeting, 2013, L9.24
24. Beomjin Kim, Seungho Kim, **Jaehyun Lee**, Hwangyu Shin, Daisuke Yokoyama, Junji Kido, and Jongwook Park, "Synthesis and Eletroluminescence Properties of Highly Efficient Blue Fluorescence Emitters Using Dual Core Chromophores", SID, 2013, P-144
25. Beomjin Kim, Youngil Park, Seungho Kim, **Jaehyun Lee**, Hwangyu Shin, and Jongwook Park, "A New Approach Way for White OLED Based on Single Emitting Layer and Large Stokes Shift", ECME, 2013, P-91
26. Seungho Kim, Beomjin Kim, **Jaehyun Lee**, and Jongwook Park, "Highly Efficient Two Color White OLEDs Using High Efficient Blue Emitter Based on Dual Core Chromophores", ME&D, 2013, PP-15-44
27. **Jaehyun Lee**, Yao Liang, Beomjin Kim, Seokwoo Kang, Yuguang Ma, and Jongwook Park, "White OLED Using Highly Efficient Green Dopant via Solution Process", ADMD, 2013, PII-12

28. **Jaehyun Lee**, Soo-Kang Kim, Hwangyu Shin, and Jongwook Park, "Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes", KJF, 2013, P-227
29. Seungho Kim, Beomjin Kim, **Jaehyun Lee**, and Jongwook Park, "Highly Efficient White OLEDs Using New Blue Fluorescence Emitter", ICNST, 2013, P1-16
30. Sunmi Lee, Beom-Soo Michael Park, **Jaehyun Lee**, and Jongwook Park, "Synthesis and Luminescent Property of Poly (9-(3-Vinyl-phenyl)-anthracene)", ICNST, 2013, P1-09
31. Youngil Park, Joong Suk Lee, Beom Joon Kim, Beomjin Kim, **Jaehyun Lee**, Do Hwan Kim, Se-Young Oh, Cheng-Yu Kuo, Hsing-Lin Wang, Jeong Ho Cho, and Jongwook Park, "High-performance Stable n-Type Indenofluorenedione Field-effect Transistors", MRS Spring Meeting, 2012, J6.3
32. Beomjin Kim, Youngil Park, **Jaehyun Lee**, Daisuke Yokoyama, Ji-Hoon Lee, Junji Kido, and Jongwook Park, "Highly Efficient New Blue Emitting Materials Based on Dual Core-Side Concepts for Fluorescence OLEDs", A-COE, 2012, Invited Paper
33. **Jaehyun Lee**, Beomjin Kim, Youngil Park, Seungho Kim, and Jongwook Park, "Fluorine Effect Using New Indenofluorenedione Derivatives for Electron Transporting Layer in OLED Devices", ME&D, 2012, MO-16
34. Seungho Kim, Kyung Jin Lee, Beomjin Kim, **Jaehyun Lee**, Kwang-Yol Kay, and Jongwook Park, "New Ambipolar Blue Emitting Materials Based on Amino Coumarin Derivatives with High Efficiency for OLEDs", Nano Korea, 2012, P1201_110
35. Beomjin Kim, **Jaehyun Lee**, Youngil Park, and Jongwook Park, "Highly Efficient New Hole Injection Materials for OLEDs Based on Dimeric Phenothiazine", ME&D, 2011, MO-30
36. **Jaehyun Lee**, Se Hun Kim, Woosung Lee, Jiwon Lee, Jae Pil Kim, and Jongwook Park, "New Metal Phthalocyanine Derivatives for Super-Capacitors", ICNST, 2011, ND-093
37. Hun-Seob Jeong, **Jaehyun Lee**, Jongwook park, Min-Chul Chung, and Ji-Hoon Lee, "A New Green Emitting Polyfluorene Copolymer with Benzo[c][1,2,5]thiadiazole Derivatives : Its Enhanced Color Purity using m-linked phenylenes", ICNST, 2011, ND-065
38. Dae-Hee Lee, Nam-Jin Lee, **Jaehyun Lee**, Jongwook Park, Min-Chul Chung, Sung-Ryong Kim, and Ji-Hoon Lee, "Molecular Design and Synthesis of New Asymmetric Hole Transporting Materials Based on Phenyloaphthalene Core for OLEDs", ICNST, 2011, ND-066

