FURMAN

Chemistry Department
2020 Summer Research Program

Research Group of Mary Elizabeth Anderson

Toward the integration of nanomaterials into device architectures, the overarching goal of this research is to investigate the bottom-up solution-phase synthesis of nanomaterials. Research in the Anderson lab examines both surface-anchored and free-standing nanomaterials to gain fundamental understanding about their growth, which is necessary to tune material properties and to integrate the material into device structures through low-energy processing techniques. This research has a broad impact benefitting those who seek to engineer the integration and application of these nanomaterials. Active collaborations with materials scientists characterize and evaluate films and nanoparticles synthesized in the Anderson lab for energy-related applications.

As a research member in this lab, you will learn methodologies for the fabrication of nanoparticles and thin films, utilizing solution-phase solid-state synthesis and metal-organic coordination chemistry. You will characterize their nanomaterials routinely with analytical instrumentation such as powder x-ray diffraction spectroscopy, atomic force microscopy, and scanning electron microscopy with energy dispersive spectroscopy. You will gain experience in the interdisciplinary field of nanoscience — from the chemistry involved in material fabrication, to the physics involved in the forces directing assembly, to the engineering involved in designing device architectures.

Thin films of metal-organic frameworks (MOFs) integrate the versatility and potential of the MOF directly into architectures for gas storage, chemical sensing, and energy storage. Building on initial work in my lab examining metal-organic coordinated multilayer films, we investigated the formation of surface-anchored MOFs (surMOFs).[1-5] With initial focus on the iconic HKUST-1 system, we determined the thin film growth mechanism by characterization with atomic force microscopy, ellipsometry, and IR spectroscopy. Research continues to investigate other surMOF systems, technologically-relevant substrates, crystal and porosity structure, and the effect of post-synthetic modifications. This fundamental research is essential to develop design rules for the integration of these promising materials into real-world applications. Recently, this was realized through a new collaboration where one of our studied surMOF systems matched their desired criteria for a solid electrolyte layer related to battery applications.

We developed a rapid and low energy synthesis for **thermoelectric nanoparticles**, a class of material capable of capturing waste heat and converting it into usable electricity.[6-8] Recently, tetrahedrite ($Cu_{12}Sb_4S_{13}$) was synthesized and its thermoelectric performance evaluated. The figure of merit values found were comparable or greater than those obtained for the same compounds fabricated using time and energy intensive conventional methods. Our modified polyol process produces nanomaterials and requires only 1 hour at ~200°C, while conventional means require days at temperatures above 600°C. Synthetic characterization is undertaken by powder x-ray diffraction, scanning electron microscopy, and energy-dispersive x-ray spectroscopy with thermoelectric performance evaluated with Prof. Morelli's lab in Materials Science and Engineering at Michigan State University. Research continues to evaluate dopants, investigate material stability, determine growth mechanism, and explore other thermoelectric targets.

---

1. "Metal-Organic Coordinated Multilayer Film Formation: Quantitative Analysis of Composition and Structure," A.S. Benson, M.B. Elinski, M.L. Ohnsorg, C.K. Beaudoin, K. Alexander, G.F. Peaslee, P. DeYoung, M.E. Anderson, *Thin Solid Films, 590*, 103, **2015**.

2. "Fundamentals of MOF Thin Film Growth via Liquid-Phase Epitaxy: Investigating the Initiation of Deposition and the Influence of Temperature," M.L. Ohnsorg, C.K. Beaudoin, M.E. Anderson, *Langmuir, 31*, 6114, **2015**.

3. "Tailoring Nanoscale Morphology of HKUST-1 Thin Films by Tuning Deposition Conditions," L.J. Bower, L.K. Gentry, A.L. Napier, and M.E. Anderson, *Beilstein Journal of Nanotechnology, 8*, 2307, **2017**.

4. "Comparison of Surface-Bound and Free-Standing Variations of HKUST-1 MOFs: Effect of Activation and Ammonia Exposure on Morphology, Crystallinity, and Composition" B. H. Bowser, L. J. Brower, M. L. Ohnsorg, L. K. Gentry, C. K. Beaudoin, and **M. E. Anderson,** *Nanomaterials, 8*, 650, **2018**.

5. "Conformal Surface-Anchored Metal-Organic Frameworks: Characterization of Thin Film Growth, Porosity, and Electronic Transport," J. Lau, A.E. Trojniak, A.C. Serino, M.L. Ohnsorg, K.M. Cheung, P.S. Weiss, B.S. Dunn, M.E. Anderson, *Chemistry of Materials*,submitted

6. "Comparative Growth Mechanism Study for Two Thermoelectric Compounds," C.F. Holder, E.E. Rugen, M.E. Anderson, *Nanomaterials and Energy*, *3*, 206, **2014**.

7. "Thermoelectric Performance of Tetrahedrite Synthesized by a Modified Polyol Process," D.P. Weller, D.L. Stevens, G.E. Kunkel, A.M. Ochs, C.F. Holder, D.T. Morelli, M.E. Anderson, *Chemistry of Materials, 29*, 1656, **2017**.

8. "Observation of n-type behavior in Fe-doped tetrahedrite at low temperature," D. P. Weller, G. E. Kunkel, A. M. Ochs, D. T. Morelli, **M. E. Anderson**, *Materials Today Physics*, *7*, 1, **2018**.