

出國報告（出國類別：開會）

參加 2015 海峽兩岸光電材料學術研討會心得報告(**The Cross-Strait
Workshop on Optoelectronic Materials**)

服務機關：科技部自然科學及永續研究發展司

姓名職稱：高世平研究員、林蓮宣博士後研究員

派赴國家：大陸蘇州

出國期間：104 年 7 月 15 日至 104 年 7 月 18 日

報告日期：104 年 8 月 20 日

2015 海峽兩岸光電材料學術研討會心得報告

1. 目的

海峽兩岸於 2011 年進行「光電材料基礎與應用研究」共同合作計畫議題，2015 年 7 月在大陸蘇州大學舉辦期末成果交流研討會，參加該研討會以確實了解雙方合作之實質效益，並與對岸商討該主題未來持續補助之必要性與可行性。

2. 過程

7 月 16 日早上 8:30 舉行簡單隆重的開幕式，隨後即進行雙方計畫主持人的結案專題報告。基本上，先由我方研究人員上台報告，再由該計畫之陸方合作團隊報告，方便瞭解雙方之研究成果及合作關係。每人的報告時間為 25 分鐘，另有 5 分鐘可進行提問、討論與交流，可讓每一團隊都能有相對充分的時間說明與展示其計畫研究成果。所有合作團隊均完成結案專題報告後，在 7 月 17 日中午進行閉幕式，為這一次的兩岸交流研討會劃下成功且完美的句點。



3. 會議議程

第一組是由周必泰教授與花建麗教授分別報告，該計畫針對一系列 *N,N'*-disubstituted dihydrodibenzo[a,c]phenazines 進行深入的探討，進而確立該類分子經光激發後，進行連續性的三步驟運動，狀似蝴蝶的振翼行為，成功解釋此一特異的光物理現象，並打破數十年來沿用的解釋模型。第二組是由周卓輝教授與段煉教授報告，該組團隊主要是基於有效節省能源之角度。由於螢光及 LED 照明光源都含有波長較短、能量較高的藍色光，在夜間使用時，更會大幅抑制褪黑激素的分泌，長期下來不僅有損身體健康，並增加罹癌機率。相對地，使用有機發光二極體為光源，可藉由調整分子結構與組成，使其發出類於燭光的光源，可有效降低對人體的傷害。第三組為鄭建鴻教授與王磊教授，該組透過分子設計，合成出多種具有 styryl 基團的 polyaromatic compounds，可作為深藍光 OLED 的 dopant 材料，而且，它們具有極高的螢光量子效率，這些有機化合物都具有 TTA 的特性，得以開發出高效能的藍光有機發光二極體。第四組團隊為許千樹教授與薄志山教授，雙方著重於有機太陽能電池中高分子予體及富勒烯衍生物受體材料的開發。關於前者分子，係將多個雜環環化在一起形成 ladder 結構，有效提升高分子主鏈的共軛性、共平面性及 π - π stacking 能力，最佳元件的能量轉換效率可達 7.34%；另外則將吸光基團，如：pyrene-modified porphyrin 作為側基團鍵結至共軛分子鏈，增加材料的吸光範圍，其效率高達 8.6%。第五組為韋

光華教授與胡斌教授的合作團隊，該團隊係設計及合成一系列具有二維結構的共軛高分子作為有機太陽能電池中的予體材料，藉由 Synchrotron X-ray scattering 技術來探討加工添加劑對於分子鏈的堆疊與予/受體混摻形態的影響。該系統之最佳元件效率可達 8.7%。最後一組為季昀教授與廖良生教授，我方季昀教授負責開發含有 Os、Ir、Pt 等過渡金屬元素的磷光分子、陶雨臺教授負責使用 self-assembled monolayer 技術來調控電極的功函數，陸方廖良生教授則負責元件的製備。

4. 心得與建議

能源是兩岸人民共同面臨的重要課題，經由光電材料及其相關元件的研究、開發、與應用，可以在節能、產能（特別是乾淨能源）及醫療議題上提供一些解決之道。此次會議每一研究團隊的報告內容均十分精彩，惟，亦顯現出並非所有團都建立實質合作關係。其中周必泰教授與大陸華東理工學院田教授與花建麗教授、許千樹教授與大陸北京師範大學的薄志山教授、陶雨臺教授、季昀教授與大陸蘇州大學的廖良生教授三個團隊是兩岸共同研究非常成功的案例，雙方專長有互補性並共同發表研究成果在優質期刊。此種基於雙方之優異研究成果與巧妙的競合關係，有助於計畫之快速推展，且具有很強的國際競爭力。

整體說來，相較於2010年前往大陸參訪相關研究單位之印象相比，大陸在研

究主題、質量、硬體設備、國際化都有跳躍式的進步，未來繼續合作絕對可達成雙贏局面，惟，合作研究議題須更聚焦在光電科技研究上最亟需克服的主題，且明訂最後的確切成果目標，解決在光電科技上最關鍵的問題，將技術實用化以及向下延伸至產業。