- National Conference -

1. **Jaehyun Lee**, Mina Jung, 尾崎雅司, 嶋崎愛, ゴパル アネシュ, 西村秀隆, 若宮淳志, 村田靖次郎, **“アズレンを核構造に用いた正孔輸送性材料の開発：ペロブスカイト太陽電池への応用とアルコキシ置換基の鎖長の効果”, 第 27 回基礎有機化学討論会**, 2016, 1P100
2. Anesh Gopal, **Jaehyun Lee**, Mina Jung, 尾崎雅司, Naoki Maruyama, 嶋崎 愛, 若宮淳志, 村田靖次郎, “酸素架橋トリアリールアミン骨格を用いたポリマー材料の開発：ペロブスカイト太陽電池への応用”, 第 27 回基礎有機化学討論会, 2016, 1P067
3. Anesh Gopal, Hidetaka Nishimura, Naoki Maruyama, Jaehyun Lee, Ai Shimazaki, Naoki Ishida, Akinori Saeki, Atsushi Wakamiya, Yasujiro Murata, “ Development of Polymers Using Partially Oxygen-bridged Triarylamine Skeleton for Hole-transporting Buffer Layer in Perovskite Solar Cells”, The 96th CSJ Annual Meeting, 2016, 3A3-20
4. Jaehyun Lee, Seungho Kim, and Jongwook Park, “Synthesis and Electroluminescence of Triple-Core Chromophores”, KSIEC Fall Meeting, 2015, 2P-41
5. Jaehyun Lee, and Jongwook Park, “New Blue Emitting Materials Based on Pyrene-Fused Chromophores for OLED”, KSIEC Fall Meeting, 2015, 2P-40
6. Hwangyu Shin, Jaehyun Lee, Jaemin Ryu, and Jongwook Park, “Synthesis and Electroluminescence Property of Hexaphenyl Benzene Derivatives for OLED Emitting Materials”, KSIEC Fall Meeting, 2015, 1P-151
7. Seungho Kim, Jaehyun Lee, Sunmi Lee, and Jongwook Park, “New Approach Way Using Substituent Group at Core Chromophore for Solution Process Blue Emitter”, KSIEC Fall Meeting, 2015, 1P-73
8. Jaehyun Lee, Seungho Kim, and Jongwook Park, “A New Blue Emitting Material for Solution Process OLEDs”, KCS Spring Meeting, 2015, MAT.P-998
9. Seungho Kim, Jaehyun Lee, and Jongwook Park, “New Polyindenopyrazine Derivatives Electroluminescent Property for OLEDs”, KCS Spring Meeting, 2015, MAT.P-995
10. Suji Lee, Hayoon Lee, Hyocheol Jung, Jaehyun Lee, and Jongwook Park, “Synthesis and Electroluminescent Properties of Highly Efficient Multi-Core Chromophores for OLEDs”, KCS Spring Meeting, 2015, MAT.P-999
11. Jaehyun Lee, Seungho Kim, and Jongwook Park, “A New Blue Emitting Material Containing t-Butyl Group for Solution Process OLEDs”, PSK Spring Meeting, 2015, 3PS-214

