CRF 8G (Revised Sep 15)

RGC Reference: CUHK1/CRF/12G
please insert ref. above

The Research Grants Council of Hong Kong
Collaborative Research Fund Group Research Projects
Completion Report

(*for completed projects only*)

Part A: The Project and Investigator(s)

1. Project Title

Functional Plasmonics with Energy Localization for Sensing, Nano-Actuation and Optoelectronics

2. Investigator(s) and Academic Department/Units Involved *(please highlight approved changes in the composition of the project team and quote the date when RGC granted approval of such changes)*

Research Team	Name/Post	Unit/Department/Institution	Average number of hours per week spent on this project in the current reporting period
Project Coordinator	Ho, Ho-pui Aaron/Professor	Electronic Engineering/CUHK	5
Co-Principal investigator(s)	Chan, Che Ting/Chair Professor	Physics/HKUST	1
	Cheah, Kok Wai/Chair Professor	Physics/HKBU	1
	Choy, Chik Ho Wallace/ Professor	Electrical and Electronic Engineering/HKU	1
	Li, Tsan Hang Jensen/Senior Lecturer	Physics/U. of Birmingham, UK	1
	Kong, Siu Kai/Professor	School of Life Sciences/CUHK	1
	Ong, Hock Chun/Associate Professor	Physics/CUHK	1
	Pun, Yue Bun Edwin/Chair Professor	Electronic Engineering/CityU	1
	Surya, Charles/Professor	Electronic and Information Engineering/PolyU	1

	Wang, Jianfang/Professor	Physics/CUHK	1
	Wong, Kam Sing/Professor	Physics/HKUST	1
	Xu, Jian-Bin/Professor	Electronic Engineering/CUHK	1
Collaborators/ Others	N/A	N/A	

3. Project Duration

	Original	Revised	Date of RGC Approval *(must be quoted*)
Project Start Date	1st March 2013	N/A	6th February 2013
Project Completion Date	29th February 2016	N/A	6th February 2013
Duration (*in month*)	36	N/A	6th February 2013
Deadline for Submission of Completion Report	28th February 2017	N/A	N/A

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. *Investigation of plasmon excitation in artificial metallic nanostructures and their variants through theoretical and experimental studies for generating energy localization and strong optical forces.*
2. *Development of plasmonic device strategies for surface plasmon-mediated applications.*
3. *Demonstration of a feasible platform integrating plasmonic biosensing as well as optical manipulation for conducting SERS, SPR, and multi-photon analysis.*
4. *Demonstration of plasmonic organic photovoltaics and light-emitting diodes with enhanced energy conversion and photon-extraction efficiencies.*
5. *Establishment of a synergistic multidisciplinary research community for the advancement of plasmonics technology.*

5.2 Revised objectives

Date of approval from the RGC: 5th March 2013

Reasons for the change: Reduction in funding as compared to the amount requested in the original proposal.

1. *Investigation of plasmon excitation in artificial metallic nanostructures and their variants through theoretical and experimental studies for generating energy localization and strong optical forces.*
2. *Development of plasmonic device strategies for surface plasmon-mediated applications.*
3. *Demonstration of a feasible platform integrating plasmonic biosensing as well as optical manipulation for conducting SERS, SPR, and multi-photon analysis.*
4. *Establishment of a synergistic multidisciplinary research community for the advancement of plasmonics technology.*

