GERMANY/HONG KONG JOINT RESEARCH SCHEME
THE PROJECT REPORT
(for Project Completion)

Project Number: G_HK004/12

Title

Colloidal Nano-Heterostructures for Photocatalytic Hydrogen Generation

Particulars

	Hong Kong team	German team
Name of Project Co-ordinator (with title)	Prof. Andrey Rogach	Dr. Frank JAECKEL
Name of Co-Investigator (if any)	Dr. Andrei Susha	Dr. Michael Carlson
Institution or Institutional affiliation	[X] CityU [ ] HKU [ ] CUHK [ ] HKUST [ ] HKBU [ ] LU [ ] HKIEd [ ] PolyU	[X] University of Munich [ ] Others:
Other project team members (if any)	Aleksandar Vaneski	Dr. Ming Fu

Funding Period

	1st year	2nd year (if applicable)
Start Date	1.01.2013	1.01.2014
Completion Date	31.12.2013	31.12.2014

Objective(s) as per original application

1. Fabrication of colloidal nano-heterostructures comprising semiconductor nanocrystals decorated with catalytic metal and metal oxide clusters
2. Evaluation of the most promising hybrid nano-heterostructures for their ability of water splitting
3. Advanced optical spectroscopy studies of light harvesting and charge carrier dynamics, including interfacial charge transfer processes, in hybrid semiconductor/metal (metal oxide) nanoheterostructures

Details of Report [Please attach relevant document(s)]

i) Outline of proposed research and results obtained

This project aimed at (i) the fabrication of colloidal nano-heterostructures for photochemical water-cleavage, (ii) the quantification of their photocatalytic performance, and (iii) a deeper understanding of the charge carrier dynamics in these systems. The knowledge gained enabled the design of such nanostructures and the development of suitable photocatalytic systems for the solar energy conversion into chemical fuel by photochemical decomposition of water. We have developed aqueous synthesis of CdS and CdSE/CdS tetrapods for photocatalytic hydrogen generation [1], and demonstrated enhanced hydrogen evolution rates at high pH with such systems [2]. Very importantly, we have discovered a redox shuttle mechanism employing a hydroxyl anion / radical redox couple to efficiently relay the hole from semiconductor to the scavenger, which leads to a marked increase in the hydrogen generation rate in a hybrid CdS/Ni system without using any expensive noble metal co-catalysts [3]. We summarized the rational choice of colloidal nanoheterostructured materials based on light-harvesting II-VI semiconductor nanocrystals combined with a variety of metal and/or non-metal co-catalysts, with optimized light harvesting, charge separation, and photocatalytic functions in a review article [4].

ii) Significance of research results

The most significant results are related to the findings of ref. [3] published in Nature Materils (IF 36.42), which became an important contribution to the field of solar fuel generation on colloidal semiconductor nanocrystals. The proposed redox shuttle mechanism, where the rate limiting step is replaced with two faster processes, is a viable approach to significantly improve the efficiency of photocatalytic systems and our analysis suggests it will also be applicable to other materials and open new pathways for water oxidation, with a marked increase in the hydrogen generation rate without using any expensive noble metal co-catalysts. These results have been highlighted in a number of open source journals and mass media worldwide, as illustrated under (iii) below.

iii) Research output

[1] A. Vaneski, J. Schneider, A. S. Susha, A. L. Rogach. Aqueous Synthesis of CdS and CdSe/CdS Tetrapods for Photocatalytic Hydrogen Generation. APL Materials 2014, 2, 012104.

[2] J. Schneider, A. Vaneski, G. R. Pesch, A. S. Susha, W. Y. Teoh, A. L. Rogach. Enhanced Hydrogen Evolution Rates at High pH with a Colloidal Cadmium Sulphide – Platinum Hybrid System. APL Mater. 2014, 2, 126102.

[3] T. Simon, N. Bouchonville, M. J. Berr, A. Vaneski, A. Adrovic, D. Volbers, R. Wyrwich, M. Döblinger, A. S. Susha, A. L. Rogach, F. Jäckel, J. K. Stolarczyk, J. Feldmann. Redox Shuttle Mechanism Enhances Photocatalytic H2 Generation on Ni-Decorated CdS Nanorods. Nature Mat. 2014, 13, 1013-1018. *Highlighted by Innovations Report, Nanotechweb, Nanowerk, R&D, Daily News (USA), Daily Fusion, Phys.org and pro-physik.*

[4] A. Vaneski, J. Schneider, A. S. Susha, A. L. Rogach. Colloidal Hybrid Nanostructures Based on II-VI Semiconductor Nanocrystals for Photocatalytic Hydrogen Generation. J. Photochem. Photobiol. C. Photochem. Rev., 2014, 19, 52-61.

iv) Potential for or impact on further research collaboration

The two participating groups have contributed to this project with their long-standing and complementary expertise on chemical synthesis of colloidal nanoparticles, fabrication of hybrid semiconductor / metal (metal oxide) nanostructures (Hong Kong), and the advanced optical studies of the resulting hybrid nanostructures (Germany). This collaboration will extend over the future years providing the solid base for other joint publications in the related areas of research (in particular on synthesis and optical spectroscopy of carbon dot based hybrid systems), which is already on the way.