12. Jaehyun Lee, Seungho Kim, Beomjin Kim, Youngil Park, and Jongwook Park, "New indenofluorenedione derivatives including fluorine atoms for electron transporting layer", KSIEC Spring Meeting, 2015, 2P-16
13. Jaehyun Lee, Seungho Kim, Mina Jung, and Jongwook Park, "A new blue host material including substituent group in white OLED", KSIEC Spring Meeting, 2015, 2P-17
14. Jaehyun Lee, Seungho Kim, Hwangyu Shin, Youngil Park, Ji-Hoon Lee, and Jongwook Park, "Core and side effect of novel 6,12-dihydro-diindeno[1,2-b;1',2'-e]pyrazine derivatives", KSIEC Spring Meeting, 2015, 2P-18
15. Jaehyun Lee, Seungho Kim, Beomjin Kim, and Jongwook Park, "Excimer formation in organic emitters due to anisotropic alignment promoted by steric hindrance", KSIEC Spring Meeting, 2015, 2P-19
16. Hayoon Lee, Beomjin Kim, Seungho Kim, Joonghan Kim, Jaehyun Lee, Hwangyu Shin, Ji-Hoon Lee, and Jongwook Park, "Highly efficient blue emitting materials based on dual core chromophores", KSIEC Spring Meeting, 2015, 2LN-6
17. Seungho Kim, Jaehyun Lee, and Jongwook Park, "Fabrication of phosphorescence WOLEDs based on dimeric phenoxazine derivative for hole injection layer", KSIEC Spring Meeting, 2015, 1P-84
18. Seungho Kim, Sunmi Lee, Jaehyun Lee, and Jongwook Park, "Bulky substitution group effect to emitting materials for OLEDs", KSIEC Spring Meeting, 2015, 1P-85
19. Seungho Kim, Jaehyun Lee, and Jongwook Park, "Highly efficient white organic light emitting diodes using new blue fluorescence emitter", KSIEC Spring Meeting, 2015, 1P-86
20. Seungho Kim, Jaehyun Lee, Sang-Ho Lee, Kwang-Yol Kay, and Jongwook Park, "New hole transporting materials based on hexaarylbenzene and aromatic amine moiety for OLEDs", KSIEC Spring Meeting, 2015, 1P-87
21. Hwangyu Shin, Kwang-Yol Kay, Seungho Kim, Jaehyun Lee, and Jongwook Park, "Synthesis and electroluminescence efficiency of hexaphenyl benzene derivatives for blue emitting materials", KSIEC Spring Meeting, 2015, 1P-220
22. Suji Lee, Hyocheol Jung, Hayoon Lee, Jaehyun Lee, and Jongwook Park, "Synthesis and electroluminescent properties of multi-chromophores having fused aromatic moieties", KSIEC Spring Meeting, 2015, 2P-2
23. Jaehyun Lee and Jongwook Park, "Blue Emission Color Control by Co-Deposition Method Using Blue Materials as Emitting Layer in Organic Light Emitting Diodes", KCS Spring Meeting, 2014, MAT.P-1002
24. Hayoon Lee, Hwangyu Shin, Jaehyun Lee, Ji-Hoon Lee, and Jongwook Park, "Synthesis and Electroluminescence Properties of Highly Efficient Dual