6. Research Outcome

6.1 Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

1. Common-path spectral surface plasmon resonance interferometric sensing with 10^{-7} RIU resolution and measurement range of 0.1 RIU (CU#11, CU#24)
2. Cytotoxic and sublethal effects of silver nanoparticles on stem-cells (CU#26)
3. Squeezing the local density of state (LDOS) in a hybrid dielectric-plasmonic ring structure for ultrasensitive plasmonic sensing (CU#5)
4. Establishment of the general condition of "absorption rate = radiative decay rate" for achieving best field enhancement in sensing devices based on 2-dimensional periodic plasmonic structures (CU#0, CU#1, CU#2, CU#3, CU#4)
5. Efficient nano-optical trapping and microfluidic actuations based on plasmon-induced localized heating (CU#6, CU#7, CU#8)
6. Demonstration of new metasurface holograms based on periodic plasmonic structures (CITYU#0)
7. Novel colloidal synthesis of periodic plasmonic nanostructures on transparent substrates (HKU#7)
8. New plasmonic gratings from random nanoparticles (HKU#0)
9. New class of room-temperature solution-process nano-metal flexible electrode (HKU#7)
10. (Gold nanorod core)/(polyaniline shell) plasmonic switches with large plasmon shifts and modulation depths (CU#9)
11. Plasmonic and structural evolutions during the sulfidation of silver nanocubes (CU#13)
12. SERS using metal nanoparticle – multi-layer graphene nanospacer (HKU#5)
13. Breaking the space charge limit in organic solar cells OSCs by a novel plasmonic-electrical conduction approach (HKU#3)
14. Enhanced OSC performance by varying the morphologies of plasmonic nanoparticles (POLYU#0)
15. Graphene/Silicon heterojunction based high performance photodetector (CU#18, CU#19, CU#20)
16. Circular polarized SHG in single-layered gold sawtooth structures (UST#1)
17. SERS based on a "trap-and-sense" strategy enabled by plasmonic localized heating (CU#22)
18. Photon-free trapping based on localized thermal heating effects (CU#23)

6.2 Potential for further development of the research and the proposed course of action *(maximum half a page)*

This project has initiated a new research direction based on plasmon-absorption induced heating effects. This topic involves a broad range of physical processes within the domain of nano-science, namely fluidics, thermal diffusion, thermo-mechanical forces and photo-acoustics. The PC and members of the project team (CT Chan, HC Ong, SK Kong) will continue to pursue in studying the details of thermo-mechanical forces through conducting extensive trapping and fluidic flow imaging experiments, as well as finite-element modelling (FEM), to map out the dynamic characteristics of fluids surrounding the plasmonic nano-structure. While new application opportunities such as (i) ultrafast spatial switching of nano-heaters by taking advantage of plasmon resonances and (ii) amplification of nucleic acids with ultra-low sample volume through temperature cycling by plasmonic absorption, one direction, currently ongoing within the PC's group, is to explore scanning nano-acousto-microscopy through plasmonic absorption of femto-second (fs) laser pulses in random nano-islands deposited on a fiber-tip.

Another potential area for further development is the exploration of surface plasmon resonance (SPR) biosensors based on spectral-phase analysis. This project has demonstrated the merits of sensitivity and measurement range of the spectral phase detection approach. Currently, the PC is developing a Fourier-Transform spectrometer, akin to the interferometers developed for optical coherence tomography (OCT), for achieving a highly compact SPR biosensing system. Ultimately, we are aiming for commercialization of the technology.

6.3 Research collaboration achieved *(please give details on the achievement and its relevant impact)*

- Mike Somekh (Department of Electronic and Information Engineering, Hong Kong Polytechnic University) – Plasmon-absorption induced ultrasound for nano-acousto-microscopy. The aim is to perform non-electromagnetic microscopy with GHz ultrasound generated through plasmonic absorption of fs laser pulses and focusing using a polymer lens. The impact is significant as high resolution microscopy below the 100nm regime is currently only achievable with electromagnetic radiation. Acoustic radiation, due to its heavy attenuation at high frequencies, has never been able to provide spatial resolution beyond the micrometer regime. With the plasmonic-absorption induced heating work established through this project, GHz ultrasound pulses have been generated by guiding fs laser pulses to an Au-coated fiber tip. Further efforts are now ongoing to fabricate a polymer based zone plate lens in front of the fiber tip to generate the final ~100nm focal spot. Since the fiber tip is a well-suited for scanning operations, we anticipate that this work will lead to a practical nano-acousto-microscope.
- Donghyun Kim (Department of Electrical and Electronic Engineering, Yonsei University) – Surface plasmon polariton (SPP) mediated nano-microscopy with metallic random nano-islands. The project PC spent two weeks in February 2015 visiting Professor Kim at Yonsei University. The extended meeting resulted in

using the plasmonic nano-island approach for high resolution optical microscopy based on field location in the random islands. This approach requires simple annealing steps and there is virtually no limitation on the area of the substrate. Hot-spots are always available anywhere within the substrate.

