

The Chinese University of Hong Kong
Division of Materials Science and Engineering

Projects

1. Nanostructured organic/inorganic hybrid solar cells (MPhil or PhD)
(Prof. Chen, T., E-mail: taochen@phy.cuhk.edu.hk)

Solar energy is perhaps the most promising renewable energy source when it comes to its quantity, safety and cleanliness. An important approach to use solar energy is conversion of sunlight into electricity via photovoltaic effect. The advancement of nanoscience and nanotechnology enlightens new concepts in solar cell designs, among which dye-sensitized solar cell and polymer solar cell are two kinds of nanostructured solar cells with respectable energy conversion efficiency and lower fabrication cost. In this project, we will take a comprehensive perspective on improving the long-term stability, overall energy conversion efficiency as well as cost-effective fabrication of the two types of solar cells. Specifically, our aims are: 1) to develop new nanostructured materials for photoanodes, focusing on the increase of film thickness and thus light utility without enhancing recombination (back reaction) probability, 2) to integrate additional energy conversions in solar devices taking advantage of thermoelectrics and plasmonics and 3) to develop more convenient approaches for device fabrication. [One student may be admitted.]

References :

1. A. Hagfeldt, G. Boschloo, L. Sun, L. Kloo and H. Pettersson, "Dye-sensitized solar cells", *Chemical Reviews* 110, pp. 6595-6663 (2010).
2. T.M. Tritt and M.A. Subramanian, "Thermoelectric materials, phenomena, and applications: A bird's eye view", *MRS Bulletin* 31, pp. 188-194 (2006).
3. J. Weickert, R.B. Dunbar, H.C. Hesse, W. Wiedemann, and L. Schmidt-Mende, "Nanostructured organic and hybrid solar cells", *Advanced Materials* 23, pp. 1810-1828 (2011).

2. Formation and properties of bulk nanostructures (MPhil or PhD)
(Prof. Kui, H.W., Room 308, ☎ (852) 3943 6368,
E-mail: hwkui@phy.cuhk.edu.hk)

By a spinodal mechanism, we were able to transform conventional eutectic alloys into bulk nanostructures with network morphology. These bulk nanostructures have superior mechanical properties, making them commercially attractive. The enhanced mechanical properties are likely due to two factors: First, the grain size of a bulk nanostructure is three orders of magnitude smaller than its eutectic alloy counterpart. Second, the constituent phases have a better spatial distribution. In this project, we will prepare bulk nanostructured specimens, measuring their mechanical properties and explain why there is an enhancement in mechanical properties. [One student may be admitted.]

Reference :

H.W. Kui, "Formation of bulk nanostructured alloys", *Encyclopedia of Nanoscience and Nanotechnology*, Edited by H.S. Nalwa, Volume 3, pp. 485-495 (2004).

3. Novel nanostructured architectures for applications in solar energy conversion (MPhil or PhD)
(Prof. Li, Q., Room 310, ☎ (852) 3943 6323,
E-mail: liquan@phy.cuhk.edu.hk)

Solar energy conversion based on the photovoltaic effect is one of the most viable choices to meet the increasing energy demand in the near future. Governed by quantum mechanics as well as mesoscale physics, nanostructured semiconductor architectures may provide novel mechanisms that can lead to improvements in carrier production efficiency and effective carrier separation and transport. They open up new routes for the design of the next generation solar cells with higher efficiency and at lower cost. In this project, we will design ordered semiconductor nanostructure networks, based on which electrochemical cells will be constructed and their photoelectrochemical properties will be measured and light energy conversion efficiency will be evaluated. [One student may be admitted.]

References :

1. P.V. Kamat, "Meeting the clean energy demand: Nanostructure architectures for solar energy conversion", *Journal of Physical Chemistry C* 111, pp. 2834-2860 (2007).
2. P.V. Kamat, "Native and surface modified semiconductor nanoclusters", *Progress in Inorganic Chemistry* 44, pp. 273-343, John Wiley & Sons, Inc. (1997).

