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Employment History

2017-2024	Canada Research Chair (renewed), Tier I
2010-2017	Canada Research Chair, Tier I
2006-present	Professor, University of Toronto
1998-2006	Associate Professor, University of Toronto
1994-1998	Associate Research Officer, National Research Council of Canada
1991-1994	Assistant Research Officer, National Research Council of Canada
1989-1991	Research Associate, Western University

Education

1989	Ph.D. in Engineering Physics, Ecole Polytechnique, l'Université de Montréal.
1983	B.Sc. in Physics, Yunnan University, China.

Recognitions

- Premier's Research Excellence Award (2000) (Canada).
- Thousand Talents Program Award (2009) (China Central Government)
- Connaught Innovation Award, University of Toronto (2013):
- Elected AAAS Fellow in 2016 for his distinguished contributions to the development of next-generation of OLEDs.
- Elected Fellow of Canadian Academy of Engineering in 2017 for his distinguished contributions to the development of next-generation of OLEDs.

Contributions to technology innovation and commercialization

- Norel Optronics (co-founder)
- OTI Lumionics Inc. (co-founder)
- Q-Materials Inc. Shenzhen (co-founder)
- Lumitronics Inc. (founded by graduate student Graham Murdoch)
- Pliant Power Devices Inc. (founded by graduate student Grayson Ingram)

Research Highlights

(A) Discovered Quantum Confinement in and Light Emission from SiO_2/Si Superlattices [Nature 378, 258, (1995)].

This seminal contribution proves the possibility of quantum confined light emission from precisely engineered SiO_2/Si superlattices. The work generates huge excitement from the scientific community, as attested from the following unsolicited comments:

- "Silicon, already the staple material of computers and electronics, would become even more useful if it could be made to glow... Zheng-H. Lu, a Canadian materials scientist has found a way to coax the stubborn crystals into luminescence.", -Science News, Vol. 148, p.359, 1995.

- "Optoelectronics is becoming increasingly important for handling information. Long-distance telecommunications are now dominated by optical fibres. Semiconductor lasers are key to compact discs for information storage. Lasers and light-emitting diodes are used in many printers, and in display devices such as liquid crystal panels and indicator lights... The work of Lu and colleagues is an important demonstration of potentially useful properties of these silicon-based structures. Their work will surely stimulate more activity in this field and may yet give silicon an even brighter future. -Nature, Vol.78, p.238, 1995.

(B) Developed a Method of Thickness Metrology for Measuring Thin Films [Appl. Phys. Lett. 71, 2764 (1997)].

With a continuous scaling down in lateral size of MOSFET transistors, the requirement for the most important gate dielectrics has now been pushed to atomic layer precision. For nanometer thick dielectrics, precise thickness measurement has been a very challenging and problematic issue. Lu led a team of scientists from Bell Labs, Texas Instrument, Nortel Networks, and National Research Council Canada on establishing a set of parameters for measuring absolute thickness of gate dielectrics. This published set of parameters is now widely used by the community.

(C) Invented chlorinated ITO electrodes [Science 332, 944, (2011)].

PI has invented a chlorinated indium tin oxide (Cl-ITO) with an unprecedented high work function which makes a record high efficiency OLED possible in an extremely simple device structure. ITO electrode is an essential technology in many devices, including liquid crystal displays, organic photovoltaics, and OLEDs. Despite the dominance of ITOs in the flat-panel display industry, its surface electronic properties are less than ideal for OLEDs. In particular, the low work function of ITO necessitates the current complex design of OLEDs. Essentially, the energy of the electrons removed from the light-emitting material is higher than the ITO can accept. As a result, multiple additional layers of organic molecules have to be added to OLEDs to compensate for the large mismatch between the low work function of ITO and the energy levels of the active organic materials. Each additional layer of organic molecules increases manufacturing costs and decreases production yield. To address this issue, PI's team chlorinated the ITO electrodes by exposing the material to o-dichlorbenzene and ultraviolet light, creating a one-atom-thick sheet of chlorine covering the ITO. This resulted in an increase in the electron energy which the electrode can accept and closed the energy gap between the ITO and the organic materials, meaning that the electrons can directly transfer between the light-emitting materials and the Cl-ITO electrode without any additional layers. This breakthrough enables manufacturing of OLEDs with a record high efficiency in an extremely simple device structure, eliminating a number of process steps and associated equipment and greatly reducing the manufacturing cost. Ever since its publication, the paper has generated worldwide excitement across a wide spectrum of society, as evidenced by extensive reporting from over 60 popular S&T websites such as American Chemical Society's Chemical & Engineering News, Photonics, Printed Electronics World, Engadget, Science Daily, The Walls Street Journal, PC World, etc. A delegation from LG Display lead by its senior VP Dr. Byung-Chul Ahn also visited the lab on Sept. 14, 2011, discussing possibilities of licensing the Cl-ITO for LG's gen-8 production line (three 55" TV panel on one mother glass substrate). A spin off company, OTI Lumionics Inc., has been formed to commercialize this technology.

