

PROCEEDINGS OF SPIE

Organic Light Emitting Materials and Devices XVI

**Franky So
Chihaya Adachi**
Editors

**12–15 August 2012
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 8476

Proceedings of SPIE 0277-786-786X, V.8476

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Organic Light Emitting Materials and Devices XVI*, edited by Franky So, Chihaya Adachi, Proceedings of SPIE Vol. 8476 (SPIE, Bellingham, WA, 2012) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819491930

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445

SPIE.org

Copyright © 2012, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/12/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

viii *Conference Committee*

SESSION 1 MATERIALS

- 8476 04 **Extremely high-efficiency multiphoton emission blue phosphorescent OLEDs with external quantum efficiency exceeding 40% (Invited Paper)** [8476-1]
H. Sasabe, K. Minamoto, Y.-J. Pu, M. Hirasawa, J. Kido, Yamagata Univ. (Japan)
- 8476 07 **Water-soluble iridium phosphorescent complexes for OLED applications (Invited Paper)** [8476-4]
M.-S. Eum, H. Yoon, T. H. Kim, Doosan Corp. (Korea, Republic of)
- 8476 0A **Heteroleptic cyclometalated Ir(III) complexes with charge transporting groups: a theoretical study (Invited Paper)** [8476-8]
A. B. Padmaperuma, C. A. Fernandez, Pacific Northwest National Lab. (United States)

SESSION 2 DEVICE PHYSICS

- 8476 0D **Role of the cathode interfacial layers in improving the stability of organic optoelectronic devices (Invited Paper)** [8476-11]
Q. Wang, H. Aziz, Univ. of Waterloo (Canada)
- 8476 0E **Considerations in device design and materials selection in organic light emitting diodes (Invited Paper)** [8476-12]
Z. B. Wang, M. G. Helander, J. Qiu, Y. L. Chang, L. Chai, D. Puzzo, Univ. of Toronto (Canada); Z. M. Hudson, S. Wang, Queen's Univ. (Canada); Z. H. Lu, Univ. of Toronto (Canada)
- 8476 0F **Investigation of aggregated structures in organic light-emitting diodes: approach from solid-state NMR (Invited Paper)** [8476-13]
H. Kaji, T. Fukushima, M. Fukuchi, Kyoto Univ. (Japan); T. Komino, C. Adachi, Kyushu Univ. (Japan)
- 8476 0G **Inverted OLEDs for flexible displays (Invited Paper)** [8476-78]
J.-J. Kim, J.-H. Lee, J. W. Kim, S.-Y. Kim, S.-J. Yoo, Seoul National Univ. (Korea, Republic of); P.-S. Wang, C.-I. Wu, National Taiwan Univ. (Taiwan)
- 8476 0I **Energy transfer and excitation migration in organic semiconductors (Invited Paper)** [8476-16]
P. A. Lane, M. A. Wolak, P. D. Cunningham, J. S. Melinger, U.S. Naval Research Lab. (United States)
- 8476 0K **Blue-emissive polymer light-emitting diodes through anode/cathode interfacial modification** [8476-18]
M.-W. Lin, C.-H. Yeh, T.-C. Wen, T.-F. Guo, National Cheng Kung Univ. (Taiwan)

- 8476 0L **Effect of horizontal molecular orientation on triplet-exciton diffusion in amorphous organic films** [8476-20]
T. Sawabe, I. Takasu, T. Yonehara, T. Ono, J. Yoshida, S. Enomoto, I. Amemiya, Toshiba Corp. (Japan); C. Adachi, Kyushu Univ. (Japan)

SESSION 3 LIGHT EXTRACTION

- 8476 0R **Compatibility of micro lens film and circular polarizer on bottom-emitting OLED display** [8476-27]
J. Jo, J. Lee, S.-Y. Jo, J.-G. Yoon, S. Yoon, LG Display (Korea, Republic of)

