(Revised 07/09)

RGC Ref.: N_CUHK464/10 NSFC Ref. : 21061160492
(please insert ref. above)

NSFC/RGC Joint Research Scheme
Joint Completion Report

(Please attach a copy of the completion report submitted to the NSFC by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Synthesis and Design of New Photocatalysts for Degradation of Toxic Organic Compounds
新型光催化材料的设计合成及有毒有机污染物降解

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Professor Jimmy Chai-mei YU 余济美教授	Professor Shuhong YU 俞书宏教授
Post	Professor 教授	Vice-Dean, School of Chemistry and Materials 化学与材料科学学院副院长
Unit / Department / Institution	Department of Chemistry, The Chinese University of Hong Kong 香港中文大学化学系	School of Chemistry & Materials, University of Science & Technology of China 中国科技大学化学与材料科学学院
Co-investigator(s) *(with title)*		

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted)*
Project Start date	1 January 2011		
Project Completion date	31 December 2013		
Duration *(in month)*	36		

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. To design novel $MM'O_x$ bimetal oxide photocatalysts.
2. To measure photocatalytic activities and propose photo-degradation mechanisms.
3. To couple photocatalysts to upconversion materials.
4. To investigate the effects of morphology, size, and crystallinity on the photoactivity of the new materials under visible-light and near-infrared irradiation.

5.2 Revised Objectives

Date of approval from the RGC: _____

Reasons for the change: _____

_____

1.

2.
3. ....

6. Research Outcome

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

The Hong Kong side carried out a detailed literature review on the Crystal Facet Engineering of Semiconductor Photocatalysts. Our findings were summarized in a Feature Article published in 2011 by *Chemical Communications*. This highly-cited article investigated the basic strategies for crystal facet engineering of photocatalysts. The unique properties of faceted photocatalysts were discussed in relation to anisotropic corrosion, interaction dependence of adsorbates, photocatalytic selectivity, photo-reduction and oxidation sites, and photocatalytic reaction order. Ideas for future research on crystal facet engineering for improving the performance of photocatalysts were also proposed.

The two research groups designed a unique 14-facets polyhedra chalcocite Cu_2S nanocrystals by using the solvothermal method. It was found that the presence of trio-n-octylphosphine during the synthesis was essential for the exposure of unconventional {110} faces. Results from photoelectrochemical measurements indicated that the polyhedra bounded by {110} facets exhibited much higher activities than the Cu2S hexagonal plates with only {001} facets.

A new class of metal-free heterojunction photocatalysts was prepared by wrapping reduced graphene oxide (RGO) and g-C_3N_4 (CN) sheets on crystals of cyclooctasulfur (α-S_8). Two distinctive structures were fabricated by wrapping RGO and CN sheets in different orders. A possible mechanism was proposed to explain the differences between photocatalytic oxidative inactivation and reductive inactivation. As a proof-of-concept, this work could offer new inroads into exploration and utilization of graphene sheets and g-C_3N_4 sheets cowrapped nanocomposites for environmental applications.

Porous TiO_2/In_2O_3 composites have been prepared by a fast ultrasonic aerosol spray-assisted approach. The obtained composites show a spherical morphology, large surface areas, and high visible-light-harvesting capability. Under visible-light irradiation, the TiO_2/In_2O_3 composites exhibit excellent photostability and photocatalytic performance toward the decomposition of organic dyes including methyl orange and rhodamine B. This simple preparation approach shows great potential for large-scale synthesis of semiconductor composites for various energy and environment-related applications.

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

Photocatalysts with different faces show very different activities on. For example, the {001} facets of anatase TiO_2 show higher activity than the {101} facets. Moreover, octahedral Cu_2O with exposed {111} facets exhibits much higher photocatalytic activity than cubes. When coupled with TiO_2, polyhedra Cu_2O also shows enhanced photocatalytic activity and photoelectrochemical performance. The search for semiconductor photocatalysts with exposed active facets remains one of the most challenging tasks for scientists. The use of graphene and g-C_3N_4 sheets as a universal substrate for supporting photocatalysts is also worth exploring. Finally, the ultimate photocatalysts should be able to harvest a wide spectrum of sunlight, including the infrared region. This requires an intimate contact of the photocatalysts with efficient upconversion nanoparticles. Our most recent unpublished findings suggest the great potential of plasmonic metal nanostructures.

