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

Projects Offered in 2019-20

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<th>No.</th>
<th>Project title</th>
<th>Degree</th>
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<tr>
<td>1</td>
<td>Development of multifunctional nanodiamond sensor (MPhil or PhD)</td>
<td>MPhil or PhD</td>
<td>Prof. Zhiqin Chu</td>
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<td>(Prof. Z. Q. Chu, <a href="mailto:zqchu@phy.cuhk.edu.hk">zqchu@phy.cuhk.edu.hk</a>, <a href="http://www.phy.cuhk.edu.hk/people/chu-zq.html">http://www.phy.cuhk.edu.hk/people/chu-zq.html</a>)</td>
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<td>Nanometer-sized diamond particles, i.e., nanodiamonds (NDs) with nitrogen-vacancy (NV) defect centers exhibit excellent biocompatibility, long-term stability, and unique quantum sensing capability by optical means. The spin-states dependent fluorescence of these atomic-scale NV centers in NDs, which show a long coherence time even under ambient conditions. This enables direct nanoscale sensing for magnetic/electric field, temperature, rotation and mechanical force/pressure. Beyond the above mentioned variables, however, it is still challenging to perform direct measurements with NDs. To expand the sensing options provided by NV centers, we will combine NDs with other functional material systems (e.g., plasmonic, magnetic nanoparticles and etc.) to pursue signal transduction, recording and/or amplification. The ultimate goal is to develop hybrid multifunctional nanoscale sensors based on NDs, being able to work under physiological conditions. This project will involve materials preparation, characterization, chemical reactions and some basic optical measurements. The candidates with backgrounds in material science, chemistry, physics, and nanotechnology are welcome to apply. [One student may be admitted.]</td>
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References:

| 2   | Synthesis and characterization of high purity single crystals (MPhil)        | MPhil or PhD              | Prof. Swee Kuan Goh      |
|     | (Prof. S. K. Goh, [skgoh@phy.cuhk.edu.hk](mailto:skgoh@phy.cuhk.edu.hk), [http://www.phy.cuhk.edu.hk/skgoh/](http://www.phy.cuhk.edu.hk/skgoh/)) |                           |                          |
|     | Motivated candidates with strong interest in the physics of correlated electron solids are invited to participate in our research programme. Our group frequently studies the some of the purest single crystals under extreme conditions to follow the fate of their constituent electrons. We run a state-of-the-art cryogen-free dilution refrigerator equipped with high magnetic field, in which several types of high pressure devices can be integrated. The successful candidate(s) will assist in the preparation and/or characterization of these single crystals for in-depth studies in our laboratory. |

References:

| 3   | Topics in nanovaccine (PhD)                                                | PhD or MPhil              | Prof. Yi Wang            |
|     | (Prof. Q. Li, [qli@phy.cuhk.edu.hk](mailto:qli@phy.cuhk.edu.hk), [http://www.phy.cuhk.edu.hk/qli/](http://www.phy.cuhk.edu.hk/qli/)) |                           |                          |
|     | Nanoparticles serve as unique carriers for drugs, enabling controlled drug release and improved drug efficacy. In this project, we are interested in developing functionalized nanoparticulate systems as a general platform for applications in vaccine development, in particular, cancer vaccine. We aim at using our non-viral mRNA delivery system based on our in-house developed hybrid nanoparticle technology, to simultaneously deliver tumor antigen and a comprehensive set of molecular adjuvants, and evaluate the tumor-reactive cytotoxic and helper T cell response. Upto one student may be admitted. |

References:
4. Developing battery materials beyond Li-ion technology (PhD)

(Prof. Q. Li, liquan@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/qli/)

This project works on materials development for batteries beyond the current Li-ion technology, such as sodium ion batteries and Li-S batteries. The project involves electrode material design, synthesis with composition and morphology control, various characterizations of the battery materials, and the performance measurement of the cells. There are two focus of the project: (i) Material/architectural design to achieve high energy density, high rate performance, and long cycle life of the respective battery systems. (ii) mechanistic study to identify the evolution of the battery materials during charge/discharge cycles and improve their cycling performance. State-of-the-art characterizations including in operando XRD and in situ TEM studies will be carried out. Up to two students may be admitted.