Core Chromophores for Blue Emission", KCS Spring Meeting, 2014, MAT.P-949

25. Jaehyun Lee, Soo-Kang Kim, Hwangyu Shin, and Jongwook Park, "Blue Emission Color Control Using Highly Efficient Blue Materials as Emitting Layer by Co-Deposition Method", PSK Spring Meeting, 2014, 3PS-239
26. Hayoon Lee, Beomjin Kim, Seungho Kim, Joonghan Kim, Jaehyun Lee, Hwangyu Shin, Ji-Hoon Lee, and Jongwook Park, "Synthesis and Electroluminsecence Properties of Highly Efficient Dual Core Derivetives for OLEDs", PSK Spring Meeting, 2014, 3PS-251
27. Hayoon Lee, Sunmi Lee, Hwangyu Shin, Beom-Soo Michael Park, Jaehyun Lee, and Jongwook Park, "Synthesis and Luminescent Property of Poly (9-(3-Vinyl-phenyl)-anthracene)", PSK Spring Meeting, 2014, 3PS-252
28. Jaehyun Lee, Soo-Kang Kim, Soo-Kang Kim, Ji-Hoon Lee, and Jongwook Park, "Electroluminescent Properties of Phenothiazyl Derivatives Having Aromatic Moieties", KSIEC Spring Meeting, 2014, 1P-193
29. Jaehyun Lee, Soo-Kang Kim, Changjun Lee, Ji-Hoon Lee, and Jongwook Park, "Synthesis and Hole-Transporting Properties of Phenyl-Carbazyl Derivatives", KSIEC Spring Meeting, 2014, 1P-194
30. Jaehyun Lee, Beomjin Kim, Ji Eon Kwon, Joonghan Kim, Soo Young Park, and Jongwook Park, "Triple Core Chromophores Making Unusual Excimer Formation Based on Steric-hindered and Distorted Structure", KSIEC Spring Meeting, 2014, 2LF-12
31. Hayoon Lee, Sunmi Lee, Hwangyu Shin, Beom-Soo Michael Park, Jaehyun Lee, and Jongwook Park, "Simple Synthesis and Luminescent Property of Poly (9-(3-Vinyl-phenyl)-anthracene) for PLEDs", KSIEC Spring Meeting, 2014, 1P-181
32. Hayoon Lee, Beomjin Kim, Seungho Kim, Joonghan Kim, Jaehyun Lee, Hwangyu Shin, Ji-Hoon Lee, and Jongwook Park, "Synthesis and Electroluminescence Properties of Highly Efficient Dual Core Chromophores with Side Groups for Blue Emission", KSIEC Spring Meeting, 2014, 1P-182
33. Jaehyun Lee, Seungho Kim, and Jongwook Park, "WOLED Using New Host Materials Including Substituent Group Based on Solution and Vacuum Methods", KCS Fall Meeting, 2014, MAT.P-1015
34. Seungho Kim, Jaehyun Lee, and Jongwook Park, "Single-Layered White OLED Based on Multi-Host, Dopant System with Interlayer", KCS Fall Meeting, 2014, MAT.P-1013
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36. Jaehyun Lee, Seungho Kim, and Jongwook Park, "New Blue Emitting Materials in White OLED Based on Co-Host System", KSIEC Fall Meeting, 2014, 1P-221
37. Seungho Kim, Jaehyun Lee, Beomjin Kim, Youngil Park, and Jongwook Park, "Synthesis and Electroluminescent Properties of New Polyindenopyrazine Derivatives for OLEDs", KSIEC Fall Meeting, 2014, 1P-245
38. Seungho Kim, Kyung Jin Lee, Jaehyun Lee, Hwangyu Shin, Kwang-Yol Kay, and Jongwook Park, "New Amino Methyl Coumarin Derivative for OLED Blue Emitter", KSIEC Fall Meeting, 2014, 1P-246
39. Hwangyu Shin, Jaehyun Lee, Sunmi Lee, Hyeonmi Kang, Hayoon Lee, Seokwoo Kang, Beomjin Kim, and Jongwook Park, "Optical and Electroluminescence Properties of Highly Efficient Dual Core Chromophores with Aromatic Amine Side Groups", KSIEC Fall Meeting, 2014, 2LF-2
40. Jaehyun Lee and Jongwook Park, "Electrochemical and Optical Characterization of Cobalt, Copper and Zinc Phthalocyanine Complexes", PSK Spring Meeting, 2013, 3PS-243
41. Jaehyun Lee, Chang-Hun Seok, and Jongwook Park, "Synthesis of New Metal Complex Derivatives Based on Azo, Naphthol and Pyrazole Moieties for Color Filter Pigments", KSIEC Spring Meeting, 2013, 1P-356
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43. Seungho Kim, Beomjin Kim, Youngil Park, Jaehyun Lee, Hwangyu Shin, and Jongwook Park, "New Polyindenopyrazine Derivatives Electroluminescent Property for OLEDs", KSIEC Spring Meeting, 2013, 1P-377
44. Garam Yang, Jaehyun Lee, Beomjin Kim, Youngil Park, Seungho Kim, and Jongwook Park, "Fluorine Effect Using New Indenofluorenedione Derivatives for Electron Transporting Layer in OLED Devices", KSIEC Spring Meeting, 2013, 1P-331
45. Jaehyun Lee, Seungho Kim, and Jongwook Park, "Three Color White OLEDs Using Highly Efficient Green Dopant based on Solution Process", KCS Fall Meeting, 2013, MAT.P-1092
46. Seungho Kim, Beomjin Kim, Jaehyun Lee, Kwang-Yol Kay, and Jongwook Park, "High Efficiency Ambipolar Blue Emitting Materials Based on Amino-Methyl-Chromen Derivatives for OLEDs", KCS Fall Meeting, 2013, MAT.P-1109
47. Jaehyun Lee, Beomjin Kim, Seungho Kim, and Jongwook Park, "White OLED Using Highly Efficient Green Dopant via Solution Process", PSK Fall Meeting, 2013, 3PS-217