- Sai Tak Chu (Department of Physics and Materials Science, City University of Hong Kong) – Optical trapping with ultrahigh-Q resonant rings. While integrated optical waveguides are known to be able to generate evanescent field that can perform optical trapping of objects, the significance of this work comes from the fact that ultrahigh-Q ring resonators can generate massive increase in field intensity within the ring structure. Preliminary results have already confirmed a significant reduction in trapping threshold. Through controlling the power balance between the counter propagating power coupling ports, we can manipulate the optical interference within the ring and thus gaining the possibility to control the movement of the trapped objects along the ring. The next stage is to deposit a layer of plasmonic random nano-islands directly above the ring and look for further reduction in trapping threshold as well as improvement in spatial resolution. This work will ultimately lead to practical integrated waveguide devices that can perform both trapping and sensing operations and be directly integrated to microfluidic systems.

7. The Layman's Summary

(describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

When electromagnetic field impinges at the surface of a metal object, the field strength immediately becomes enhanced because of the induced oscillatory movement of the free electrons inside. These oscillations are also called surface plasmons. Plasmonics is a new term that collectively describes the science and technology of this effect. Surface plasmons have many desirable attributes, including amplification of intensity near a metal surface and strong field localization within the nanometer scale. Such properties are very attractive for a wide range of photonics applications. One excellent example of which is the plasmonic biosensor, capable of detecting biomolecules in extremely low concentration levels. Because of plasmonics, optical traps for the manipulation of nano-sized objects have become possible.

This project aims to investigate the design and application of nano-structures that possess "hotspots" with highly intensified optical intensity levels. We shall also demonstrate their unique merits in several applications including "label-free" bio-detection (i.e., no requirement of fluorescent tags), non-linear optical activities, polarisation manipulation, nano-optical trapping, organic solar cells and light-emitting diodes. In addition, knowledge gained through this project on the management of electromagnetic field has impacts in many applications where light-matter interaction is of prime importance.

Part C: Research Output

8. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal/Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of RGC *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance (For paper accepted but not yet published)	Under Review	Under Preparation (optional)						
CU#0 2014				ZhaoLong Cao, Lei Zhang, Chung-Yu Chan, and Hock-Chun Ong*	Interplay between absorption and radiative decay rates of surface plasmon polaritons for field enhancement in periodic arrays, Opt. Lett. 39, 501-503 (2014)	Yes (2014)	Yes	Yes	No
CU#1 2014				ZhaoLong Cao, and Hock-Chun Ong*	Determination of the absorption and radiative decay rates of dark and bright plasmonic modes, Opt. Exp. 22, 16114-16129 (2014)	Yes (2014)	Yes	Yes	No
CU#2 2013				ZhaoLong Cao, and Hock-Chun Ong*	Determination of coupling rate of light emitter to surface plasmon polaritons supported on nanohole array, App. Phys. Lett. 102, 241109 (2013)	Yes (2014)	Yes	Yes	No
CU#3 2013				C.Y. Chan, Z.L. Cao, and H.C. Ong*	Study of coupling efficiency of molecules to surface plasmon polaritons in surface-enhanced Raman scattering	Yes (2014)	Yes	Yes	No

					(SERS), Opt. Exp. 21, 14674-82 (2013)				
CU#4 2014				Z. L. Cao, S. L. Wong, S. Y. Wu, H. P. Ho, and H. C. Ong*	High performing phase-based surface plasmon resonance sensing from metallic nanohole arrays, Applied Physics Letters, 104, 171116 (2014)	Yes (2014)	Yes	Yes	No
CU#5 2014				Haixi Zhang, Yanyan Zhou, Xia Yu, Feng Luan, Jianbin Xu, Hock-Chun Ong, and Ho-Pui Ho*	Dressing plasmon resonance with particle-microcavity architecture for efficient nano-optical trapping and sensing, Optics Letters, 39, 873-876 (2014)	Yes (2014)	Yes	Yes	No
CU#6 2014				Zhiwen Kang, Haifei Lu, Jiajie Chen, Kun Chen, Fang Xu, and Ho-Pui Ho*	Plasmonic graded nano-disks as nano-optical conveyor belt, Optics Express 22, 19567-19572 (2014)	Yes (2014)	Yes	Yes	No
CU#7 2015				Zhiwen Kang, Jiajie Chen, Shu-Yuen Wu, Siu-Kai Kong, Ken-Tye Yong, and Ho-Pui Ho*	Trapping and assembling of particles and live cells on large-scale random gold nano-island substrates, Scientific Reports 5, 9978 (2015)	Yes (2014)	Yes	Yes	No
CU#8 2015				Jiajie Chen, Zhiwen Kang, Guanghui Wang, Fong-Chuen Loo, Siu-Kai Kong and Ho-Pui Ho*	Optofluidic Guiding, Valving, Switching and Mixing based on Plasmonic Heating in Random Gold Nanoisland Substrate，Lab Chip 15, 2504 (2015)	Yes (2014)	Yes	Yes	No