SESSION 4 TRANSPARENT ELECTRODE

- 8476 0T **Transparent composite electrode for high-efficiency polymer LEDs (Invited Paper)** [8476-29]
L. Li, Z. Yu, J. Liang, C.-H. Chang, W. Hu, Q. Pei, Univ. of California, Los Angeles (United States)
- 8476 0U **Large area organic light emitting diodes with multilayered graphene anodes (Invited Paper)** [8476-30]
J. Moon, J. Hwang, Electronics and Telecommunications Research Institute (Korea, Republic of); H. K. Choi, Univ. of Science and Technology (Korea, Republic of); T. Y. Kim, S.-Y. Choi, KAIST (Korea, Republic of); C. W. Joo, J.-H. Han, J.-W. Shin, B. J. Lee, D.-H. Cho, J. W. Huh, S. K. Park, N. S. Cho, H. Y. Chu, J.-I. Lee, Electronics and Telecommunications Research Institute (Korea, Republic of)

SESSION 5 LASERS AND NOVEL DEVICES

- 8476 0Y **Solution processed polymer light-emitting diodes with single layer graphene anode** [8476-34]
J. Ha, S. Park, D. Kim, Seoul National Univ. (Korea, Republic of); J. Ryu, Sungkyunkwan Univ. (Korea, Republic of); C. Lee, B. H. Hong, Y. Hong, Seoul National Univ. (Korea, Republic of)
- 8476 0Z **Investigation of the influence of laser radiation on material properties of transparent conductive layers** [8476-35]
M. Schaefer, A. Esser, M. Schulz-Ruhtenberg, J. Holtkamp, A. Gillner, Fraunhofer Institute for Laser Technology (Germany)
- 8476 11 **Nanoimprinted resonators for polymer lasers pumped by light-emitting diodes (Invited Paper)** [8476-37]
G. A. Turnbull, G. Tsiminis, Y. Wang, Univ. of St. Andrews (United Kingdom); A. L. Kanibolotsky, P. J. Skabara, Univ. of Strathclyde (United Kingdom); I. D. W. Samuel, Univ. of St. Andrews (United Kingdom)
- 8476 12 **Electrically-pumped organic laser device with a coupled microcavity structure** [8476-38]
X. Liu, J. Lin, Y. Li, S. Qu, Changchun Institute of Optics, Fine Mechanics and Physics (China)

SESSION 6 **NOVEL DEVICES**

- 8476 14 **Metal substrates with nanometer scale surface roughness for flexible electronics (Invited Paper)** [8476-40]
J.-L. Lee, K. Kim, Pohang Univ. of Science and Technology (Korea, Republic of)
- 8476 15 **Strongly modified angular dependence of emission from OLEDs (Invited Paper)** [8476-41]
S. Zhang, G. A. Turnbull, I. D. W. Samuel, Univ. of St. Andrews (United Kingdom)
- 8476 16 **Methods to protect and recover work function of air exposed transition metal oxide thin films (Invited Paper)** [8476-42]
I. Irfan, C. Wang, Univ. of Rochester (United States); A. J. Turinske, Univ. of Wisconsin (United States); Y. Gao, Univ. of Rochester (United States) and Central South Univ. (China)
- 8476 17 **In situ photoluminescence spectroscopy study of dynamic doping in sandwich-type light-emitting electrochemical cells (Invited Paper)** [8476-43]
S. B. Meier, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany) and Siemens AG (Germany); D. Hartmann, W. Sarfert, Siemens AG (Germany); D. Tordera, H. J. Bolink, Univ. de València (Spain); A. Winnacker, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany)