2015

The Cross-Strait

Workshop on Optoelectronic Materials

海峡两岸光电材料学术研讨会

2015年7月15日-7月18日·苏州



国家自然科学基金委员会



李国鼎科技发展基金会

欢 迎 辞

尊敬的各位代表、来宾：大家好！

热忱欢迎您前来苏州参加由国家自然科学基金委员会和李国鼎科技发展基金会主办、苏州大学功能纳米与软物质研究院（FUNSOM）承办的“海峡两岸光电材料学术研讨会”！

我们将竭诚做好服务工作，以会议的顺利召开来表示对您最诚挚、最衷心的感谢！

祝各位代表、来宾在苏州度过愉快的时光！预祝会议取得圆满成功！

“海峡两岸光电材料学术研讨会”会务组

2015年7月2日

会议须知

各位代表、来宾：

为确保此次会议顺利召开，保证各位专家会议期间安全、健康、愉快，特提醒以下重要信息。

注册报到：请各位代表至苏州敬斋酒店（苏州工业园区仁爱路 158 号，中国人民大学国际学院内）一楼大厅注册报到，领取会议材料。

用餐安排：见会议日程安排（第 VIII-IX 页）

用车安排：会议期间，从酒店往返会议地点有大巴接送（集合时间地点请参见第 VIII-IX 页会议日程安排）

无线网络：

会场 WIFI: MeetingRoom 密码: funsom2013

温馨提示

1. 请参会代表在会议期间佩戴胸牌，便于会务组服务。
2. 因会议时间比较紧凑，会务组建议各位报告人提前将 PPT 存入会议用电脑，会务组承诺在会议结束后立即将 PPT 永久删除。

会务组联系方式

与会期间如有需要帮助的事项，请与会务组联系。

会务组人员：

廖良生（秘书长）	15995726527
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王 静	18706201056

交通指南

附近机场大巴参考信息：

机场名称	距酒店里程	机场大巴发车时间	乘车地点	参考票价	历时
无锡苏南硕放机场	约 50 公里	10:20; 12:00; 14:10; 16:10; 18:40; 20:10	国内到达出口	30 元	约 1 小时
上海虹桥国际机场	约 80 公里	1-2 班/小时	国内出口处对面	53 元	约 80 分钟
上海浦东国际机场	约 130 公里	1-2 班/小时	出口 15 号门对面	83 元	约 2 小时

抵达上海虹桥机场或浦东机场的代表，亦可选择乘坐高铁/动车。

附近火车站参考信息：

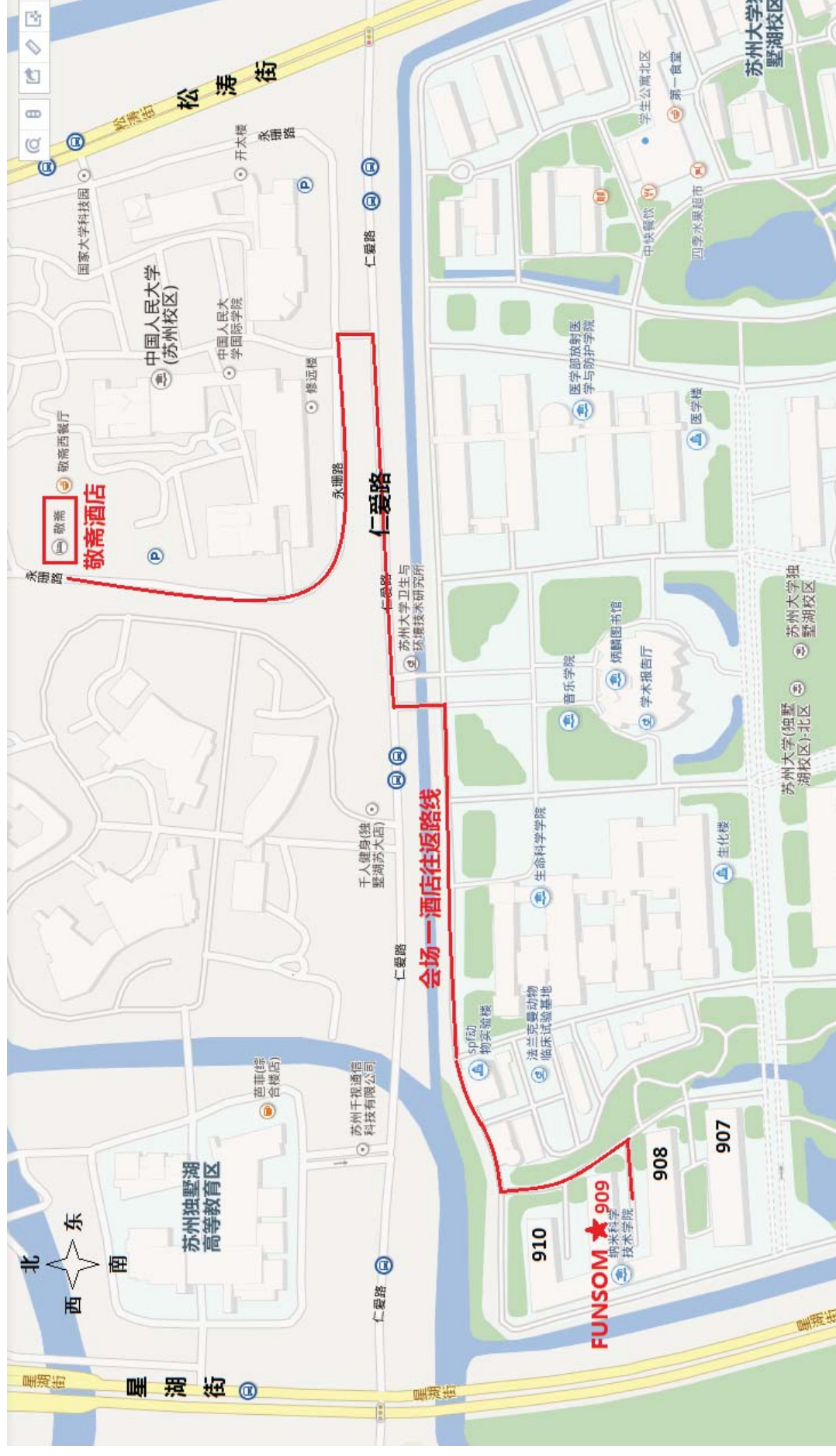
到达站	距离酒店公里数	打车花费时间预计
苏州园区站	10 公里	约 20 分钟
苏州火车站	18 公里	约 30 分钟
苏州火车北站	27 公里	约 40 分钟