CU#9 2014				Nina Jiang, Lei Shao, and Jianfang Wang*	(Gold Nanorod Core)/(Polyaniline Shell) Plasmonic Switches with Large Plasmon Shifts and Modulation Depths, Adv. Mater. 26, 3282-3289 (2014)	Yes (2014)	Yes	Yes	No
CU#10 2013				Shuwen Zeng, Xia Yu, Wing-Cheung Law, Yating Zhang, Rui Hu, Xuan-Quyen Dinh, Ho-Pui Ho, Ken-Tye Yong*	Size dependence of Au NP-enhanced surface plasmon resonance based on differential phase measurement, Sensors and Actuators B 176, 1128-1133 (2013)	No	Yes	No (The project PC helped in the analysis of field enhancement between AuNP and the Au underlay, also the hardware setup for differential phase detection.)	No
CU#11 2013				Siu Pang Ng, Fong Chuen Loo, Shu Yuen Wu, Siu Kai Kong, Chi Man Lawrence Wu, and Ho Pui Ho*	Common-path spectral interferometry with temporal carrier for highly sensitive surface plasmon resonance sensing, Opt. Exp. 21, 20268-20273(2013)	No	Yes	No (This project has provided hardware and technical support for the work reported in this publication.)	No
CU#12 2014				Shuwen Zeng, Dominique Baillargeat, Ho-Pui Ho and Ken-Tye Yong*	Nanomaterials enhanced surface plasmon resonance for biological and chemical sensing applications, Chem. Soc. Rev. 43, 3426-3452 (2014)	Yes (2014)	Yes	No (The PC has contributed to the writing of this review article. Some of the data reported in this article were produced through	No

								this project.)	
CU#13 2013				Caihong Fang, Yih Hong Lee, Lei Shao, Ruibin Jiang, Jianfang Wang,* and Qing-Hua Xu*	Correlating the Plasmonic and Structural Evolutions during the Sulfidation of Silver Nanocubes，ACS Nano 7, 9354-9365 (2013)	Yes (2014)	Yes	Yes	No
CU#14 2014				Lei Shao, Qifeng Ruan, Ruibin Jiang, and Jianfang Wang*	Macroscale Colloidal Noble Metal Nanocrystal Arrays and Their Refractive Index-Based Sensing Characteristics，Small 10, 802-811(2014)	Yes (2014)	Yes	Yes	No
CU#15 2014				Qifeng Ruan, Lei Shao, Yiwei Shu, Jianfang Wang,* and Hongkai Wu*	Growth of Monodisperse Gold Nanospheres with Diameters from 20 nm to 220 nm and Their Core/Satellite Nanostructures，Adv. Opt. Mater. 2, 65-73 (2014)	Yes (2014)	Yes	Yes	No
CU#16 2016				Zhiwen Kang, Jiajie Chen and Ho-Pui Ho*	Surface-enhanced Raman scattering via entrapment of colloidal plasmonic nanocrystals by laser generated microbubbles on random gold nano-islands, Nanoscale 8, 10266 (2016)	No	Yes	Yes	No
CU#17 2013				Jiajie Chen, Zhiwen Kang, Siu Kai Kong, and Ho-Pui Ho*	Plasmonic random nanostructures on fiber tip for trapping live cells and colloidal particles, Opt. Lett. 40,	No	Yes	Yes	No