SESSION 7 **SOLID STATE LIGHTING AND OLEDs: JOINT SESSION WITH CONFERENCE 8476 AND 8484**

- 8476 19 **OLED-based physiologically-friendly very low-color temperature illumination for night (Invited Paper)** [8476-44]
J.-H. Jou, S.-M. Shen, M.-C. Tang, P.-C. Chen, National Tsing Hua Univ. (Taiwan); S.-H. Chen, Y.-S. Wang, C.-C. Chen, C.-C. Wang, Industrial Technology Research Institute (Taiwan); C. Y. Hsieh, C.-C. Lin, C.-T. Chen, National Tsing Hua Univ. (Taiwan)

SESSION 8 **SSL**

- 8476 1B **Novel design for high-production-yield and high-efficacy large-area OLED lighting panels (Invited Paper)** [8476-46]
M.-H. Ho, C.-C. Lin, Y.-C. Chin, C.-C. Chen, M.-T. Lee, T.-Y. Cho, C.-W. Chen, AU Optonics Corp. (Taiwan)
- 8476 1C **Large-area high-efficiency flexible PHOLED lighting panels (Invited Paper)** [8476-47]
H. Pang, P. Mandlik, P. A. Levermore, J. Silvernail, R. Ma, J. J. Brown, Universal Display Corp. (United States)

SESSION 9 **CHARACTERIZATION**

- 8476 1F **Use of delayed electroluminescence as a tool to investigate the emission mechanism of phosphorescent organic light emitting devices** [8476-50]
H. Zamani Siboni, D. Song, H. Aziz, Univ. of Waterloo (Canada)

- 8476 1G **Modelling of hole transport in a small-molecule organic material assuming carrier heating in a Gaussian density of states** [8476-51]
C. Zimmermann, M. Slawinski, RWTH Aachen Univ. (Germany); M. Bösing, D. Bertram, Philips Technologie GmbH (Germany); P. Loebel, Philips Research Labs. (Germany); M. Heuken, AIXTRON SE (Germany); H. Kalisch, A. Vescan, RWTH Aachen Univ. (Germany)
- 8476 1H **Characterization of charge carrier injection in organic and hybrid organic/inorganic semiconductor devices by capacitance-voltage measurements** [8476-52]
M. Weingarten, M. Slawinski, F. Urbain, D. Föhle, RWTH Aachen Univ. (Germany); D. Bertram, Philips Technologie GmbH (Germany); M. Heuken, RWTH Aachen Univ. (Germany) and AIXTRON SE (Germany); H. Kalisch, A. Vescan, RWTH Aachen Univ. (Germany)
- 8476 1I **Quantification of charge carrier density in organic light-emitting diodes by time-resolved electroluminescence** [8476-53]
C. Weichsel, S. Reineke, M. C. Gather, K. Leo, B. Lüssem, Technische Univ. Dresden (Germany)

SESSION 10 DEVICE FABRICATION

- 8476 1J **Extraction of internal emission characteristics from printed OLEDs (Invited Paper)** [8476-54]
M. L. Hildner, J. M. Ziebarth, DuPont Displays (United States)
- 8476 1K **Highly efficient organic light emitting diodes based on solution/evaporation hybrid process (Invited Paper)** [8476-55]
J.-Y. Liao, H.-C. Yeh, T.-C. Chao, J.-S. Lin, M.-R. Tseng, Industrial Technology Research Institute (Taiwan)
- 8476 1L **Organic Vapor Phase Deposition (OVPD) for efficient OLED manufacturing: the specific advantages and possibilities of carrier-gas enhanced vapor phase deposition for the manufacturing of organic thin film devices (Invited Paper)** [8476-56]
J. Kreis, M. Schwamberger, D. Keiper, M. Gersdorff, M. Long, M. Heuken, AIXTRON SE (Germany)