4. Nanoparticulate systems for cancer therapeutics (PhD)
(Prof. Li, Q., Room 310, ☎ (852) 3943 6323)

With the recent development of nanotechnology, it is now possible to utilize various nanoparticulate systems in many innovative ways for medical applications such as drug delivery, with improved drug efficiency and reduced side effects. In this project, we are interested in developing functionalized nanoparticulate systems for cancer therapies. The specific magnetic/optical/electrical properties of nanoparticles not only provide novel means for tumor cell recognition, target delivery and effective treatment, but also make them effective biomarkers for tracing the drug delivery process, serving as feed-back messengers for identifying the mechanisms of drug uptake, functioning, and metabolism at the molecular and cellular level. Design and synthesis of nanostructured particles with controllable size and desired physical properties, functionalization of the particle surface, identification of the interaction between nanoparticles and cancer cells, as well as investigating the physiologic impact of nanoparticles to normal and cancer cells such as apoptosis and mutagenesis, will be the main focus of this project. Through integrated physical property measurements and biological evaluation of the nanoparticles, we will find out their delivery and functioning mechanisms in human cells, and also evaluate the efficacy of these nano-medicines. [One student may be admitted.]

Reference :

S. Nie, Y. Xing, G.J. Kim, and J.W. Simons, "Nanotechnology applications in cancer", *Annual Review of Biomedical Engineering* 9, pp. 257-288 (2007).

5. Single molecules studies (MPhil or PhD)
(Prof. Ong, D.H.C., Room G10, ☎ (852) 3943 6324,
E-mail: hcong@phy.cuhk.edu.hk)

Single molecules techniques such as confocal scanning optical microscopy will be applied to study the optical properties of semiconductor quantum dots and molecular dyes in the presence of near field created by plasmonic or photonic crystals. Appropriate modeling based on finite-difference-time-domain method will be used. The method will eventually be extended to biological materials. [Up to 2 students may be admitted.]

Reference :

F.D. Stefani, K. Vasilev, N. Bocchio, N. Stoyanova, and M. Kreiter, "Surface-plasmon-mediated single-molecule fluorescence through a thin metallic film", *Physical Review Letters* 94, pp. 023005(1-4) (2005).

6. Topics in plasmonics (MPhil or PhD)
(Prof. Ong, D.H.C., Room G10, ☎ (852) 3943 6324)

Recently, surface plasmon polaritons (SPPs) arising from metal/dielectric interface have evolved into a new research area in bio- and nano-technologies. Not only that they have been used for making chemical and biological sensors, SPPs are being proposed as a new medium to deliver light signal at the length scale beyond diffraction limit. Several unexpected phenomena including extraordinary transmission, superlensing, waveguiding, etc., have been observed from the world. "Plasmonic" is coined on this subject after the eras of "Photonics" and "Electronics". In this project, we will investigate the effects of SPP on the light emission of semiconductors and phosphors by using a variety of near field optical spectroscopic techniques. In particular, special attention will be paid on the interactions between semiconductor and individual metal nanoparticles and/or clusters. Theoretical calculation based on finite-difference-time-domain method will be used. [Up to 2 students may be admitted.]

References :

1. A.V. Zayats, I.I. Smolyaninov, and A.A. Maradudin, "Nano-optics of surface plasmon polaritons", *Physics Reports* 408, pp. 131-314 (2005).
2. C.W. Lai, J. An, and H.C. Ong, "Surface-plasmon-mediated emission from metal-capped ZnO thin films", *Applied Physics Letters* 86, pp. 251105(1-3) (2005).

7. Multifunctional microspheres (MPhil or PhD)
(Prof. Wang, J.F., Room G9, ☎ (852) 3943 4167,
E-mail: jfwang@phy.cuhk.edu.hk)

Multifunctional microspheres have potential applications in a number of areas, including controlled drug delivery, biosensing, bioimaging, and environmental cleaning. We are going to prepare such microspheres using an aerosol spray process. Our targeted functions include luminescence, magnetism, porosity, photoacid generation, surface plasmon resonance, drug delivery, and photocatalysis. Please see <http://www.phy.cuhk.edu.hk/~jfwang/> for more information. [One student may be admitted.]