					3926-3929 (2013)				
CU#18 2013				Xiaomu Wang, Zhenzhou Cheng, Ke Xu,Hon Ki Tsang，and Jian-Bin Xu*	High-responsivity graphene/silicon-heterostructure waveguide photodetectors, Nature Photonics 7, 888–891 (2013)	No	Yes	Yes	No
CU#19 2015				Jiaqi Wang, Zhenzhou Cheng, Zefeng Chen*, Jian-Bin Xu, Hon Ki Tsang, and Chester Shu	Graphene photodetector integrated on silicon nitride waveguide, JOURNAL OF APPLIED PHYSICS 117, 144504 (2015)	No	Yes	Yes	No
CU#20 2015				Zefeng Chen, Zhenzhou Cheng, Jiaqi Wang, Xi Wan, Chester Shu, Hon Ki Tsang, Ho Pui Ho, Jian-Bin Xu*	High Responsivity, Broadband, and Fast Graphene/Silicon Photodetector in Photoconductor Mode, Adv. Optical Mater. 3, 1207–1214 (2015)	No	Yes	Yes	No
CU#21 2015				H.F. Lu, X. Ren, E.I. Wei, J.J. Chen, Z.W. Kang, H.X. Zhang, H.P. Ho and W. C. Choy*	Experimental and Theoretical Investigation of Macro-Periodic and Micro-Random Nanostructures with Simultaneously Spatial Translational Symmetry and Long-Range Order Breaking, Scientific Reports, DOI:10.1038/srep07876 (2015).	No	Yes	Yes	No
CU#22 2016				Zhiwen Kang, Jiajie Chen and Ho-Pui Ho*	Surface-enhanced Raman scattering via entrapment of colloidal plasmonic nanocrystals by laser generated	No	Yes	Yes	No

					microbubbles on random gold nano-islands, Nanoscale 8, 10266-72 (2016).				
CU#23 2016				Jiajie Chen, Hengji Cong, Fong-Chuen Loo, Zhiwen Kang, Minghui Tang, Haixi Zhang, Shu-Yuen Wu, Siu-Kai Kong and Ho-Pui Ho*	Thermal gradient induced tweezers for the manipulation of particles and cells, Scientific Reports 6, 35814 (2016) DOI: 10.1038/srep35814	No	Yes	Yes	No
CU#24 2015				Jacky F.C. Loo, S.S. Wang, F.Peng, J.A. He, L. He, Y.C. Guo, D.Y. Gu, H.C. Kwok, S.Y. Wu, H.P. Ho, W.D. Xie, Y.H. Shao and S.K. Kong*	A non-PCR SPR platform using RNase H to detect MicroRNA 29a-3p from throat swabs of human subjects with influenza A virus H1N1 infection, Analyst 140, 4566-75 (2015)	No	Yes	Yes	No
CU#25 2016				F. Peng, J. He, J.F. Loo, J. Yao, L. Shi, C. Liu, C. Zhao, W. Xie, Y. Shao, S.K. Kong,* D. Gu	Identification of microRNAs in Throat Swab as the Biomarkers for Diagnosis of Influenza, Int J Med Sci. 25, 77-84 (2016).	No	Yes	Yes	No
CU#26 2016				T.S. Cheung, P.M. Lau, H Lu, H.P. Ho, P.P.Y. Lui, S.K. Kong*	Cytotoxic and sublethal effects of silver nanoparticles on tendon-derived stem cells-implications for tendon engineering, Toxicol. Res. 5, 318-330 (2016).	No	Yes	Yes	No
HKU#0 2015				Haifei Lu, Xingang Ren, Wei E. I. Sha, Ho-Pui Ho, Choy Wallace*	Broadband near-field enhancement in the macro-periodic and micro-random structure with a hybridized excitation of propagating Bloch-plasmonic and localized surface-plasmoni	No	Yes	Yes	No

					c modes, Nanoscale 7, 16798 (2015).				
HKU#1 2014				Wallace C. H. Choy*	The emerging multiple metal nanostructures for enhancing the light trapping of thin film organic photovoltaic cells, Chem. Comm. 50, 11984-11993 (2014).	Yes (2014)	Yes	Yes	No
HKU#2 2014				A. Ng, W. K. Yiu, Y. S. Foo, Q. Shen, A. Bejaoui, Y. Y. Zhao, H. C. Gokkaya, A. B. Djurišić, J. A. Zapien, W. K. Chan and C. Surya*	Enhanced performance of PTB7:$PC_{71}BM$ solar cells via different morphologies of gold nanoparticles, ACS Appl. Mater. Interfaces 6 (23), 20676–20684 (2014).	No	Yes	Yes	No
HKU#3 2014				Wei E. I. Sha, Xuanhua Li & Wallace C. H. Choy*	Breaking the Space Charge Limit in Organic Solar Cells by a Novel Plasmonic-Electrical Concept, Scientific Reports 4, 6236 (2014).	Yes (2014)	Yes	Yes	No
HKU#4 2014				Wallace C. H. Choy *, Wei E. I. Sha, Xuanhua Li, and Di Zhang	Multi-Physical Properties of Plasmonic Organic Solar Cells，Progress In Electromagnetics Research 146, 25-46 (2014).	Yes (2014)	Yes	Yes	No
HKU#5 2014				Xuanhua Li, Wallace C. H. Choy,* Xingang Ren, Di Zhang, and Haifei Lu	Highly Intensified Surface Enhanced Raman Scattering by Using Monolayer Graphene as the Nanospacer of Metal Film–Metal Nanoparticle Coupling	Yes (2014)	Yes	Yes	No