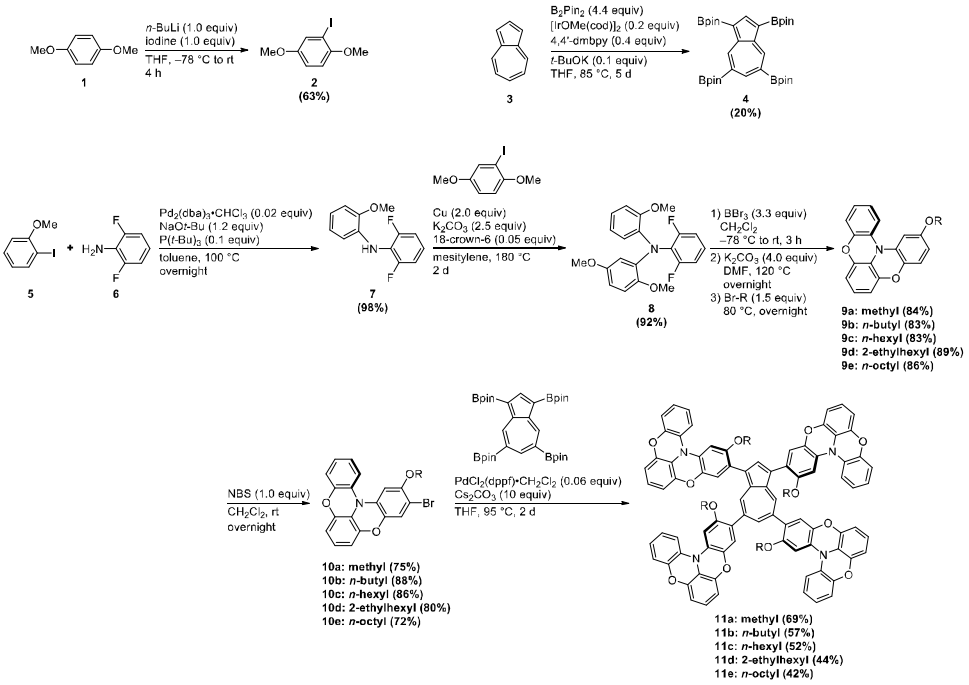
48. Seungho Kim, Sang-Ho Lee, **Jaehyun Lee**, Kwang-Yol Kay, and Jongwook Park, "New Hole Transporting Materials Based on Tetraphenylbenzene and Aromatic Amine Derivatives for OLEDs", PSK Fall Meeting, 2013, 1PS-235
49. **Jaehyun Lee**, Soo-Kang Kim, Seungho Kim, and Jongwook Park, "White OLED Using Highly Efficient Green Dopant via Solution Process ", KSIEC Fall Meeting, 2013, 1P-283
50. **Jaehyun Lee**, Soo-Kang Kim, Hwangyu Shin, and Jongwook Park, "Blue Emission Color Control by Co-Deposition Method in Organic Light Emitting Diodes", KSIEC Fall Meeting, 2013, 1P-284
51. Seungho Kim, Kyung Jin Lee, Beomjin Kim, **Jaehyun Lee**, Kwang-Yol Kay, and Jongwook Park, "High Efficiency New Ambipolar Blue Emitting Materials Using Amino Coumarin Derivatives", KSIEC Fall Meeting, 2013, 1P-294
52. Seungho Kim, Hayoon Lee, Beomjin Kim, **Jaehyun Lee**, Hwangyu Shin, Joonghan Kim, Ji-Hoon Lee, and Jongwook Park, "Synthesis and Electroluminescence Properties of Highly Efficient Dual Core Chromophores Having a Side Group", KSIEC Fall Meeting, 2013, 2LH-2
53. Hwangyu Shin, Yun-Fan Wang, **Jaehyun Lee**, and Jongwook Park, "Synthesis and Electroluminescence Property of New Hexaphenyl Benzene Derivatives Including Amine Group for Blue Emitters", KSIEC Fall Meeting, 2013, 1P-281
54. Sunmi Lee, Seungho Kim, **Jaehyun Lee**, Beomjin Kim, and Jongwook Park, "Effects of Substituents to Emitting Materials in Solution Process OLEDs", KSIEC Fall Meeting, 2013, 1P-285
55. **Jaehyun Lee** and Jongwook Park, "Electrochemical and Optical Characterization of Cobalt, Copper and Zinc Phthalocyanine Complexes", KCS Spring Meeting, 2012, ORGN.P-964

