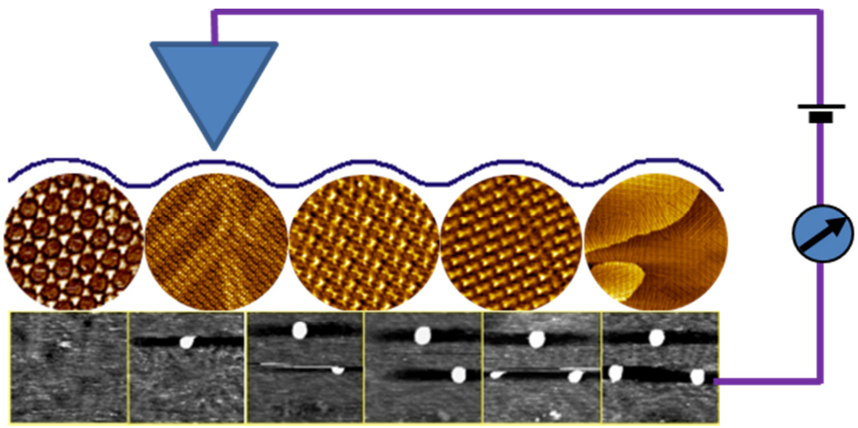
Research interest:

With the increase of human population, energy and environmental become important for our daily life and future. The modern society consumes much more energy and produces more environmental-hazard waste than any past age in the human history. To meet these challenges, our research is focused on the electrochemical energy conversion and environmental-related studies, aiming to promote the fundamental understanding of environmentally benign energy systems, such as solar cells, fuel cells, and rechargeable batteries. These studies may facilitate the discovery of more efficient "clean" energy resource and/or catalysts to protect our environments.



We will employ the state-of-the-art nanotechnology, such as scanning tunneling microscopy (STM), atomic force microscopy (AFM) in combination with classic electrochemistry to fulfil the above purpose. Specific research topics include nano-materials and applications in solar cells, molecular devices, electrochemical impedance, electrochemical STM on surface corrosion, preparation of nanoparticles and their applications in sensing environmental pollutants, molecular assembly and single-molecule electrical properties.

Preparation, Characterization, and Applications of Metal-Oxide Semiconducting Nanomaterials and their Applications in Solar Cells

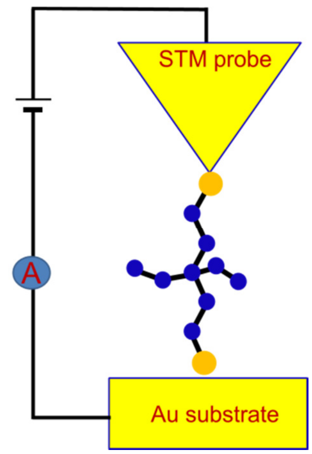
The development of clean energy resources is an urgent task to meet the future demand for renewable energy. Solar cells (photovoltaic cells, PV) represent a promising solution as an environmentally benign system converting solar energy (sun light) to electricity. To harvest solar energy irradiation a particular structure is required that is able to generate free electrons from emitted photons.

Owing to its small band gap value and low cost, Nickel Tungstate ($NiWO_4$) nanomaterials are promising candidates for application in solar cells. In this project, nanoscale particles of $NiWO_4$ as well as other metal-oxide nanomaterials will be prepared using different chemical approaches (thermal decomposition, co-precipitation, and sol-gel method). The prepared materials will be characterized with different techniques such as STM, AFM, electrochemical impedance, etc. and further study their

Single Molecule Charge Transport and Molecular Devices

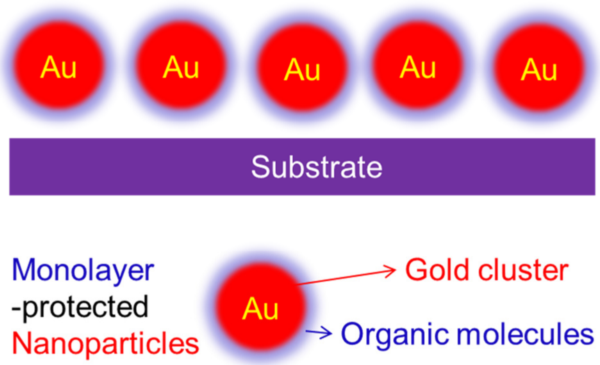
Charge transport through individual molecules is important in many chemical and biological processes and represents a central theme in molecule-based devices. To measure and control the charge transport through molecule requires the formation of metal-Molecule-metal (m-M-m) junctions with a proper choice of linker moiety – the so-called "alligator clips" that connect the molecular core to the electrode.

