Reg. No: 2021/43/P/ST5/01729; Principal Investigator: dr Xiao Zhang

Noble metal clusters incorporated g-C_3N_4 nanosheets based heterostructures toward solar-driven photo- and electrochemical conversion

The ever increasing in global energy demand, excess use of fossil fuels and associated environment issues involving emission of greenhouse gases (e.g., CO_2) are serious challenges facing the society today. Developing advanced materials that assist conversion of renewable energy (e.g., hydrogen, valuable carbon-based fuels) from a variety of intermittent energy sources (including solar energy) for continuous power supply related applications helps sorting out effective ways in solving energy crisis and supporting environmental protection. Due to the sluggish kinetics of the multistep charge transfer process of photo-/electro-chemical reactions, appropriate semiconducting photocatalysts with increased absorbance in the whole solar spectrum region are required to carry out various catalytic reactions. These semiconducting catalysts have been developed and utilized for water splitting to generate H_2 and O_2, CO_2 reduction, as well as pollutants degradation and reduction related applications. Development of solar light responsive carbon-based catalyst has been receiving considerable attention. Among the various carbon-based materials exploited, graphitic carbon nitride (g-C_3N_4), as a stable semiconducting base material composed of earth-abundant carbon and nitrogen elements, has been considered a promising stable catalyst material with diverse properties that can be applied in visible-light-driven catalysis related applications (e.g., hydrogen generation, CO_2 reduction). Compared with bulk g-C_3N_4 with partially blocked reactive sites that hinders the participation of g-C_3N_4 into catalytic reactions, ultrathin g-C_3N_4 possessing larger specific surface area and higher conductivity has been considered a popular base material for constructing composites catalysts with enhanced photo-/electro-catalytic performances. Methodologies such as morphology control and heterostructure formation are keys in improving catalytic activity of the g-C_3N_4-based composite materials. Among the various methodologies exploited, surface and structural engineering (e.g., homojunction and heterostructure construction) has become one compelling and feasible approach in enhancing photo-/electro-catalytic performances of the g-C_3N_4 based material. Due to the flexibility and opened-up 2D flat morphology nature of g-C_3N_4 nanosheets, g-C_3N_4 nanosheets can be considered an ideal substrate material for constructing g-C_3N_4-based composites (e.g., metal/g-C_3N_4, inorganic semiconductor/g-C_3N_4, polymer/g-C_3N_4 heterostructure etc). The objective of this project is to generate fundamental knowledge on construction of highly efficient and low-cost photo-/electro-catalysts with simplified synthesis steps for practical applications. Noble metal (e.g., Pt, Au, Cu) clusters are expected to be incorporated into the g-C_3N_4 system via control on polymerization processes. Homogeneous distribution of these metal clusters in the g-C_3N_4 nanosheets system can be of significant importance in causing drastic increase in photo-/electro-catalytic activities of the composite material. Exploitation on novel approaches of the synthesis of metal/g-C_3N_4 based tungsten oxide/transition metal dichalcogenides (e.g., MoS_2, SnS_2, WS_2, with the ability of expanding light response range) composite materials with improved photo-/electro-catalytic activities are also expected. Detailed formation and catalytic reaction mechanisms as well as photo-/electro-catalytic performances (involving CO_2 photoreduction, hydrogen evolution, benzene oxidation) of these heterostructure materials are expected to be exploited, particularly, the magnetic and photoelectrochemical properties of the Cu clusters modified g-C_3N_4 composites will be systematically investigated. These novel catalyst technologies that aims to enhance the energy conversion efficiency and to reduce greenhouse emission, can be key in renewable carbon-neutral fuel production and supporting environmental protection, particularly in achieving the Green Deal objectives.