POSTER SESSION

- 8476 1N **The mechanism of charge generation in charge generation units containing HATCN for high-luminance tandem OLED display** [8476-14]
S. Lee, J.-H. Lee, J.-H. Lee, J.-J. Kim, Seoul National Univ. (Korea, Republic of)
- 8476 1O **Host materials for blue phosphorescent OLEDs** [8476-58]
D. Wagner, M. Rothmann, P. Strohrriegel, Univ. of Bayreuth (Germany); C. Lennartz, I. Münster, G. Wagenblast, C. Schildknecht, BASF SE (Germany)
- 8476 1P **Mechanical study of the enhanced electron injection via using a Bphen interlayer at Alq₃/Cs₂CO₃ interface** [8476-59]
J. Lian, C. Pan, S. Su, R. Liu, P. Zeng, Shenzhen Univ. (China)
- 8476 1Q **Boosting the performance of red PHOLEDs by exciton harvesting** [8476-60]
Y.-L. Chang, Z. B. Wang, M. G. Helander, J. Qiu, Z. H. Lu, Univ. of Toronto (Canada)

- 8476 1R **An organic p-n junction for electrode-independent electron injection layer in organic light emitting diodes** [8476-61]
J.-H. Lee, J. W. Kim, S.-Y. Kim, S.-J. Yoo, J.-H. Lee, J.-J. Kim, Seoul National Univ. (Korea, Republic of)
- 8476 1S **High-efficiency non-blocking phosphorescent organic light emitting diode with ultrathin emission layer** [8476-62]
J. Qiu, M. G. Helander, Z. Wang, Y.-L. Chang, Z. Lu, Univ. of Toronto (Canada)
- 8476 1T **Using an embedded nanocomposite scattering film for increasing out-coupling of white phosphorescent organic light-emitting devices** [8476-64]
C.-H. Chang, C.-Y. Shin, K.-Y. Chang, Y.-J. Lo, T.-F. Chang, Yuan Ze Univ. (Taiwan); H.-H. Chang, Vanung Univ. (Taiwan)
- 8476 1U **Enhancement of white light OLED efficiency by combining both internal and external light extraction structures** [8476-65]
I.-L. Kao, C.-N. Ku, Y.-P. Chen, D.-Z. Lin, Industrial Technology Research Institute (Taiwan)
- 8476 1W **Sol-gel deposited gallium-doped zinc oxide electrode for polymer light-emitting diode applications** [8476-67]
D. Kim, J. Ha, C. Lee, Y. Hong, Seoul National Univ. (Korea, Republic of)
- 8476 1X **High-efficiency green electrophosphorescent organic light-emitting diodes with a simple device structure** [8476-68]
C.-H. Yuan, National Taiwan Univ. of Science and Technology (Taiwan); S.-W. Liu, Ming Chi Univ. of Technology (Taiwan); L.-A. Liu, Y.-S. Chen, P.-C. Lai, C.-C. Lee, National Taiwan Univ. of Science and Technology (Taiwan)
- 8476 1Y **Wavelength fine-tuning flexible photonic crystal rods laser** [8476-69]
K.-T. Lai, Academia Sinica (Taiwan) and National Chiao Tung Univ. (Taiwan); M.-Y. Kuo, Academia Sinica (Taiwan); K.-S. Hsu, Academia Sinica (Taiwan) and National Chiao Tung Univ. (Taiwan); C.-T. Lin, National Chiao Tung Univ. (Taiwan); M.-H. Shih, Academia Sinica (Taiwan) and National Chiao Tung Univ. (Taiwan)
- 8476 1Z **Optical configuration of the encapsulation layer with the organic and inorganic multilayer structure for top emitting organic light emitting diodes** [8476-70]
Y. Zhang, G. Bea, C.-B. Moon, W.-Y. Kim, C. G. Jhun, Hoseo Univ. (Korea, Republic of)
- 8476 21 **Advanced plasma technology for large scale PECVD processes** [8476-72]
J. Landrock, M. Zeuner, M. Nestler, D. Rost, MicroSystems GmbH (Germany)
- 8476 22 **In situ lifetime testing of organic light emitting diodes** [8476-73]
C. W. Merkel, M. G. Helander, J. Qiu, Univ. of Toronto (Canada); Z. H. Lu, Univ. of Toronto (Canada) and Yunnan Univ. (China)
- 8476 23 **Reduced excimer formation in polyfluorenes by introducing coil-like poly[penta(ethylene glycol) methyl ether methacrylate] block segments** [8476-74]
S. J. Noh, S. I. Heo, S. H. Jang, H. H. Ahn, J. Y. Han, M. G. Suk, S. J. Jin, Y. K. Kwon, Inha Univ. (Korea, Republic of)