(D) Created the world's most efficient OLEDs [Nature Photonics 5, 753, (2011)].

PI has developed an effective method to unlock the full potential of organic light-emitting diodes on flexible plastic. One of the most striking features of OLED technology has been its potential to be manufactured on low-cost plastics for flexible displays and lighting. Although the molecule used in state-of-the-art OLEDs can reach quantum efficiencies approaching 100%, most of the light emitted in conventional devices remains trapped inside the OLED due to optical refraction and reflection inside the device, resulting in much lower (20–30%) external quantum efficiencies (EQEs). PI has developed a new layered electrode technology which simultaneously addresses multiple issues; including electrical conduction, charge injection to organic molecules, and optical coupling. Using multifunctional anode stacks, consisting of a high-index optical coupling layer, electrically conductive metal layer and hole-injection oxides layer, PI's group has set new world record efficiencies, achieving a 63% external quantum efficiency and a 290 lumen-per-watts power efficiency. This advance solves two key problems for the broad realization of OLED applications; it enables much higher out-coupling efficiencies and it avoids the cost-intensive ITO electrode employed in most OLEDs. Moreover, the use of a plastic substrate will enable low-cost mass production of flexible OLEDs using roll-to-roll processing.

(E) Developed a universal rule of energy-level alignment [Nature Materials 11, 76, (2012)].

The energy level alignment at this interface dictates the energy barrier for electrical charge injection, which directly impacts on the OLED's operating voltage, efficiency, and stability. The science and engineering of this interface has been one of the most researched areas in academia and industry in recent years. In this paper, PI and his students conclusively established a scientific principle of energy alignment between electrodes and molecules. We observed a universal energy alignment trend for a set of transition-metal oxides (representing a broad diversity of electronic properties) with several organic semiconductors. Our research demonstrated that, despite the variance in their electronic properties, oxide energy alignment is governed by one driving force: electron chemical-potential equilibration. Furthermore, we have developed a formula to predict this alignment. This formula now serves as a general guide in selecting the most suitable electrode materials for a particular type of molecular system. The universal alignment rule also helps develop better devices and processes in related fields such as dye-sensitized solar cells, organic photovoltaics, and molecular electronics.

2018 Journal Publications

319 Junghwan Kim, Olivier Ouellette, Oleksandr Voznyy, Mingyang Wei, Jongmin Choi, Min - Jae Choi, Jea Woong Jo, Se - Woong Baek, James Fan, Makhsud I Saidaminov, Bin Sun, Peicheng Li, Dae - Hyun Nam, Sjoerd Hoogland, Zheng - Hong Lu, F Pelayo García de Arquer, and Edward H Sargent, "Butylamine - Catalyzed Synthesis of Nanocrystal Inks Enables Efficient Infrared CQD Solar Cells", Adv. Mater. 1803830 (2018).

318 JX Man, SJ He, DK Wang, HN Yang, ZH Lu, "Tailoring Mg: Ag functionalities for organic light-emitting diodes", Organic Electronics 63, 41-46 (2018).

317 Jun Xing, Yongbiao Zhao, Mikhail Askerka, Li Na Quan, Xiwen Gong, Weijie Zhao, Jiaxin Zhao, Hairen Tan, Guankui Long, Liang Gao, Zhenyu Yang, Oleksandr Voznyy, Jiang Tang, Zheng-Hong Lu, Qihua Xiong, Edward H Sargent, "Color-stable highly luminescent sky-blue perovskite light-emitting diodes", Nature Communications 9, 3541 (2018).

316 Kailong Wu, Tao Zhang, Zian Wang, Lian Wang, Lisi Zhan, Shaolong Gong, Cheng Zhong, Zheng-Hong Lu, Song Zhang, Chuluo Yang, "De Novo Design of Excited-State Intramolecular Proton Transfer Emitters via a Thermally Activated Delayed Fluorescence Channel", Journal of the American Chemical Society 140, 8877-8886 (1998).

315 Min Qian, Quan Liu, Wen-Shi Li, Yong-Biao Zhao, Zheng-Hong Lu, "Study on the light extraction mechanism of organic light-emitting diodes with corrugated Ag cathode made by soft nanoimprint", Japanese Journal of Applied Physics 57, 080306 (2018).

314 Shou-Jie He, Deng-Ke Wang, Zhen-Xin Yang, Jia-Xiu Man, Zheng-Hong Lu, "Integrated tandem device with photoactive layer for near-infrared to visible upconversion imaging", Appl. Phys. Lett. 112, 243301 (2018).

