AY2017-18
UROP PROJECTS

School of Materials Science & Engineering

PROJECT OFFERED BY
ASST PROF. TAN KWAN WEE

Direct access to periodically ordered block copolymer-directed transition metal nitride mesostrucutres

Project Objectives:

- (1) Learn and apply the knowledge of sol–gel chemistry in nanoparticle synthesis.
- (2) Understand and explain the reaction mechanism in the self-assembly of block copolymers and inorganic nanoparticles.
- (3) Learn to interpret and construct a hybrid composite morphology map based on block copolymer/inorganic nanoparticle composition ratio.
- (4) Learn to use various electron and X-ray characterization equipment in data collection and analysis.

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Direct access to periodically ordered block copolymer-directed transition metal nitride mesostrucutres

Project Description:

- Key words: block copolymers, self-assembly, transition metal nitrides, sol–gel chemistry, electrochemistry

- Ordered mesoporous materials with intriguing periodic morphologies and length scale features have many current and potential applications, including metamaterials, catalysis, and energy conversion and storage[1]. A well-established approach to synthesize such ordered mesostructures is through the self-assembly of block copolymers mixed with inorganic nanoparticles, enabling direct formation of periodic organic-inorganic hybrid structures with mesoscopic (10–100 nm) and higher length scale features, as well as novel multifunctional properties[2,3].

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Direct access to periodically ordered block copolymer-directed transition metal nitride mesostrucutres

Project Description:

- Recently transition metal nitrides, such as titanium nitride (TiN), have generated increasing interest for their desirable materials properties, such as high melting temperature and excellent electrochemical performance. In particular, TiN in the form of periodically ordered 3D network nanostructures would be appealing to many communities due to the highly accessible surface area and porosity, 3D interconnectivity and exceptional mechanical stability.

- Mesoporous periodic 3D TiN network structures generated by block copolymer self-assembly, had exhibited highly interesting novel properties such as superconductivity[4] and enhanced electrocatalytic performance and stability[5]. However, the current method to fabricate ordered block copolymer-TiN mesostructures typically involves several high-temperature heat treatments in air and ammonia environments, thereby increasing both the production time and cost.

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Project Description:

- Here, we propose the student to study and design a simpler synthesis approach to generate periodical block copolymer-directed TiN mesostructures. He/She would first synthesize the sol–gel derived TiN precursor nanoparticles (<5 nm) by a wet solution method reported in the literature[6]. Next, the student would mix the TiN precursor nanoparticles with a self-assembling block copolymer to form periodically ordered organic-inorganic mesostructures. The student would characterize the resulting materials using electron microscopy and X-ray diffraction, and evaluate the resulting electrochemical properties for potential energy storage applications. If successful, he/she could further explore the experimental parameter space, such as varying the block copolymer/TiN nanoparticle composition, to construct a morphology map that would be highly valuable as a guide for the experimental fabrication of other hybrid composite systems.

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Direct access to periodically ordered block copolymer-directed transition metal nitride mesostrucutres

Project Description:

Major Tasks:

- (1) Introduce to the concept of self-assembly and applications in the fields of materials chemistry and nanoscience.
- (2) Gain hands-on experience in using state-of-the-art materials characterization equipment that are not readily available in classes.
- (3) Develop critical and creative thinking skills by questioning and proposing research hypotheses, as well as evaluating and analysing experimental results.
- (4) Grow confidence in public speaking through effective communication with laboratory peers and presentation data to the scientific community.
- (5) Practise high levels of research integrity and good research ethics that contribute to professional career development

PROJECT OFFERED BY ASST PROF. TAN KWAN WEE

Laser-induced hierarchically porous metal oxide-carbon films

Project Objectives:

- (1) Learn and apply the knowledge of sol–gel chemistry in nanoparticle synthesis.
- (2) Understand and explain the reaction mechanism in the self-assembly of block copolymers and inorganic nanoparticles.
- (3) Understand and explain the nonequlibrium reaction mechanisms during transient laser heating of the hybrid composites.
- (4) Learn to use various electron and X-ray characterization equipment in data collection and analysis.