Jaehyun Lee

- **Results (From April 2016 to August 2016)**

1. Synthesis of the Azulene-Core Derivatives

The oxygen-bridged triarylamine derivatives using the azulene core unit were prepared as shown in Scheme 1. The compounds of each steps were synthesized in excellent yields.



Scheme 1. Synthetic routs of the azulene derivatives.

2. UV-vis Absorption Properties

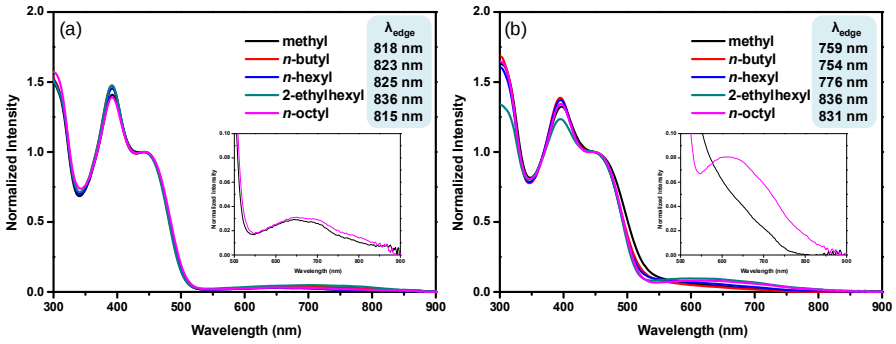


Figure 1. UV-vis absorption spectra of the azulene derivatives: (a) in CH_2Cl_2 solution, (b) spin-coated films.

The photophysical and electronic properties were evaluated in detail. UV-vis absorptions of these compounds were measured both in solution and in film (see Figure 1). Compared to *n*-octyl-substituted derivative, UV-vis absorption of the methyl compound in the film is more

red-shifted. This optical shift in the solid state suggests that intermolecular interaction increases, which would induce a denser ´-stacking to enhance a hole transporting ability.

3. Space-Charge-Limitation of Current (SCLC) Measurements

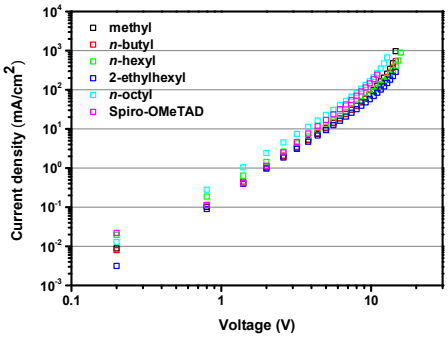


Figure 2. J-V characteristics of SCLC of non-doped HTMs. The device structure: ITO / PEDOT:PSS / HTM / Au.

Table 1. The hole mobility examined by SCLC method.

