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Chemistry for nano, and nano for medicine & energy

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Over the last 18 years, our laboratory has focused on the designed chemical synthesis, assembly and applications of uniform-sized nanocrystals. In particular, we developed a novel generalized procedure called as the "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. Using 3 nm-sized iron oxide nanoparticles, new non-toxic MRI contrast agent was realized for high resolution MRI of blood vessels down to 0.2 mm.[2] We fabricated tumor pH-sensitive magnetic nanogrenades composed of self-assembled iron oxide nanoparticles and pH-responsive ligands for theranostic application, enabling the visualization of small tumors of < 3 mm via pH-responsive T1 MRI and fluorescence imaging and superior photodynamic therapeutic efficacy in highly drug-resistant heterogeneous tumors.[3]

I will present recent advances on the fabrication of ultraflexible and stretchable electronic and optoelectronic devices integrated with various functional nanomaterials and their applications to wearable and 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 reported the designed fabrication of multifunctional wearable electronic devices for sensing, data storage, and drug-based feedback therapy of motion-related neurological disorders such as Parkinson's disease.5 We reported the first successful demonstration of a wearable red-green-blue (RGB) colloidal quantum dot light-emitting diode (QLED) array with resolution up to 2,460 pixels per inch using a novel intaglio transfer printing technique.[6]

More 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] These iron oxide-based nanomaterials exhibited very high specific capacity and good cyclability for lithium ion battery anodes. We present a synthesis of highly durable and active oxygen reduction electrocatalysts based on ordered fct-PtFe nanoparticles coated with N-doped carbon shell.[9]

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2. "Large-scale Synthesis of Uniform and Extremely Small-sized Iron Oxide Nanoparticles for High-resolution T1 MRI Contrast Agents," J. Am. Chem. Soc. 2011, 133, 12624.
3. "Multifunctional Tumor pH-Sensitive Self-Assembled Nanoparticles for Bimodal Imaging and Treatment of Resistant Heterogeneous Tumors," J. Am. Chem. Soc. 2014, 136, 5647.
4. "A graphene-based electrochemical device with thermo-responsive microneedles for diabetes monitoring and therapy," Nature Nanotech. 2016, doi:10.1038/nnano.2016.38.
5. "Multifunctional wearable devices for diagnosis and therapy of movement disorders," Nature Nanotech. 2014, 9, 397-404.
6. "Wearable Red-Green-Blue Quantum Dot Light-Emitting Diode Array Using High Resolution Intaglio Transfer-Printing," Nature Commun. 2015, 6, 7149.
7. "Galvanic Replacement Reactions in Metal Oxide Nanocrystals," Science 2013, 340, 964.
8. "Hybrid Cellular Nanosheets for High-Performance Lithium Ion Battery Anodes," J. Am. Chem. Soc. 2015, 137, 11954.
9. "Highly durable and active PtFe nanocatalyst for electrochemical oxygen reduction reaction," J. Am. Chem. Soc. 2015, 137, 15478.