8. Scanning tunneling microscopy studies of surface quantum diffusion (PhD)
(Prof. Wang, K.D., N8 Lab., ☎ (852) 3943 7961,
E-mail: kdwang@phy.cuhk.edu.hk)

Observation and understanding of surface diffusion phenomenon in the past largely depend on the development of techniques. Among the techniques, scanning tunneling microscopy (STM) is advantageous in directly providing the atomistic mechanisms of diffusion but was severely limited to slow diffusion rates (<10Hz). Thus, processes in quantum diffusion of light atoms with fast diffusion rates were inaccessible by the STM technique in the past. Recently, we had established a new STM-based method that can expand the range by at least 3 orders of magnitude faster (~10000Hz). This leads to significant overlaps in measurable diffusion rates with other techniques while retaining the atomic resolution. Using this new technique, we are studying the fast quantum diffusion of hydrogen atoms on metal surfaces. [One student may be admitted.]

References :

1. Kedong Wang, Chun Zhang, M.M.T. Loy, and Xudong Xiao, "Time-dependent tunneling spectroscopy for studying surface diffusion confined in nanostructures". *Physical Review Letters* 94, pp. 036103(1-4) (2005).
2. R. Gomer, "Diffusion of adsorbates on metal surfaces". *Reports on Progress in Physics* 53, pp. 917-1002 (1990).

9. Organic electronic and optoelectronic devices based on polymeric materials (MPhil or PhD)
(Prof. Wong, K.Y., Room 345, ☎ (852) 3943 6161,
E-mail: kywong@phy.cuhk.edu.hk)

Organic electronic and optoelectronic devices are important technologies of the future. Polymeric materials have shown great promises in flat-panel display and photovoltaic technologies. In this project we will study the basic mechanisms that affect the operations and performances of the devices, and investigate new device concepts. This project is multi-disciplinary in nature, which will involve polymer physics and chemistry, surface and interface sciences, and optical physics. [One or two students may be admitted.]

References :

1. X.J. Wang, W.M. Lau, and K.Y. Wong, "Display device with dual emissive and reflective modes", *Applied Physics Letters* 87, pp. 113502(1-3) (2005).
2. X.Y. Deng, K.Y. Wong, Y.Q. Mo, "Three-color polymeric light-emitting devices using selective photo-oxidation of multilayered conjugated polymers", *Applied Physics Letters* 90, pp. 063505(1-3) (2007).

10. Topics in polymer and colloidal physics (PhD)
(Prof. Wu, C., Room 239, ☎ (852) 3943 6106,
E-mail: chiwu@cuhk.edu.hk)

Using a combination of synthetic chemistry, polymer physics and molecular biology, we design and execute decisive experiments to answer important physical questions of polymers, colloids and biology, including 1) development of non-viral vectors for molecular medicines; 2) nucleation of neuron-degenerative diseases related protein aggregation; 3) design, synthesis and assembly of functional macromolecules; 4) dynamics and structures of polymer solutions and gel networks; 5) molecular characteristic properties of intractable and special polymers. [One student may be admitted.]

References :

1. C. Wu and X.H. Wang, "Globule-to-coil transition of a single homopolymer chain in solution", *Physical Review Letters* 80, pp. 4092-4094 (1998).
2. T.J. Hu and C. Wu, "Clustering induced collapse of a polymer brush", *Physical Review Letters* 83, pp. 4105-4107 (1999).
3. G.Z. Zhang and C. Wu, "The reentrant coil-to-globule-to-coil transition of a single linear homopolymer chain in a water/methanol mixture", *Physical Review Letters* 86, pp. 822-825 (2001).
4. G.Z. Zhang, F.M. Winnik, and C. Wu, "Structure of a collapsed polymer chain with stickers: A single- or multiflower?", *Physical Review Letters* 90, pp. 035506(1-4) (2003).
5. F. Jin and C. Wu, "Observation of the first-order transition in ultrafiltration of flexible linear polymer chains", *Physical Review Letters* 96, pp. 237801(1-4) (2006).

11. Thin film based photovoltaic solar cells (MPhil or PhD)
(Prof. Xiao, X.D., Room 210, ☎ (852) 3943 4388,
E-mail: xdxiao@phy.cuhk.edu.hk)

Energy is important for the sustainable development of our modern society. In the past, we have been heavily relying on fossil fuels which are not renewable and contribute heavily to environmental pollution. Thus, alternative energy sources must be sought. In our lab, we are engaged in studying semiconductor thin film photovoltaic solar cells that convert solar energy into electricity. Our main interest is to search for new concepts, new designs, and cost effective fabrication processes to grow high quality compound semiconductor films that possess high energy conversion efficiency. [One student may be admitted.]