313 Jongmin Choi, Jea Woong Jo, F Pelayo García de Arquer, Yong - Biao Zhao, Bin Sun, Junghwan Kim, Min - Jae Choi, Se - Woong Baek, Andrew H Proppe, Ali Seifitokaldani, Dae - Hyun Nam, Peicheng Li, Olivier Ouellette, Younghoon Kim, Oleksandr Voznyy, Sjoerd Hoogland, Shana O Kelley, Zheng - Hong Lu, Edward H Sargent, "Activated Electron - Transport Layers for Infrared Quantum Dot Optoelectronics", Adv. Mater. 1801720 (2018).

312 HN Yang, SJ He, T Zhang, JX Man, N Jiang, DK Wang, ZH Lu, “Glass transition temperatures in pure and composite organic thin-films”, Org. Electron. 60, 45 (2018)

311 Zhihui Yi, Yongbiao Zhao, Peicheng Li, Kevin Ho, Nykola Blozowski, Gilbert Walker, Shaffiq Jaffer, Jimi Tjong, Mohini Sain, Zhenghong Lu, “The effect of tannic acids on the electrical conductivity of PEDOT:PSS Films”, Appl. Surf. Sci. 448, 583 (2018).

310 Y. Li and Z.H. Lu, “Failure of Fermi Level in Referencing Chemical Shift of Molecules on Solid Surfaces”, Adv. Mater. Interfaces, 1800150 (2018).

309 Y Li, P Li, and Z-H Lu, “Probing molecular orientations in thin films by x-ray photoelectron spectroscopy”, AIP Advances 8, 035218 (2018).

308 M Qian, Q Liu, WS Li, JX Man, YB Zhao, Z.H. Lu, “Dual Ag electrodes for semitransparent organic light-emitting diodes”, Organic Electronics 57, 98-103 (2018).

307 K Wu, T Zhang, L Zhan, Z Wang, C Zhong, S Gong, Z.H. Lu, C Yang, “Highly efficient orange–red electroluminescence enabled by fluorenone-based thermally activated delayed fluorescent emitter”, Journal of Photonics for Energy 8, 032107 (2018)

306 X Li, YB Zhao, F Fan, L Levina, M Liu, R Quintero-Bermudez, X Gong, L. Quan, J. Fan, Z. Yang, S. Hoodland, O. Voznyy, Z.H. Lu, and E.H. Sargent, “Bright colloidal quantum dot light-emitting diodes enabled by efficient chlorination”, Nature Photonics 12, 159 (2018)

305 W Zeng, Y Zhao, W Ning, S Gong, Z Zhu, Y Zou, Z.H. Lu, and C Yang “Efficient non-doped fluorescent OLEDs with nearly 6% external quantum efficiency and deep-blue emission approaching the blue standard enabled by quaterphenyl-based emitters”, J. Mater. Chem. C6, 4479-4484 (2018)

304 X. Li, J. Zhang, Z. Zhao, L. Wang, H. Yang, Q. Chang, N. Jiang, Z, Liu, Z. Bian, W. Liu, Z.H. Lu and C. Huang, “Deep Blue Phosphorescent Organic Light-Emitting Diodes with CIEy Value of 0.11 and External Quantum Efficiency up to 22.5%”, Adv. Mater. 30, 1705005 (2018).

303 Y.B. Zhao, G.L. Ingram, X.W. Gong, X.Y. Li, L.N. Quan, P. Li, J.Q. Xie, E.H. Sargent, and Z.H. Lu, “Excitonic Creation of Highly Luminescent Defects In Situ in Working Organic Light - Emitting Diodes”, Adv. Opt. Mater. 6, 1700856 (2018).

302 KL Sampson, DS Josey, Y Li, JD Virdo, ZH Lu, TP Bender, “The Ability to Fine-Tune the Electronic Properties and Open-Circuit Voltage of Phenoxy-Boron Subphthalocyanines through Meta-Fluorination of the Axial Substituent”, J. Phys. Chem. C122, 1091-1102 (2018)

301 S.J. He and Z.H. Lu, “Excitonic processes at organic heterojunctions”, Sci. China-Phys. Mech. Astron. 61, 027301 (2018).

Books/Book Chapters

M. Greiner and Z.H. Lu, “Charge Injection Layer” in “Fundamentals of High-Efficiency OLEDs: Basic Science to Manufacturing of Organic Light-Emitting Diodes”, edited by Evgueni Polikarpov and Dan Gaspar, (CRC Press, Inc., 2015)

Y.L. Chang and Z.H. Lu, “Organic Light Emitting Diodes”, Wiley Encyclopaedia of Electrical and Electronics Engineering, edited by J. Webster, p1-15 (Wiley 2014).

Z.B. Wang, M.G. Helander, and Z.H. Lu, “Transparent Conducting Thin Films for OLEDs” in “Organic Light-Emitting Diodes (OLEDs): Materials, Devices and Applications”, edited by Alastair Buckley, (Woodhead, 2013), p. 49-76.

M.G. Helander, Z.B. Wang, and Z.H. Lu, “Electrode/Organic Interface Physics”, in “Encyclopedia of Nanotechnology”, (Springer, 2012), p. 702-710.