Chemistry for Nano, and Nano for Medicine & Energy

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Over the last 20 years, our laboratory has focused on the designed chemical synthesis, assembly and applications of uniform-sized nanocrystals. Especially, we developed a novel generalized procedure, called as "heat-up process" for the direct synthesis of uniform-sized nanocrystals of many metals, oxides, and chalcogenides.[1] For the last 10 years, our group has been focused on medical applications of various uniform-sized nanoparticles. We reported that uniform 2 nm iron oxide nanoclusters can be successfully used as T1 MRI contrast agent for high-resolution MR angiography of monkeys.[2] We reported the first successful demonstration of high-resolution in vivo 3-photon imaging using biocompatible and bright Mn^{2+}/ZnS nanocrystals.[3]

I will present recent advances on the fabrication of stretchable electronic & optoelectronic devices integrated with various functional nanomaterials and their applications to wearable & implantable healthcare devices. We reported graphene-hybrid electrochemical devices integrated with thermo-responsive micro-needles for the sweat-based diabetes monitoring and feedback therapy.[4] We introduced electromechanical cardioplasty using an epicardial mesh made of electrically conductive and elastic Ag nanowire-rubber composite material to resemble the innate cardiac tissue and confer cardiac conduction system function.[5] We report a highly sensitive and selective K^+ nanosensor that can quantitatively monitor extracellular K^+ concentration changes in the brains of freely moving mice experiencing epileptic seizures.[6]

Recently we have focused on the architecture engineering of nanomaterials for their applications to lithium ion battery, fuel cell electrocatalysts, solar cells, and thermoelectrics. We reported the first demonstration of galvanic replacement reactions in metal oxide nanocrystals, and were able to synthesize hollow nanocrystals of various multimetallic oxides including Mn_3O_4/γ-Fe_2O_3.[7] We report a simple synthetic method of carbon-based hybrid cellular nanosheets loaded with SnO_2 nanoparticles.[8] We designed hollow anatase TiO_2 nanostructures composed of interconnected ~5 nm-sized nanocrystals, which can individually reach the theoretical lithium storage limit and maintain a stable capacity during prolonged cycling.[9] We present a synthesis of highly durable and active electrocatalysts based on ordered fct-PtFe nanoparticles and FeP nanoparticles coated with N-doped carbon shell.[10] The effect of porous structures on the electrocatalytic activity of N-doped carbon is studied by using electrochemical analysis techniques, and the results are applied to synthesize highly active and stable Fe-N-C catalyst for oxygen reduction reaction (ORR).[11] We report on the design and synthesis of highly active TiO_2 photocatalysts incorporated with site-specific single copper atoms (Cu/TiO_2) that exhibit reversible & cooperative photoactivation process, and enhancement of photocatalytic hydrogen generation activity.[12] We synthesized multigrain nanocrystals consisting of Co_3O_4 nanocube cores and Mn_3O_4 shells. At the sharp edges of the Co_3O_4 nanocubes, we observed that tilt boundaries of the Mn_3O_4 grains exist in the form of disclinations, and we obtained a correlation between the defects and the resulting electrocatalytic behavior for the oxygen reduction reaction.[13]

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