附近火车站位置分布图：



酒店地址：苏州敬斋酒店，苏州工业园区仁爱路158号（中国人民大学国际学院内），电话：0512-62601999

会议地址：苏州大学功能纳米与软物质研究院（FUNSOM），苏州工业园区仁爱路199号909幢一楼B厅



会议日程

7月15日			
10:00-20:00	会议注册（敬斋酒店，一楼大厅）		
18:00-20:00	晚餐（敬斋酒店）		
7月16日			
8:15 在住地（敬斋酒店）乘车前往会议地点（约5分钟车程） 会议地点：苏州大学功能纳米与软物质研究院 909幢一楼B厅			
开幕式			
08:30-09:00	欢迎致辞： 苏州大学校长助理 嘉宾致辞： 国家自然科学基金委员会港澳台办主任 李国鼎科技发展基金会顾问	张晓宏先生 邹立尧先生 彭丽春女士	主持人： 廖良生
光电材料学术研讨会报告（25分钟报告，5分钟提问）			
时间	报告人	报告题目	主持人
09:00-09:30	周必泰	Excited-State Conformational/Electronic Responses of Hole Transporting Saddle-Shaped <i>N,N'</i> -Disubstituted-Dihydrodibenzo[<i>a,c</i>]-phenazines; A Paradigm of True Cross-Strait Collaboration	许千树 薄志山
09:30-10:00	花建丽	The Strategies to Develop Highly Efficient Sensitizers for DSSC	
10:00-10:30	合影，休息		
10:30-11:00	周卓辉	Healthy light-a killer application of OLED lighting	
11:00-11:30	段炼	Highly efficient and stable white OLEDs using materials with TADF	
11:30-14:00	午餐（敬斋酒店）		
14:00-14:30	郑建鸿	Organic Blue Dopants Having Triplet-Triplet Annihilation	周卓辉 胡斌
14:30-15:00	王磊	Materials, Interfaces and Device Structures for Highly Efficient Organic Light-emitting Diodes	
15:00-15:20	休息		

15:20-15:50	许千树	Development of Conjugated Polymers and Fullerene Derivatives for Organic Solar Cell Applications	
15:50-16:20	薄志山	Synthesis of Broad Band Gap Conjugated Polymers for Polymer Solar Cells	
16:20-17:00	参观苏州大学功能纳米与软物质研究院		
17:00	晚 餐		
7 月 17 日 8:15 在住地（敬斋酒店）乘车前往会议地点（约 5 分钟车程） 会议地点： 苏州大学功能纳米与软物质研究院 909 幢一楼 B 厅			
时间	报告人	报告题目	主持人
08:30-09:00	韦光华	Band-gap and Solubility Tunable Two-dimensional Conjugated Polymers for Photovoltaic Applications	周必泰 花建丽
09:00-09:30	胡 斌	Dynamic Donor:Acceptor and Electrode Interfaces in Organic Bulk-Heterojunction and Perovskite Solar Cells Under Device-Operating Condition	
09:30-09:50	休 息		
09:50-10:20	季 昀	New Trends in the Design of Transition-Metal Based OLED Phosphors	
10:20-10:50	廖良生	High-Efficiency Organic Solid-State Lighting Sources	
10:50-11:10	休 息		
11:10-11:40	总结交流		陶雨台
闭 幕 式			
11:40-12:00	嘉宾致辞： 李国鼎科技发展基金会顾问 高世平女士 国家自然科学基金委员会 高飞雪女士 化学科学部项目主任		廖良生
12:00	午餐（敬斋酒店）		
14:00-17:30	参观考察苏州工业园区		
7 月 18 日 08:30 从住地（敬斋酒店）乘车参观苏州大学其它校区和苏州高新区			

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Excited-State Conformational/Electronic Responses of Hole Transporting Saddle-Shaped N,N'-Disubstituted-Dihydrodibenzo[a,c]phenazines; A Paradigm of True Cross-Strait Collaboration

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During the past three years, through the intensive and solid cross-strait collaboration between Taipei and Shanghai, a great puzzle regarding the anomalous emission in a series of hole transporting N,N'-disubstituted-dihydrodibenzo[a,c]phenazines has been solved. The representative compounds DMAC (N,N'-dimethyl), DPAC (N,N'-diphenyl) and FIPAC (N-phenyl-N'-fluorenyl) reveal significant non-planar distortions (i.e., a saddle shape) and remarkably large Stokes-shifted emission independent of the solvent polarity. For DPAC and FIPAC with higher steric hindrance on the N,N'-substituents, normal Stokes-shifted emission also appears, for which the peak wavelength reveals solvent-polarity dependence. These unique photophysical behaviors are rationalized by electronic configuration coupled conformation changes en route to the geometry planarization in the excited state. This proposed mechanism is different from the symmetry rule imposed to explain the anomalously long-wavelength emission for DMP and is firmly supported by polarity-, viscosity-, and temperature-dependent steady-state and nanosecond time-resolved spectroscopy. Together with femtosecond early dynamics and computational simulation of the reaction energy surfaces, the results lead us to establish a sequential, three-step kinetics. Upon electronic excitation of N,N'-disubstituted-dihydrodibenzo[a,c]phenazines, intramolecular charge transfer takes place, followed by the combination of polarization stabilization and skeletal motion toward the planarization, i.e., elongation of the π -delocalization over the benzo[a,c]phenazines moiety. Along the planarization, DPAC and FIPAC encounter steric hindrance raised by the N,N'-disubstitutes, resulting in a local minimum state, i.e., the intermediate. The combination of initial charge-transfer state, intermediate, and the final planarization state renders the full spectrum of interest and significance in their anomalous photophysics. Depending on rigidity, the N,N'-disubstituted-dihydrodibenzo[a,c]phenazines exhibit multiple emissions, which can be widely tuned from red to deep blue and even to white light generation upon optimization of the surrounding media.

References

1. Z. Zhang, Y.-S. Wu, K.-C. Tang, C.-L. Chen, J.-W. Ho, J. Su, H. Tian, P.-T. Chou, *J. Am. Chem. Soc.*, 2015, DOI: 10.1021/jacs.5b03491.



Biography: The Florida State University (Ph.D. 1984), DOE Postdoctoral Fellow, University of California, Berkeley (1985-1987), Assistant Professor, University of South Carolina (1987-1994), Professor, National Chung-Cheng University (1994-2000), Professor, National Taiwan University (since 2001), Director, Center for Emerging Materials and Advanced Devices, National Taiwan University (since 2011).

Research Interests: Molecular Spectroscopy and Ultrafast Chemical Phenomena, Molecular Design, Synthesis and Applications, Semiconductor and Metal Nanomaterials in Optoelectronics, Solar Energy and OLEDs Relevant Research

The Strategies to Develop Highly Efficient Sensitizers for DSSC

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As the light-harvesting antennas of dye-sensitized solar cells (DSSC), sensitizers are the core part of the whole DSSC system. This research project is focused on the molecular design, chemical synthesis, structural analysis and performance measurement of novel highly efficient organic sensitizers for DSSCs. The main achievements are as follows: (1) Study on the performance of D-A- π -A organic sensitizers. Compared with the traditional D- π -A sensitizers, the introduction of strong electron-withdrawing group can easily tune the energy levels, enlarge the absorption wavelength range and improve the photostability of the sensitizer. We synthesized several series of sensitizers with strong electron-withdrawing quinoxaline, pyrido[3,4-b]pyrazine, [1,2,5]thiadiazolo[3,4-c]pyridine, and dithiazole unit as the auxiliary acceptor for the application on DSSC. DSSC based on quinoxaline as the additional acceptor and bulky indoline donor, exhibited the highest efficiency of 10.65 %; (2) Study on the high performance dye sensitizers. Organic sensitizers containing diketopyrrolopyrrole (DPP), quinacridone or isoindigo have good chemical and photochemical stabilities, as well as show strong absorption of light around 300~600 nm. These groups can not only expand conjugated system and spectral response range, but also enhance the intramolecular charge transfer efficiency and stability. We synthesized several series of organic sensitizers based on the high performance dyes, among which the device performance of a 2-ethyl-hexyl branched DPP-based sensitizer reached efficiency of 7.63 %; (3) Study on the performance of sensitizers containing double acceptors without COOH as anchors. The acceptors of organic sensitizers are normally featured with carboxylic acid (COOH). However, dye dissociation problems exist in this kind of sensitizers after longtime irradiation. We have reported a novel electron acceptor 2-(1,1-dicyanomethylene)rhodanine (DCRD). This acceptor group consists of strong electron-accepting rhodanine and dicyanomethylene, which can widen absorption spectra effectively; the O and N atoms of rhodanine in DCRD can chelate onto the TiO₂ surface to form coordination bond, improving the stability of sensitizers.

