Functional Organic and Polymeric Materials for Optical, Electronic, and Thermal Applications

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Rationally designed functional organic and polymeric materials are emerging active components for many modern technologies. My research group has been developing various custom designed and synthesized functional soft materials such as organic phosphors, chromophores, conjugated polymers, sensory molecules, polymer systems having unique thermal properties, and a chemical formula for surface functionalization.[1-11] We have used these soft materials to build plastic electronics, such as solar cells, thin layer field effect transistors, and organic light emitting diodes, to manage phonon transport in thermal engineering, to devise highly selective and sensitive optical sensors, and to conceive simple and convenient, yet robust surface functionalization and patterning.

We have developed the following four proposal ideas for industrial application. Each project needs one graduate student or a postdoc at the budget of $250,000 for two years.

Project 1: Thermally Insulating Additives
- Highly branched architecture
- Diverse atomic composition
- Porous hollow nano particles

Project 2: Patternable Surface Functionalization
- Instant robust thin film formation by photochemistry
- High density functional groups
- Patterned surface functionalization via photomasks

Designer Polymeric and Organic Materials

Computation-aid rational molecular design, chemical synthesis, and fabrication engineering

Project 3: Polymers for Sustainable Pavement
- Interface adhesion engineering
- Versatile dopamine chemistry
- Excellent weatherability

Project 4: Tailor-made Optical Materials
- Instant robust thin film formation by photochemistry
- High density functional groups
- Patterned surface functionalization via photomasks

1. Polymers and their hollow nanoparticles for thermal insulating additives

We have systematically studied thermal transport properties of amorphous polymers and devised strategies to enhance their thermal conductivity one order of magnitude.[3,4] By applying what we learned from the development, we plan to devise highly branched polymers having diverse atomic composition to achieve extremely low thermal conductivity.[5] We will also develop crosslinked porous hollow spheres of the polymer to develop thermal insulating additives for paint formula. Our knowledge and experience in chemical design, thermal engineering, and chemical synthesis serve as a solid foundation for this proposed research topic.

2. Versatile photopolymerization for patterned surface functionalization

Simple, versatile, robust, and effective functionalization methods of material surface are highly desirable for many applications yet highly demanding. Recently we found a generally applicable photochemistry to form a robust thin layer having specific functional groups on virtually any type of materials.[6,7] The placed functional groups can be used for subsequent modifications of the surface. We propose to further investigate the photochemistry combined with photomasks to prepare patterned surface functionalization for various biomaterial and bio-sensor and device applications.

3. Adhesive engineering polymers for sustainable pavement

The road condition in cold states is far from desirable. As polymer chemists and engineers, my research team hope to solve this asphalt failure problem. We believe that failure at the interface between two dissimilar materials is the common cause of the problem. We are interested in developing engineering polymers having excellent weatherability as well as strong adhesion to inorganic materials. We will investigate the dopamine chemistry to give the required adhesion property to the polymer.[6,7] For that purpose, protection and de-protection of the sticky catechol and/or tannic acid moieties for storage and application will be explored.

4. Tailor-made UV, visible, IR absorbers and emitters

My research group has extensive experience in designing conjugated organic molecules and conjugated polymers having tailor-made absorption and emission properties from UV, through visible, to IR regimes.[8] For example, we developed bright organic phosphors having various emission colors and lifetimes, thermally activated delayed fluorescent molecules, and transparent selective IR absorbers.[1,2] The concept of excited state proton transfer has also been implemented in various dye designs to achieve an extremely large Stoke's shift.[11] We are interested in developing dyes, pigments, fluorophores, and phosphors having required specific properties by applying our knowledge and computation-aided rational molecular design.

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