					System, Adv. Functional Mat. 24, 3114–3122 (2014).				
HKU#6 2014				Wallace C. H. Choy,* Wai Kin Chan,* and Yuping Yuan	Recent Advances in Transition Metal Complexes and Light-Management Engineering in Organic Optoelectronic Devices, Adv. Mat., invited 26, 5368-5399 (2014).	Yes (2014)	Yes	Yes	No
HKU#7 2014				Haifei Lu, Di Zhang, Xingang Ren, Jian Liu, and Wallace C. H. Choy*	Selective Growth and Integration of Silver Nanoparticles on Silver Nanowires at Room Conditions for Transparent Nano-Network Electrode, ACS Nano 8, 10980–10987 (2014).	Yes (2014)	Yes	Yes	No
HKU#8 2014				Feng Xian Xie, Di Zhang, Huimin Su, Xingang Ren, Kam Sing Wong, Michael Grätzel, and Wallace C. H. Choy*	Vacuum-assisted thermal-annealing process to control $CH_3NH_3PbI_3$ perovskite morphology for highly stable and efficient solar cells, ACS Nano 9, 639–646 (2014).	No	Yes	Yes	No
UST#0 2014				Yilin Zhang, Jie Li, Ben Zhong Tang, and Kam Sing Wong*	Aggregation Enhancement on Two-Photon Optical Properties of AIE-Active D□TPE□A Molecules, J. Phys. Chem. C, 118 (46), (2014)	No	Yes	Yes	No
UST#1 2016				H. Su, Y. Guo, W. Gao, J. Ma, Y. Zhong, W. Y. Tam, C. T. Chan and K. S. Wong*	Multipolar effects in the optical active second harmonic generation from sawtooth chiral metamaterials, Scientific	No	Yes	Yes	No

					Reports 6, 22061 (2016).				
UST#2 2015				X. L. Zhang, S. B. Wang, Z. F. Lin, H. B. Sun and C. T. Chan*	Optical force on toroidal nanostructures: toroidal dipole versus renormalized electric dipole, Physical Review A 92, 043804 (2015).	No	Yes	Yes	No
UST#3 2015				C. Han, H. M. Leung, C. T. Chan and W. Y. Tam*	Giant plasmonic circular dichroism in Ag staircase nanostructures, Optics Express 23, 33065-33078 (2015).	No	Yes	Yes	No
UST#4 2015				Hong Zhang, Jian Mao, Hexiang He, Di Zhang, Hugh L. Zhu, Fengxian Xie, Kam Sing Wong, Michael Grätzel and Wallace C. H. Choy*	A smooth $CH_3NH_3PbI_3$ film via a new approach for forming the PbI_2 nanostructure together with strategically high CH3NH3I concentration for high efficient planar heterojunction solar cells, Advanced Energy Materials 23 1501354 (2015); DOI:10.1002/aenm.201501354	No	Yes	Yes	No
UST#5 2015				Zonglong Zhu, Qifan Xue, Hexiang He, Kui Jiang, Zhicheng Hu, Yang Bai, Teng Zhang, Shuang Xiao, Kenan Gundogdu, Bhoj Raj Gautam, Harald Ade, Fei Huang, Kam Sing Wong,* Hin-Lap Yi, Shihe Yang and He Yan	A PCBM electron transport layer containing small amounts of dual polymer additives that enables enhanced perovskite solar cell performance, Advanced Science 1500353 (2015); DOI:10.1002/advs.201500353	No	Yes	Yes	No
UST#6 2015				Mei-Feng Xu, Hong Zhang, Su Zhang, Hugh L. Zhu, Hui-Min Su, Jian Liu,	A low temperature gradual annealing scheme for	No	Yes	Yes	No