References

1. J. Mao, J. Hua, H. Tian, *Angew. Chem. Int. Ed.*, 2012, 51, 9873.
2. J. Yang, J. Hua, S. Zakeeruddin, H. Tian, *J. Am. Chem. Soc.*, 2014, 136, 5722.
3. W. Ying, J. Hua, S. Zakeeruddin, H. Tian, *Chem. Sci.*, 2014, 5, 206.
4. X. Li, J. Hua, H. Tian, *Chem. Sus. Chem.*, 2014, 7, 2879.
5. X. Li, Y. Zhou, J. Hua, H. Tian, *Chem. Commun.*, 2015, 10349.



Biography: Prof. Jianli Hua received her Ph.D. degree in Organic Chemistry from Wuhan University in 2002. From 2002 to 2004, Dr. Hua was a postdoctoral fellow at East China University of Science and Technology (ECUST) and she was a visiting scholar at the Hong Kong University of Science and Technology in 2005. Since 2002, she has been full professor and works at ECUST now.

Research Interests: The syntheses of novel functional organic dyes and polymers for optical-electronic and photovoltaic applications.

Organic Blue Dopants Having Triplet-Triplet Annihilation

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The limitation of fluorescent OLEDs can be overcome by the up-conversion of triplet to singlet states via two possible mechanisms. One is thermally activated delayed fluorescence (TADF)¹ and the other is triplet-triplet annihilation (TTA). For TADF materials, a small singlet-triplet energy gap of the material is necessary to enable fast conversion of the triplet excitons to singlet excitons by reverse intersystem crossing. In general, TADF material-based OLEDs can provide very high efficiency, but most of these devices show large efficiency roll-off, low luminance and low operational lifetime. TTA materials with high EL efficiencies are considered to be potential candidates for practical use.

In this talk, we will show you several new deep-blue dopants containing a styryl group as the core.^{2,3} Most of these dopants exhibit very high fluorescence quantum efficiencies near 100%. The deep-blue OLEDs fabricated using a suitable host such as 1-(2,5-dimethyl-4-(1-pyrenyl)phenyl)pyrene (DMPPP) doped with one of the dopants as the emitting layer exhibit very high external quantum efficiencies with CIE_y less than 0.14. The devices show delayed electroluminescence, but the dopants do not reveal any delayed photoluminescence.³ These observations suggest that these deep blue molecules possess TTA properties. In most cases, the EQEs and current efficiencies of these doped OLEDs increased with an increase in luminance, without compromising on the efficiency, owing to the increased TTA contribution at larger applied voltages.

References

1. H. Uoyama, K. Goushi, K. Shizu, H. Nomura, C. Adachi, *Nature*, 2012, 492, 234.
2. H. H. Chou, Y. H. Chen, H. P. Hsu, W. H. Chang, Y. H. Chen, C. H. Cheng, *Adv. Mater.*, 2012, 24, 5867.
3. P.-Y. Chou, H.-H. Chou, Y.-H. Chen, T.-H. Su, C.-Y. Liao, H.-W. Lin, W.-C. Lin, H.-Y. Yen, I.-C. Chen, C.-H. Cheng, *Chem. Commun.*, 2014, 50, 6869.



Biography: National Tsing Hua University (B. S.), University of Rochester (Ph.D.), Chairman, Department of Chemistry, NTHU (1990-93), Director General, Department of Natural Sciences, National Science Council, Taiwan(2006-9), President, Chemical Society Located in Taipei (2011-2012), Senior Vice President for Academic Affairs, NTHU (2010~2014).

Research Interests: (I) Synthesis of new organic and organometallic electroluminescent materials and fabrication of electroluminescent devices. (II) Transition metal-catalyzed organic reactions.