References:

5. Synchrotron based studies on organic/perovskite solar cells (MPhil or PhD)

(Prof. X. H. Lu, xhlu@phy.cuhk.edu.hk, http://app.phy.cuhk.edu.hk/xhlu/)

Nowadays, solar industry becomes the fastest growing industry due to the rising demands to solve energy crisis and environmental problems. Among various types of solar cells, organic photovoltaic devices offers low-cost, light weight and flexible solar energy harvesting, have attracted a lot of research efforts. Recently, organic and inorganic halide perovskite solar cell has emerged as a rising star in the solar industry due to its astonishing progress in power conversion efficiency. This project focuses at using state-of-art synchrotron radiation technique to characterize the molecular and nano-scale structure information of this two types of thin film solar cell, understanding its correlation with device performance and in turn improving the power conversion efficiency of solar cells. [Two students may be admitted.]

References:


6. Topics in plasmonics and metamaterials (MPhil or PhD)

(Prof. D. H. C. Ong, hcong@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/people/ong.html)

Recently, plasmonics and metamaterial have both been named as a new era after photonics and electronics. They serve as an important platform for studying the fundamentals of light matter interaction by manipulating the electromagnetic waves in an unconventional manner. Their applications include making high efficient light emitting diodes (LEDs) and solar cells, ultrahigh sensitive biosensors, passive and active optical elements for photonic circuitry, optical tweezers, etc. Our group focuses on two projects. The first one studies the interaction between plasmonic systems/metamaterials and quantum dots [1]. We engineer the near-fields around the quantum dots and study how their absorption and emission properties are affected. In particular, we measure the local density of the optical states around one single quantum dot in frequency, momentum, time, and space domains by using several home-built, specially designed microscopes. Its spontaneous emission rate, chirality, photocurrent generation efficiency, etc, are then studied accordingly so that LEDs and solar cells can be implemented eventually. The second project combines plasmonic tweezers and surface enhanced Raman scattering (SERS)/surface plasmon resonance (SPR) sensing in attempt to image single molecules. In principle, this combination produces an analogy of “line of sight” method by placing the target molecules at the right position where they can be seen easily. However, since both the manipulation and the sensing require the precision at the length scale of nanometers, a full knowledge of designing the plasmonic/metamaterial systems to yield suitable hotspots for biosensing, building appropriate characterization tools, generating strong optical force for grabbing the molecules, etc, is essential [2]. These two projects involve extensive collaboration with the theoretical group in Hong Kong University of Science and Technology. [Up to two students may be admitted.]

References:
The production of large-scale diamond crystals has been a long-term goal. The conventional approaches to produce artificial diamond usually require extremely critical conditions. Advances in the growth of two-dimensional (2D) large-scale graphene layers with layer-by-layer control lead scientists to search possible route for diamond originated from graphene layers. Recent theoretic and experimental works have demonstrated a novel route for the production of two-dimensional diamond films by chemically induced diamondization of graphene layers. In this project, we will employ scanning tunneling microscopy and related surface characterization techniques to explore the growth, doping, as well as structural and electronic properties of 2D diamond films on various substrates via diamondization of graphene layers. [One student may be admitted]

References:

8. Plasmonic material for smart color display (PhD preferred)
(Prof. L. Shao, shaolei@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/people/shao.html)

Plasmonic metasurfaces are arrays of nanoresonators that can support unique optical resonances. With a thickness of less than 100 nm, such metasurfaces can generate distinct colors covering the full range of the visible spectrum and with extremely high DPI (Dots per inch) values. Further integration of the plasmonic metasurface with electrically or electrochemically active materials, such as liquid-crystal and electrochromic polymers, provides a possibility to dynamically switch on and off the colors, paving the way to produce reflective electronic papers like that used in the popular device Kindle, but with a full color display. In this project, we will fabricate metasurfaces composed of either colloidal metal nanocrystals or lithographically fabricated nanostructures, combine them with electrochemically active materials, and explore the possibility of using such hybrid metasurface as a candidate in the next generation display technology. The study will involve material preparation, optical characterization, electrochemistry measurements, and some electrodynamic simulation. Up to one student may be admitted.

Reference:

9. Develop efficient plasmonic photocatalysts for photosynthesis (PhD)
(Prof. J. F. Wang, jfwang@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/~jfwang/)
References:

11. Biomaterial self-organization and self-assembly (PhD or MPhil)
(Prof. Y. L. Wu, ylwu@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/ylwu/index.html)

Life is the most fascinating state of matter. The research in our lab lies at the interface of physics, biology, and material sciences: We seek to understand how living materials function, adapt and evolve.