- 8476 24 **Transient thermal analysis of white organic light-emitting diode for heat-dissipation application** [8476-75]
H. Yang, National Taipei Univ. of Technology (Taiwan)
- 8476 25 **Microwave-assisted synthesis of nanocrystalline TiO₂ for dye-sensitized solar cells** [8476-76]
T.-C. Kuo, T.-F. Guo, P. Chen, National Cheng Kung Univ. (Taiwan)

Author Index

Conference Committee

Symposium Chair

Zakya H. Kafafi, National Science Foundation (United States)

Conference Chair

Franky So, University of Florida (United States)

Conference Cochair

Chihaya Adachi, Kyushu University (Japan)

Conference Program Committee

Andrew B. Holmes, Bio21 Molecular Science and Biotechnology
Institute (Australia)

Hisao Ishii, Chiba University (Japan)

Hironori Kaji, Kyoto University (Japan)

Jang-Joo Kim, Seoul National University (Korea, Republic of)

Jaewon Lee, LG Display (Korea, Republic of)

Mathew K. Mathai, Plextronics, Inc. (United States)

Jongwook Park, The Catholic University of Korea (Korea, Republic of)

Yong-Jin Pu, Yamagata University (Japan)

Ifor D. W. Samuel, University of St. Andrews (United Kingdom)

Joseph Shinar, Ames Laboratory (United States)

Richard J. Wilson, Cambridge Display Technology Ltd.
(United Kingdom)

Takeshi Yamada, Sumitomo Chemical Company, Ltd. (Japan)

Session Chairs

OLEDs and Solid State Lighting Plenary Session

Mathew K. Mathai, Plextronics, Inc. (United States)

Matthew H. Kane, Massachusetts Maritime Academy (United States)

1 Materials

Chihaya Adachi, Kyushu University (Japan)

Sunghun Lee, Seoul National University (Korea, Republic of)

2 Device Physics

Bernard Kippelen, Georgia Institute of Technology (United States)

Asanga B. Padmaperuma, Pacific Northwest National Laboratory
(United States)

- 3 Light Extraction
Jong-Lam Lee, Pohang University of Science and Technology
(Korea, Republic of)
Graham A. Turnbull, University of St. Andrews (United Kingdom)
- 4 Transparent Electrode
Jong-Lam Lee, Pohang University of Science and Technology
(Korea, Republic of)
Graham A. Turnbull, University of St. Andrews (United Kingdom)
- 5 Lasers and Novel Devices
Qibing Pei, University of California, Los Angeles (United States)
John C. de Mello, Imperial College London (United Kingdom)
- 6 Novel Devices
Qibing Pei, University of California, Los Angeles (United States)
John C. de Mello, Imperial College London (United Kingdom)
- 7 Solid State Lighting and OLEDs: Joint Session with Conference 8476
and 8484
Ian T. Ferguson, The University of North Carolina at Charlotte
(United States)
Juergen Kreis, AIXTRON SE (Germany)
- 8 SSL
Jian Li, Arizona State University (United States)
Russell J. Holmes, University of Minnesota, Twin Cities (United States)
- 9 Characterization
Jian Li, Arizona State University (United States)
Russell J. Holmes, University of Minnesota, Twin Cities (United States)
- 10 Device Fabrication
Jian Li, Arizona State University (United States)
Russell J. Holmes, University of Minnesota, Twin Cities (United States)