	Mobility [cm^2 / (V·s)]
methyl	2.4×10^{-4}
n-butyl	2.0×10^{-4}
n-hexyl	1.4×10^{-4}
2-ethylhexyl	1.1×10^{-4}
n-octyl	1.2×10^{-4}
Spiro-OMeTAD	2.1×10^{-4}

The hole mobilities of these compounds were examined by SCLC method. The comparison of hole mobility among a series of derivatives (Figure 2 and Table 1) shows that the hole mobility increases as the length of alkoxy chain is shorten.

4. Device Performance

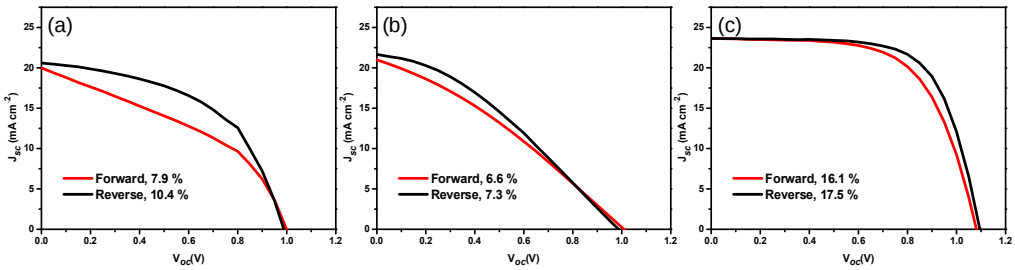


Figure 3. Current densityī voltage characteristics for perovskite solar cells of (a) methyl, (b) *n*-octyl, and (c) Spiro-OMeTAD. The device structure: FTO / compact TiO_2 / mesoporous TiO_2 : perovskite ($CH_3NH_3PbI_3$) / HTM / Au.

The perovskite solar cells using these compounds as p-type buffer materials. The results are shown in Figure 3. The methyl compound shows a higher PCE value compared with *n*-octyl compound. However, the performance of the cells using azulene derivatives are lower than that using Spiro-OMeTAD, suggesting that further device optimization is required.

Jaehyun Lee

1. Research Plan

Perovskite solar cells have attracted much attention as cost-effective next generation printable photovoltaics. Since 2009, the device power conversion efficiencies (PCEs) have rapidly increased more than 5 times from 3.7% to exceed 20%. In perovskite solar cells, the device is composed of a perovskite layer, such as methylammonium lead halide perovskite ($MAPbX_3$), as a photoabsorber and p-type and n-type buffer layers that are essentially used for the charge collection to each electrode (Figure 1). **In order to obtain >23% PCEs for world best record, my research plan is aimed at developing novel hole transporting materials (HTMs) as a p-type material for perovskite solar cells.**

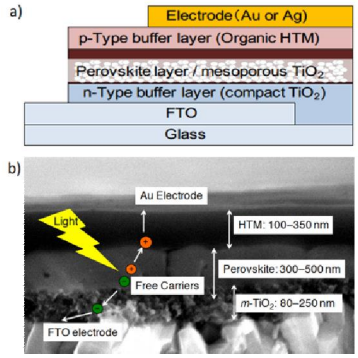


Figure 1. a) The typical device structures of perovskite solar cells, and b) cross sectional SEM image and working principle of perovskite solar cells.

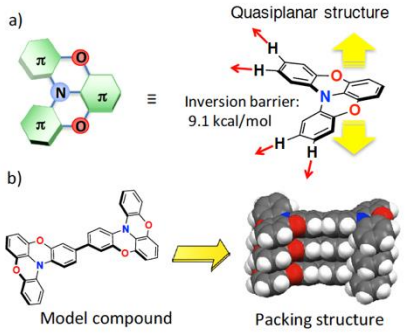


Figure 2. a) The partially oxygen-bridged triarylamine using quasiplanar structure, and b) on-top ´-stacking structure of the model compound.

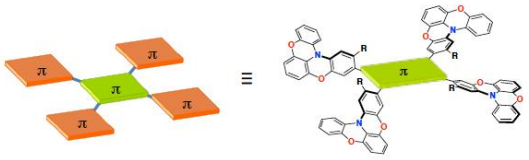


Figure 3. The molecular design of the HTMs for p-type buffer materials in perovskite solar cells.