Single molecule charge transport experiments are experimentally achieved using scanning tunneling microscopy break junctions (STM-BJ). In a break junction experiment, individual molecules are wired between two electrodes, STM tip and substrate electrodes, via proper anchoring groups. Basically, metal junctions are formed and subsequently broken in the presence of target molecules to form metal-molecule-metal (m-M-m) junctions while current versus distance traces are recorded. Then these current-distance traces are used to construct current/conductance histograms to obtain the statistical single molecule conductance values.



Nano-materials and properties

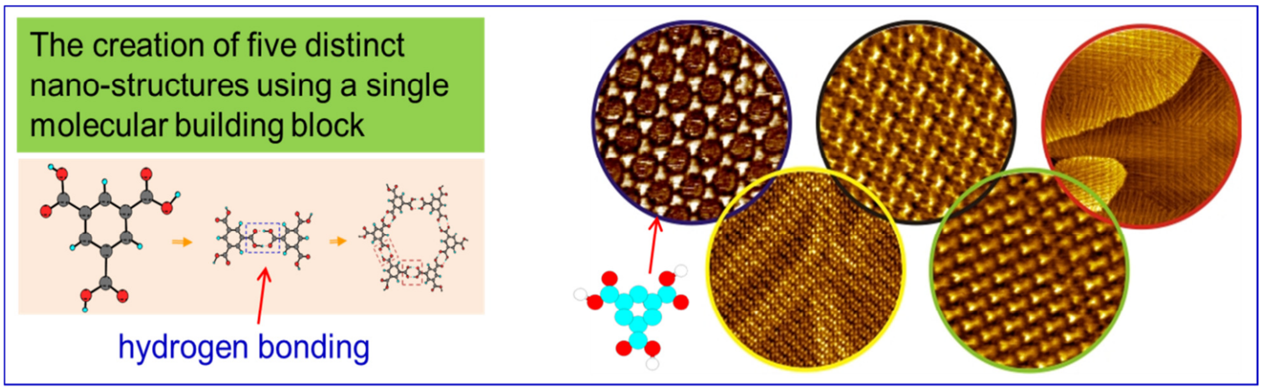
Monolayer-protected nanoparticles have attracted major interest recently, not only because of their applications to electrocatalysis, biology, sensors, and medicine, but also due to their unique electrical properties as nanoscale building blocks for constructing nano-devices and/or future molecular circuits. In this project, we aim to prepare size-controlled nanoparticles from different metals (Au, Pt, Pd, etc.) and further characterize these nanoparticles with UV-vis spectroscopy, TEM, atomic force microscopy (AFM), scanning tunneling microscopy (STM), and electrochemical techniques. The electrochemical properties of these nanoscale entities will be investigated and their applications in molecular electronics and fuel cells will be explored.



A schematic cartoon of monolayer-protected nanoparticles immobilized on a metal or semi-conductor substrate for the electrochemical properties, electron transfer and device study.

Functional assembly of novel two-dimensional nanomaterials

As the miniaturization of electronic components approaches the nanometer scale, new concepts and strategies are essential to overcome the fundamental physical and economic limitations of conventional inorganic silicon technology. Bottom up assembly of well-defined nanoscale building blocks, such as molecules, quantum dots, and nanowires, having key properties controlled by size, morphology and chemical composition on well-defined surfaces (single crystal electrodes) represent an attractive alternative. We will apply a bottom-up strategy to build a series of functional two-dimensional (2D) nanomaterials based on novel molecular materials. We expect to fabricate large 2D porous nano-sheets, and these functional 2D nanomaterials will be characterized by STM and AFM, and further used as templates to create highly ordered quantum dots.



Initial corrosion and surface passivation of metal materials

Electrochemical corrosion of iron (steel) is a ubiquitous phenomenon and the corrosion and aging of iron products can cause severe economic and technical, or even safety problems. Thus, the understanding and further preventing, or at least decreasing the speed of the corrosion processes is vastly important. The study of the initial steps of metal deposition or dissolution on electrodes represents a basic step toward understanding complex surface corrosion and is the key to control corrosion processes. Electrochemical scanning tunneling microscopy (EC-STM) is a powerful tool which combines electro-analytical techniques with surface sensitive scanning probe microscopy (SPM) to investigate surface processes and chemical reactivity at the atomic level.

◆Probe surface corrosion at atomic level