				Kam Sing Wong,* Liang-Sheng Liao and Wallace C. H. Choy	achieving high performance perovskite solar cells with no hysteresis, J. Mater. Chem. A, 3, 14424 (2015)				
UST#7 2016				Hong Zhong, Jiaqi Cheng, Francis Lin, Hexiang He, Jian Mao, Kam Sing Wong, Alex K. Y. Jen and Wallace C. H. Choy*	Pin-hole free and surface-nanostructured NiOx film by room-temperature solution process for achieving high performance flexible perovskite solar cells with good stability and reproducibility, ACS Nano 10, 1503 (2016); DOI: 10.1021/acsnano.5b07043	No	Yes	Yes	No
UST#8 2016				Dongyu Zhao, Hexiang He, Xinggui Gu, Lin Guo, Kam Sing Wong, Jacky W. Y. Lam and Ben Zhong Tang	Circularly Polarized Luminescence and a Reflective-Photoluminescent Chiral Nematic Liquid Crystal Display Based on an Aggregation-Induced Emission Luminogen, Advanced Optical Materials 4, 534 (2016); DOI: 10.1002/adom.201500646	No	Yes	Yes	No
CITYU#0 2015				Dandan Wen, Fuyong Yue, Guixin Li, Guoxing Zheng, Kinlong Chan, Shumei Chen, Ming Chen, King Fai Li, Polis Wing Han Wong, Kok Wai Cheah, Edwin Yue Bun Pun,* Shuang Zhang and Xianzhong Chen	Helicity multiplexed broadband metasurface holograms, Nat. Comms. 6, 8241 (2015) DOI: 10.1038/ncomms9241	No	Yes	Yes	No

POLYU#0 2014				A. Ng, W. K. Yiu, Y. S. Foo, Q. Shen, A. Bejaoui, Y. Y. Zhao, H. C. Gokkaya, A. B. Djurišić, J. A. Zapien, W. K. Chan and C. Surya*	Enhanced performance of PTB7:$PC_{71}BM$ solar cells via different morphologies of gold nanoparticles, ACS Applied Materials and Interfaces 6, 20676–84 (2014)	No	Yes	Yes	No

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each conference abstract)*

FROM INTERIM REPORT

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of RGC *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
C#1 Aug/2014/ Neuchatel, Switzerland	Circular polarized second harmonic generation in single-layered gold sawtooth structures	6th EPS-QEOD Europhoton Conference	Yes 2014	Yes	Yes	No
C#2 May/2014/ Singapore	Optical trapping and sensing with hybrid plasmonic particle-microcavity structures	The 5th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 2014)	Yes 2014	Yes	Yes	No
C#3 August/2013/ Stockholm	Plasmonic Scattering Studies of Photo-chemically Generated Metallic Nanoparticles on Optical Fiber Double-tapers through Evanescent Field Interference	Progress in Electromagnetics Research Symposium (PIERS 2013)	Yes 2014	Yes	Yes (Acknowledged made during presentation)	No
C#4 July/2013/ Philadelphia, USA	Silver nanodecahedron based core-shell nanoparticles as surface enhanced Raman scattering (SERS) tags for labeling biomolecules	4th International Conference on Biomarkers & Clinical Research	Yes 2014	Yes	Yes (Acknowledged made during presentation)	No
C#5 August/2014/ Guangzhou	Tunable Plasmonic Absorption in Random Metallic Nano-islands for Optofluidic Applications	Progress in Electromagnetics Research Symposium (PIERS) 2014	Yes 2014	Yes	Yes (Acknowledged made during presentation)	No
C#6 August/2013/ Stockholm	Shape Dependent Broadband Plasmonic Absorption in Metallic Nanoparticles for Efficient Organic Solar Cells	Progress in Electromagnetics Research Synmposium (PIERS 2013)	Yes 2014	Yes	Yes (Acknowledged made during presentation)	No