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)

Photocatalysis is an environmentally friendly technique to eliminate toxic organic substances in air and water. The process is initiated by the irradiation of semiconductor materials with a suitable light source. The subsequently formed free radicals with strong oxidizing ability could mineralize organic pollutants to CO_2 and H_2O. The major objective of this proposal is to develop novel functional nanomaterials with outstanding photocatalytic properties by controlled synthesis of high-quality inorganic nanostructures and fabrication of their macroscopic assemblies. The objective was realized, and new photocatalysts were fabricated that can utilize the clean and renewable solar energy to solve environmental problems. Findings from this research projects are significant and highly-cited. The two principal investigators have been named recently "The World's Most Influential Scientific Minds" by Thomson Reuters.

Part C: Research Output

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

(Please attach a copy of each 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)	Title and	Submitted	Attached	Acknowled
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*	***(bold the** authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Journal/Book *(with the volume, pages and other necessary publishing details specified)*	to RGC *(indicate the year ending of the relevant progress report)*	to this report *(Yes or No)*	ged the support of this Joint Research Scheme *(Yes or No)*

2011				Gang Liu, **Jimmy C. Yu***, Gao Qing (Max) Lu, Hui-Ming Cheng*	"Crystal Facet Engineering of Semiconductor Photocatalysts: Motivations, Advances and Unique properties" *Chemical Communications,* 2011, 47, 6763–6783	2012	Yes	Yes
2012				Yecheng Li, Lei Zhang, **Jimmy C. Yu***, **Shu-Hong Yu**	"Facet Effect of Copper(I) Sulfide Nanocrystals on Photoelectrochemical Properties" *Progress in Natural Science: Materials International*, 2012, 22, 585-591	2012	Yes	Yes
2013				Wanjun Wang, **Jimmy C. Yu***, Dehua Xia, Po Keung Wong, Yecheng Li	"Graphene and g-C_3N_4 Nanosheets Co-wrapped Elemental α-Sulfur as a Novel Metal-Free Heterojunction Photocatalyst for Bacterial Inactivation Under Visible-Light" *Environmental Science and Technology* 2013, 47, 8724–8732		Yes	Yes
2014				Chuanhao Li, Tian Ming, Junxin Wang, Jianfang Wang, **Jimmy C. Yu***, **Shu-hong Yu**	"Ultrasonic Aerosol Spray-Assisted Preparation of TiO_2/In_2O_3 Composite for Visible-Light-Driven Photocatalysis," *Journal of Catalysis* 2014, 310, 84-90		Yes	Yes

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

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 this Joint Research Scheme *(Yes or No)*

Jan/2011/ Singapore	Materials for Near-Infrared Induced Photocatalysis	International Conference on Big Ideas in Molecular Materials	2012	Yes	Yes
April/2013 Taiwan	Novel Photocatalytic Materials for Environmental and Energy Applications	2013 Jade Mountain Forum on Sustainable Environment		Yes	Yes
Oct/2013 Taiwan	An Antibacterial Graphene-Based Metal-Free Photocatalyst	The 6th Asia-Pacific Congress on Catalysis		Yes	Yes
Jan/2014 Singapore	The Development of Nonmetal Solar-Driven Photocatalysts	The 2nd Workshop on Coherent Energy Transport and Optimization in Photosynthesis		Yes	Yes

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
Chuanhao Li	Ph.D.	August 1, 2008	July 31, 2011
Feng Wang	Ph.D.	August 1, 2008	May 31, 2012
Zhuofeng Hu	Ph.D.	August 1, 2010	May 31, 2014
Yecheng Li	Ph.D.	August 1, 2012	July 31, 2015

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

Both Principal Investigators, Jimmy C. Yu and Shuhong Yu, appear on the prestigious list of Highly Cited Researchers 2014 (www.highlycited.com), which identifies the world's most influential scientific minds. The new photocatalysts that we discovered have attracted a lot of attention. We are collaborating with two companies (one overseas and one local) for potential technology transfer. Non-disclosure agreements were signed on 26 August 2013 and 7 Nov 2013.