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Laser-induced hierarchically porous metal oxide-carbon films

Project Description:

- Key words: block copolymers, self-assembly, resols, metal oxides, sol–gel chemistry, electrochemistry

- Ordered mesoporous materials with intriguing periodic morphologies and length scale features have many current and potential applications, including metamaterials, catalysis, and energy conversion and storage[1]. A well-established approach to synthesize such ordered mesostructures is through the self-assembly of block copolymers mixed with inorganic nanoparticles, enabling direct formation of periodic organic-inorganic hybrid structures and systems with mesoscopic (10–100 nm) and higher length scale features, as well as novel multifunctional properties[2,3].

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Laser-induced hierarchically porous metal oxide-carbon films

Project Description:

- Recently, a simple rapid method coupling all–organic block copolymer-resols structure formation with transient laser heating was reported, enabling direct generation of 3D mesoporous continuous resin structures and shapes[4]. Further exploring laser heating of other block copolymer-directed hybrid systems, e.g., with metals, metal oxides or carbides as the additives, could potentially introduce more functional properties and increase the accessible application space[5,6].

- Here the student would investigate multicomponent resols-metal oxide precursor mixtures with promising functional property combinations, and mix with self-assembling block copolymers to generate periodically ordered hybrid mesostructures. He/She would first synthesize sol–gel derived metal oxide nanoparticles (<5 nm) and oligomeric resols using wet solution methods as reported in the literature.[5,6] Next, the student would mix the metal oxide precursor nanoparticles and resols with a self-assembling block copolymer to form periodically ordered organic–organic–inorganic mesostructures. The student would characterize the resulting materials using electron microscopy and X-ray diffraction. He/She would then perform laser heating experiments to generate hierarchically porous multicomponent metal oxide–carbon films and evaluate the electrochemical properties for potential energy storage applications.

PROJECT OFFERED BY ASST PROF. JASON XU

Understanding the electrochemistry of transition metal oxides

Project Objectives:

- The student is expected to learn the knowledge of electrochemistry, metal oxides, crystallography, solid state chemistry, and physics. By doing this project, the student will be able to learn how materials determine the performance of an energy storage or conversion device like a supercapacitor, battery, or fuel cell. The training on the lab skills on chemical synthesis and physical characterizations will be given to the student as well.

PROJECT OFFERED BY ASST PROF. JASON XU

Understanding the electrochemistry of transition metal oxides

Project Description:

- Key words: such as chemistry, nanomaterials, Li-ion battery, biological, diagnosis, drug delivery, supercapacitor, etc.

- The limited fossil fuel resource and increasing environmental problems have stimulated great interest in sustainable energy resources. To relate the sustainable energy resources to our daily life, efficient energy storage and conversion technologies are highly demanded for smart grid, zero-emission transport, and portable devices. The energy storage and conversion technologies include batteries, supercapacitors, solar cells, fuel cells, electrolyzers, and etc. The performance of these techniques highly relies on the materials used. Metal oxides are most popular materials in these techniques. For example, supercapacitors are a class of attractive energy storage devices due to their high power density, low cost, high safety, and long lifetime. According to the charge storage mechanism, there are two types of supercapacitors. One is the electrical double layer capacitors (EDLCs), which use carbon as electrode materials. EDLCs often give high power density, but low energy density. The other is the pseudocapacitors, which use redox materials like metal oxides and conducting polymers as active electrode materials. Depending on the active materials (metal oxides), pseudocapacitors can achieve fairly high energy density and power density.
- This project will study the redox ability of transition metal oxides and correlate this ability with its electrochemical performance.

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Understanding the electrochemistry of transition metal oxides

Major Tasks:

- To conduct literature review on energy conversion and storage techniques and related materials;
- To learn lab skills on chemical synthesis of metal oxide materials;
- To learn the analysis skill on materials characterizations;
- To analyze the data and correlate materials' properties with the performance.
- To work as a team member with graduate students.
- To draw meaningful conclusions using collected data.