C#7 July/2016/ Vancouver	Plasmonic Absorption Induced Optical Tweezers with in situ Surface Enhanced Raman Scattering Capability	OSA Advanced Photonics	No	Yes	Yes (Acknowledged made during presentation)	No
C#8 Aug/2015/ Busan, South Korea	Optofluidic Guiding Based on Plasmonic Absorption	CLEO-Pacific Rim 2015	No	Yes	Yes (Acknowledged made during presentation)	No
C#9 June/2015/ Singapore	Gold Nanoisland Coated Fiber Tip as Plasmonic Optical Tweezers	ICMAT2015 & IUMRS-ICA2015	No	Yes	Yes (Acknowledged made during presentation)	No
C#10 July/2015/ Prague, Czech Republic	Plasmonic scattering studies of photo-chemically generated metallic nanoparticles on optical fiber double-tapers through evanescent field interference	The 36th Progress In Electromagnetics Research Symposium (PIERS 2015)	No	Yes	Yes (Acknowledged made during presentation)	No
C#11 May/2015/ Changchun, China	Plasmonics of random metallic nano-islands-nano-optical-trapping and optofluidics	The 8th International Conference on Nanophotonics (ICNP 2015)	No	Yes	Yes (Acknowledged made during presentation)	No
C#12 June/2015/ Wuhan	Plasmonic Absorption in Random Metallic Nano-islands: Sensing, Nano optical-trapping and Optofluidics	OSA Topical Meetings: Optoelectronic Devices and Integration, POEM 2015	No	Yes	Yes (Acknowledged made during presentation)	No
C#13 Feb/2014/ San Francisco, USA	Plasmonic nano-optical tweezers with in-situ sensing capability	Photonics West 2014	No	Yes	Yes (Acknowledged made during presentation)	No
C#14 June 2014/Changwon/Korea	Interferometric Phase Detection in Surface Plasmon Resonance Biosensors	International Conference on Computational & Experimental Engineering and Sciences (ICCES'14)	No	Yes	No	No

10. ***Student(s) trained*** (please attach a copy of the title page of the thesis)

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
Jiajie CHEN	PhD	1 August 2013	31 July 2016

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

This project has enabled further collaboration with colleagues at Nanjing University (Prof. Guanghui Wang and Xuping Zhang, School of Modern Engineering and Applied Sciences) on the topic of optofluidics and trapping, and City University of Hong Kong (Dr Lawrence Wu, Department of Materials Science and Applied Physics) on the topic of SPR sensing. So far, the collaboration has generated 4 publications and one US patent.

1. G.H. Wang, Z.F. Ying, H.P. Ho, Y. Huang, N.M. Zou, X.P. Zhang, Nano-optical conveyor belt with waveguide-coupled excitation, Optics Letters, 41(2016), 528-531. (DOI: 10.1364/OL.41.000528)
2. H.F. Lu, Z.W. Kong, J.M. Lei, H.P. Ho, Tunable double resonance of silver nanodecahedron on the insulator/conductor film, Optics Express, 24(2016), 10611-19. (DOI: 10.1364/OE.24.010611)
3. W.X. Jiao, G.H. Wang, Z.F. Ying, Y. Zou, H.P. Ho, T.Y. Sun, Y. Huang, X.P. Zhang, Switching of nanoparticles in large-scale hybrid electro-optofluidics integration, Optics Letters, 41(2016), 2652-2655. (DOI: 10.1364/OL.41.002652)
4. Z. Ying, G. Wang, X. Zhang, Y. Huang, H. P. Ho, Y. Zhang, Ultracompact TE-Pass Polarizer Based on a Hybrid Plasmonic Waveguide, IEEE Photonics Technology Letters, 27(2015), 201-204.
5. S.P. Ng, C.M.L. Wu, S.Y. Wu and H.P. Ho, Optical Sensing Apparatus and A Method for Detecting Characteristics of a Sample, US Patent No. 9,322,778 B2 (04/2016)

The PC has established a start-up company, ATSPIN Ltd, in January 2014 to commercialize lab-on-a-disc bio-detection devices developed through several projects undertaken by his team. Plasmonic absorption-induced heating effects developed through this project will be used as a localized heating source for laser-actuated manipulation of microfluidics and nucleic acid amplification through polymerase chain reaction (PCR).

Team members of this project (CH Choy, C. Surya, HP Ho) have presented project results in a series of local half-day workshops organized by the Hong Kong Optical Engineering Society in 2015 and 2016.

This project has further expanded the PC's international recognition within the photonics community. In 2015, the project PC, in honor of his contribution to the advancement of SPR biosensors, was elected as Fellow of SPIE.

This project has facilitated the publication of a book entitled "Handbook of Photonics for Biomedical Engineering", Springer (2017), co-edited by Aaron H.P. Ho, Donghyun Kim and Michael G. Somekh.

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