Materials, Interfaces and Device Structures for Highly Efficient Organic Light-emitting Diodes

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In this report, we carried out the research on materials, interfaces and devices for the organic light-emitting diodes (OLEDs), and obtained many important research achievements. A series of high performance organic optoelectronic materials, including high efficiency blue fluorescent emitters, high efficiency red, green, blue and orange phosphorescent emitters, bipolar and electron-transporting phosphorescent hosts, and electron transporters with high mobility, high triplet energy and high thermal stability were designed and synthesized. We also developed several interfacial materials for cathodes and anodes to improve the performance of OLEDs, and developed novel organic semiconductor heterojunctions as the electrode interfacial layers to eliminate the dependence of device performance on the used electrodes. In addition, a series of high performance OLEDs were designed and fabricated by us. Among them, the red, green and blue tandem phosphorescent OLEDs showed very high power efficiency of 50, 121 and 47 lm/W at the brightness of 1000 cd/m² without any light out-coupling techniques, respectively, and the red and green tandem devices possessed long lifetime of over 50000 hours. A hybrid white OLED by doping an orange phosphorescent guest into a blue fluorescent host was fabricated, and a high power efficiency of 63 lm/W was obtained at the brightness of 1000 cd/m² without light out-coupling technique, and its lifetime was more than 20000 hours.

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Research Interests: OLED 材料制备与器件制作; 有机/无机杂化近红外 OLED

Healthy Light-a Killer Application of OLED Lighting

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‘Energy-saving-only’ should no longer be crowned a top priority in the innovation of lighting science and technology. Energy-efficient white fluorescent and LED lights have been criticized for possessing blue hazards, including causing irreparable retina damage and suppression of melatonin secretion, while physiologically-friendly candlelight or incandescent light are blamed for energy-wasting. Thanks to the inherent design freedom, OLED based light sources can easily be made free of blue hazard, with also a relatively high light quality, e.g. high SRI (natural light spectrum resemblance index), and high power efficiency. Taking the candlelight-style OLED for example, it shows a less than 2% melatonin suppression sensitivity, and little threat to retina damage, while having a more than 900 times the efficacy of a candle. Along with a greater efficiency progress and cost-down effort made by the OLED giants, OLED promises to be the mainstream lighting technology very soon in the future.

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Research Interests: 有机发光二极管，高分子材料，薄膜应力测量，专家系统应用

Highly Efficient and Stable White OLEDs Using Materials with TADF

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White organic light-emitting diodes (WOLEDs) are widely researched due to their potential applications in flat panel displays and solid-state lightings. To solve the trade-off between the high efficiency and the long lifetime, hybrid WOLEDs with a tandem structure seem to be the most promising approach. For the phosphorescent unit in the tandem WOLEDs, a suitable host material should possess both a first triplet energy level (T1) high enough to fit the excited level of the emitting phosphors, and a first singlet energy level (S1) low enough to improve carrier injecting into the emitting layers (EMLs) and reduce the driving voltage. Besides, to obtain balanced charge transporting, hosts with bipolar features are highly desired. Here, materials with small singlet-triplet splits (ΔE_{ST}) show the potential to satisfy those demands through carefully design. Using materials with TADF as hosts for phosphorescent OLEDs, high efficiency, low efficiency roll-off, low voltage and long lifetime can be achieved simultaneously. Moreover, single-unit hybrid white OLEDs with a TADF blue emitter also showed high performance.

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Biography: Dr. Lian Duan was born in 1975. He received his Ph.D. from Department of Chemistry, Tsinghua University, in 2003. He is now with the Department of Chemistry, Tsinghua University. He has authored and co-authored over 100 SCI indexed papers. He has 74 patents filed and 39 issued.

Research Interests: Organic light-emitting materials and devices

Development of Conjugated Polymers and Fullerene Derivatives for Organic Solar Cell Applications

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Polymer solar cells (PSCs) are a promising alternative for clean and renewable energy due to their potential to be fabricated onto large area, light-weight flexible substrates by solution processing at low cost. Our recent progress in the molecular design of p-type conjugated polymers containing multi-fused ladder-type structure and the n-type fullerene derivatives containing cross-linkable styryl or epoxy groups will be presented. Both ladder-type conjugated polymers and n-type fullerene derivatives are used to fabricate high efficient bulk heterojunction PSCs. The cross-linkable fullerene derivatives are also used to fix the morphology of bulk heterojunction (BHJ) layer so as to improve the stability of PSCs. Finally a series of novel DA copolymers were developed by utilizing pyrene-modified porphyrin as complementary light-harvesting unit (LHU). It was found that adding proper amount of the LHU increased light absorption in the 400-500 nm region, rendering the porphyrin-incorporated D-A copolymers (PPor) panchromatic light absorbers. Voc-Jsc trade-offs commonly seen in many D-A polymers were not found in the PPors reported in this work. This is attributed to the presence of the LHUs increasing the Jsc without sacrificing the Voc and FF of the polymer solar cells (PSCs). Thus, 8.0% PCE was observed for the PPor-2: PC71BM single-junction PSCs. Significantly, 8.6% PCE was achieved when a C-PCBSD cathodic interlayer was introduced to suppress linkage current.

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Research Interests: Green Energy materials, OLED materials and devices, Organic photovoltaics materials and devices

Synthesis of Broad Band Gap Conjugated Polymers for Polymer Solar Cells

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Recently, polymer solar cells (PSCs) with conjugated polymers as the donor and (6,6)-phenyl-C61-butyric acid methyl ester (PC61BM) or (6,6)-phenyl-C71-butyric acid methyl ester (PC71BM) as the acceptor have afforded the power conversion efficiency up to 11%. However, most high efficiency (>7%) polymer donor materials are small band gap materials, and high efficiency large band gap polymers are very rare. For the fabrication of high efficiency tandem solar cells, both high efficiency small band gap and large band gap polymers are required. We report the design and synthesis of a new kind of large band gap conjugated polymer HD-PDFC-DTBT, in which 3,6-difluorocarbazole was used as the acceptor unit and 5,6-dialkyloxybenzothiazole as the acceptor unit. Inverted polymer solar cells with HD-PDFC-DTBT as the donor and PC71BM as the acceptor showed a PCE of 7.39%. Considering a large band gap of 1.96 eV, HD-PDFC-DTBT is a very promising large gap material for the fabrication of tandem solar cells.

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Biography: Jilin University (Ph.D. 1997), Assistant engineer in Shanxi Chemical engineering Institute (1989-1991). Postdoctoral fellow, Free University Berlin and North Carolina State University (1997-2002). Professor, Institute of Chemistry Chinese Academy of Sciences (2002-2010). Professor, Beijing Normal University (since 2010).

Research Interests: Synthesis of conjugated polymers and polymer solar cells.

Band-gap and Solubility Tunable Two-dimensional Conjugated Polymers for Photovoltaic Applications

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We used Stille coupling of electron-rich benzo[1,2-b:4,5-b']dithiophene (BDT) presenting conjugated alkylthiophene (T), alkylphenyl (P), or alkylfuran (F) side chains with electron-deficient alkoxy-modified 2,1,3-benzooxadiazole (BO) moieties to obtain a series of two-dimensional, conjugated, D- π -A polymers (PBDTTBO, PBDTPBO, and PBDTFBO). We also synthesized a series of novel two-dimensional Se-atom-substituted donor (D)- π -acceptor (A) conjugated polymers—PBDTTTBO, PBDTTTBS, PBDTTSBO, PBDTSTBO, PBDTTSBS, PBDTSTBS, PBDTSSBO, and PBDTSSBS—featuring benzodithiophene (BDT) as the donor, thiophene (T) as the π -bridge, and 2,1,3-benzooxadiazole (BO) as the acceptor with different number of Se atoms at different π -conjugated locations. Synchrotron X-ray¹ determined the molecular packing for these polymers. When using 1-chloronaphthalene (1 vol %) or 1,8-diiodooctane (1 vol %) as an additive² for processing the active layer, the power conversion efficiencies (PCEs) of photovoltaic devices incorporating blends of PBDTFBO, PBDTPBO, or PBDTTBO and PC71BM (1:2) improved to 5.4, 6.4, and 7.4%, respectively, due to their optimized morphologies³. The rational structural modification of the 2-D conjugated Se-substituted polymers⁴ the resulting PCEs could vary over 3-fold (from 2.4 to 7.6%), highlighting the importance of careful selection of appropriate chemical structures such as the location of Se atoms when designing efficient D- π -A polymers for use in solar cells. For the PBDTTBO:PC71BM (1:2, w/w) device featuring PEI/ZnO electron transport layer, the PCE improved to 8.7%.

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Biography: UMass/Amherst (Ph.D., 1987), Fellow, Materials Research Society, Taiwan (since 2010), Distinguished Professor, National Chiao Tung Univ., Taiwan (2011-2017), Chair Professor, National Chiao Tung Univ., Taiwan (since 2015)

Research Interests: Synthesis of donor-acceptor conjugated polymers for solar cells and light emitting diodes, II-VI group colloidal quantum dots/ block copolymer nanocomposites, graphene, MoS₂ 2D materials, polyhedral oligomeric silsesquioxane/polymer nanocomposites

Dynamic Donor:Acceptor and Electrode Interfaces in Organic Bulk-Heterojunction and Perovskite Solar Cells Under Device-Operating Condition

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Organic bulk-heterojunction and perovskite solar cells have shown surprisingly high photovoltaic actions with the efficiencies reaching 15 % from simple device designs. These quick advancements bring a fundamental demand to the field: revealing deeper internal photovoltaic processes at dynamic donor:acceptor (D:A) and electrode interfaces under-device-operating condition. At this moment, the deeper internal photovoltaic processes at the dynamic D:A and electrode interfaces still remain largely un-revealed, forming a great challenge to further advance the field of organic solar cells. To respond to this great challenge, we have investigated the dynamic D:A and electrode interfaces under device-operating condition by using our previously defined unique experimental methods: magnetic field effects of photocurrent and photo-induced capacitance. Our fundamental studies have focused on two timely-important issues: (i) controlling the electron-hole binding energies at D:A interface through polarization and energy parameters and (ii) enhancing the charge collection at electrode interface through dielectric effects in both bulk-heterojunction and perovskite solar cells. This presentation will discuss the critical understanding and effective knowledge base on controlling the useful and non-useful photovoltaic processes at both D:A and electrode interfaces towards further photovoltaic advancements in bulk-heterojunction and perovskite solar cells.



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Research Interests: Spin-dependent processes in excited states and charge transport in organic semiconductors; Magneto-optic studies on photovoltaic processes at different length scales; Electric polarization-controllable thermoelectric effects in organic materials.

New Trends in the Design of Transition-Metal Based OLED Phosphors

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Luminescent third-row transition metal Os(II), Ir(III) and Pt(II) based complexes, particularly those with cyclometalating chelates and equivalent ancillaries, play a key role in the development of optoelectronic technologies such as organic light emitting diode (OLED), light emitting electrochemical cells, and solid-state organic lighting applications. Their attractiveness comes from their higher chemical stability due to the strong metal-ligand bonding, as well as the shortened excitation lifetimes and higher emission quantum yields versus the pure organic phosphorescent materials. Furthermore, the strong spin-orbit coupling induced by the central metal ion promotes an efficient intersystem crossing from the singlet to the triplet excited state manifold, which then facilitates strong electroluminescence by harnessing both singlet and triplet excitons of the as-fabricated optoelectronic devices. As a result, these transition metal based complexes were extensively examined as the dopant emitter for high efficient OLEDs. In this presentation, the recently development of new OLED phosphors, particularly those constructed with dianionic bidentate and tridentate chromophores, such as biazolate and 2-azolyl-6-phenylpyridine chelates, alone with diimine, NHC carbene, and other functional monoanionic tridentate chelates, as well as those showed horizontal arranged transition dipole moment during deposition of EML, will be elaborated in a systematic manner.

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Biography: He obtained his Ph.D. from University of Illinois at Urbana-Champaign in 1986. After a one-year postdoctoral work at MIT, he joined National Tsing Hua University (NTHU) as associated professor, and now is appointed as Distinguished Chair Professor. He has coauthored ~295 research papers and 3 book chapters, as well as held > 30 domestic and international patents. He received the National Chair Professorship in 2010 and introduced into the Asia Pacific Academy of Materials (APAM) in 2013.

Research Interests: organometallic and material chemistry

Electrode work function modulation with self-assembled monolayer and its effect on charge balance and device lifetime in organic light-emitting diodes

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Organic light-emitting diodes (OLEDs) have become a realistic technology in fabricating flat panel displays because of the rapid progress in academia and industry research efforts. The major focus in OLED research is the improvement of the device efficiency and extension of device life time. Various factors are contributing to the efficiency of the device, among which the balance of charge carriers is one factor that is difficult to quantitatively characterized. The amount of charge carriers injected depends on the energy barrier of charge injection, which can be systematically modulated by surface modification. In this work we used a well-ordered organic monolayer to modify a metal electrode to change its surface properties including wetting characteristics, roughness, as well as work function through the use of a series of molecules with different functional groups, molecular chain length, and composition in mixed monolayers. Analysis of the trends in current density and device efficiency were conducted to reveal the information on the charge balance within the device. Depending on the hole transporting material or electron transporting material used, different surface modification is needed to achieve the charge balance, which leads to optimal efficiency for given materials.

In addition to the efficiency, the surface modification also provide a work function that is stable during the device operation so that great enhancement of device life time is observed.

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Biography: Research Fellow, Institute of Chemistry, Academia Sinica (since 2006), University of Rochester (Ph.D. 1981). Associate Research Fellow(1984-1990), Research Fellow(1990-2006).

Research Interests: materials chemistry, surface and interfacial chemistry, electronic materials and devices.

High-Efficiency Organic Solid-State Lighting Sources

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Organic light-emitting diodes (OLEDs) are potentially useful as solid-state lighting sources. However, an OLED is actually a current-driven device. With increasing current density, its luminance increases but its operational lifetime decreases. Thus, it is a challenge to fabricate high performance OLEDs which could meet lighting requirements for both high brightness ($> 1000 \text{ cd/m}^2$) and long operational time ($>30,000 \text{ h}$).

A tandem OLED can be accomplished by vertically stacking several individual electroluminescent (EL) units together, which are internally connected in series and driven by a single power source. In a tandem OLED with N EL units ($N > 1$), the current efficiency can be about N times as high as that of a conventional OLED that contains only one EL unit. Therefore, the tandem OLED needs only about $1/N$ times the current density used in the conventional OLED to obtain the same luminance, which results in an operational lifetime N times that of the conventional OLED.

In this presentation, we will discuss the device structure, light extraction, design of light-emitting materials, and fabrication of large panels of high-efficiency and long lifetime tandem OLEDs. Our results demonstrate that tandem OLEDs are indeed promising for use as organic solid-state lighting sources.



Figure 1 OLED panels fabricated in the lab at Soochow University



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Research Interests: Architecture, physics and materials of organic light-emitting diodes and organic solar cells.

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