2. Proposed Plan

A triarylamine group has been widely used as typical core skeleton of conventional HTMs in perovskite solar cells. In Profs. Wakamiya and Murata group, the charge transporting materials using a quasiplanar structure were first developed as a novel core group [*Angew. Chem. Int. Ed.* **2014**, *53*, 5800-5804] (Figure 2). The partially oxygen-bridged triarylamines facilitate a delocalized ´-conjugation and on-top ´-stacking in the solid state which can promote high carrier mobility in the ´-stacking direction. Through structural expansion of this group, recently, the two-dimensionally expanded compound using *n*-octyloxy groups in alkoxy (R) parts has been reported in the paper [*J. Am. Chem. Soc.* **2015**, *137*, 15656-15659] from Profs. Wakamiya and Murata group (Figure 3). Perovskite solar cells using this new compound as a HTM exhibited a higher PCEs (15.7%) relative to those using Spiro-OMeTAD (13.6%) as one of the most

widely-used HTM.

Based on these results, **I have been developing the two-dimensionally expanded materials with optimizing the varying lengths of alkoxy chain from methoxy group to *n*-octyloxy group as a reference compound.** In order to improve the efficiency, the proper chain length in HTM is important because a hole mobility strongly depends on the packing structure, thus the chain length. As well as optimizing of the chain length, the number of partially oxygen-bridged triarylamine group and the center part are being modified to achieve the higher efficiency in perovskite solar cells.

New symmetrical propeller-shaped HTMs comprise of the fully oxygen-bridged triarylamine core and electron-rich methoxy-engineered substituents (Figure 4). **The fully oxygen-bridged triarylamine core has a planar structure and it can be induced denser π-stacking to enhance a hole transporting ability.** Using this core skeleton, I designed the two-dimensionally expanded system with a sheet-shaped structure with three substituents of partially oxygen-bridged triarylamines as quasiplanar scaffolds for high carrier mobility. This molecule is possible to enhance the horizontal orientation by the two-dimensionally expanded molecular shape that makes face-on molecular orientation of the HTMs on the perovskite layer, which could facilitate charge collection.

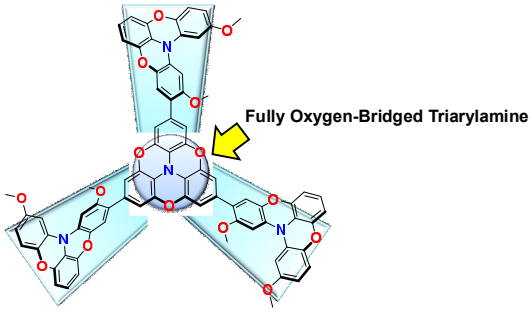


Figure 4. The molecular structure of a propeller type HTM using fully oxygen-bridged triarylamine core group.

3. Purpose of Proposed Research

To improve the performance, perovskite solar cells has gained huge momentum focused on designing and compositional engineering of perovskite materials, deposition techniques, device architecture, and n-type and p-type charge transporting materials. Among them, major topics in perovskite solar cells are a finding of efficient and ideal p-type materials for the higher PCE and long-term stability compared to spiro-OMeTAD and polytriarylamine (PTAA) used as conventional HTMs. Although tremendous efforts have been devoted to the development of improved HTMs for buffer layers so far, the number of high-performance HTMs is still limited.

Prof. Wakamiya group achieves >20% PCE, recently, first in Japan by a perovskite layer to optimize the fabrication protocol even though this device was used spiro-OMeTAD as HTM. **Based on the outstanding results of Profs. Wakamiya and Murata group, purpose of my research is to achieve >23% PCEs using newly developed HTMs for world best record, which require short-circuit**

current densities (J_{sc}) near the maximum of >24 mAcm^{-2}, >0.80 fill factors (FFs) and >1.2 V open-circuit voltages (V_{oc}).