Our current research aims to elucidate the principles that govern biomaterial self-organization and self-assembly. Knowledge learned from our studies may find applications in tissue engineering and in fabricating new bio-inspired devices or self-assembled materials. The study may also inspire new strategies to control the self-organization of “active matter”. As a fast-growing and interdisciplinary field, active matter science studies systems composed of units where energy is spent to produce motion. This includes all living organisms, the subcellular constituents driven by molecular motors, and synthetic materials resulting from the self-organization of active elements. Students with background in biology, chemistry, soft matter, or engineering are welcome to apply. Knowledge in molecular biology, chemical/biological engineering, microscopy, electrical engineering, or digital image processing is preferred (but NOT required). [One or two students may be admitted.]

References:
1. To learn more about our current research please visit our lab website: http://www.phy.cuhk.edu.hk/ylwu/index.html

12. Study of magnetotaxis of magnetotactic bacteria (MPhil or PhD)
(Prof. K. Q. Xia, kxia@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/turbulence/)

Magnetotactic bacteria (MB) are microorganisms that contain magnetic crystals 30-50 nm in size. These crystals are enclosed by a lipid bilayer membrane and are called magnetosomes, which are usually formed in chain structures inside the cell. It is generally believed that MBs use their magnetosomes to align with the local magnetic field and move along the magnetic field lines. Such a behavior is referred to as magnetotaxis (or magneto-aerotaxis). An important issue in the studies of MB is whether the magnetotaxis is passive or active. In the former case, the magnetic field only aligns the MBs and their motion are driven by the oxygen gradients. This presumably simplified their search for favorable oxygen environment in aquatic habitat. In the latter case, MBs are thought to possess magnetic receptors similar to chemotaxis. In this project, student will carry out experiments that are designed to address the issue of whether the magnetotaxis of MBs are passive or active. [One student may be admitted.]

References:

13. Thin film based photovoltaic solar cells (MPhil or PhD)
(Prof. X. D. Xiao, xdxiao@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/people/xiao.html)

Photovoltaic solar energy is an important form of renewable energy and is playing increasingly vital role in our modern society. Although large scale deployment of solar panels has started to contribute significant electric energy generation worldwide, the cost of solar electricity remains high. In our lab, we aim to produce high energy conversion efficiency but low cost photovoltaic solar cells by using thin film semiconductor technology. Our main interest is to develop new materials, new concepts, new designs, new characterization, and cost effective fabrication processes to grow high quality compound semiconductor films such as Cu(InGa)Se2 (CIGS) and Cu2ZnSnS4 (CZTS). While CIGS has reached 22.6% world record conversion efficiency in 2016, the highest among all types of thin film solar cells, active control of impurity doping, band structure engineering, and buffer layer alternation are plausible routes to further improve the conversion efficiency. As a potential candidate to replace CIGS to reduce materials cost and to avoid the scarcity of indium element in the earth crust, CZTS is a promising new thin film solar cell material. Development of effective methods to fabricate high quality CZTS thin films is presently a major task in our group. [Two students may be admitted.]

References:
Surface and interface studies of important thin films and nano-materials (PhD)
(Prof. J. Y. Zhu, imjyu@phy.cuhk.edu.hk, http://www.phy.cuhk.edu.hk/people/jhu.html)

“The Surface is the Devil’s work.” Surface can be considered as a two dimensional defect of a perfect crystal. Reactions, important physical and chemical processes often happen on surface. Surface has a profound effect on many material physical problems. Tuning surface properties can be critical in thin film growth and device properties. Many famous surface science problems have been solved using density functional theory (DFT) calculations. Applying DFT calculations and classic molecular dynamics calculations can be effective to study surface phenomena. Our goals are: investigating the surface reconstructions, surface passivation, surface diffusion, surfactant effects, surface effects on doping in many different thin films and nano-materials, including CZTS, InGaN, CIGS, AlGaP, diamond, SiC, ScTiO3, various topological insulators and super conductors. With deep understanding of the surface phenomena, it will be possible to reveal hidden physics mechanisms of important surface physics problems and enhance thin film or nano-materials performance. [One student may be admitted.]

References: