DEPARTMENT OF MECHANICAL AND MATERIALS ENGINEERING
COLLEGE OF ENGINEERING AND APPLIED SCIENCES

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PROJECT TITLE: Nanoscale 3D Printing

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Project Description

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The UC Micro and Nano Manufacturing Laboratory
The mission of the UC Micro and Nano Manufacturing Laboratory is to expand the horizons of what is possible in manufacturing at increasingly small size scales. Each new process studied is intended to pave the way for new technology to meet the increasing demands of performance and portability across various industries (medicine, consumer products, electronics, aerospace, automotive, defense, and many others). For example, the massive computers of the mid-20th century have come a long way to the much smaller and more powerful smartphones of today, with the possibility of quantum computing coming in the future. Such shifts in technology have been made possible by ongoing research on the harnessing of scientific phenomena to perform material addition, removal, and/or modification at increasingly small size scales. These may range from that of hair (micro) down to individual atoms (nano). The UCMAN lab studies each process using a two-fold experimental and computational approach to build knowledge on its behavior.

Electrochemical Additive Manufacturing
One of the processes being studied is electrochemical additive manufacturing (ECAM). ECAM is a novel, emerging method of additive manufacturing (also known as 3D printing) that uses localized electrochemical deposition (localized metal plating) between a tool and a substrate when they are sufficiently close together in a metal plating bath. When combined with a positioning and control system, this allows for 3D metal shapes to be created. A video of the process can be seen online at https://www.youtube.com/watch?v=0efMAGZl9XI

While the ECAM process has been extensively studied at the micro size scale, the ability to shrink the resolution down to the nano or atomic level is still in progress. Control of the process at this scale requires an entirely different set of hardware capable of moving, controlling reactions, and sensing current at the nanoscale. Understanding of the process at nanoscale resolution also requries a shift in perspective. The process is no longer optically visible at the nanoscale, requiring special characterization methods to see what is printed. It is also no longer occuring in a fluid continuum, but instead may be understood and modeled as the behavior of individual molecules.

Project Goals
The student may choose to assist with either the experimental or computational goals of the work.
Experimental goals include:
- Determination of the effective process conditions in which to run deposition. This involves testing behavior under different chemical, voltage, and geometrical conditions.
- Designing a method of tool path planning to build a 3D CAD model under a given set of process conditions.
- Evaluating the deposition behavior using in-process monitored signals and post-process imaging and characterization methods.

Computational goals include:
- Writing and executing postprocessing codes that connect atomic-scale simulation to experimental data by integrating understanding of theoretical concepts and real-life behaviors of the setup.
- Evaluating effectiveness of different modeling approaches at the quantum and classical levels.
- Comparing performance of the experimental and simulation setups under the same set of process parameters, and evaluating what simulation can explain that experimentation alone cannot.

Learning opportunities for students

Participating in this project will expose the undergraduate student to hands-on, interdisciplinary research. Students will build have the opportunity to build rare and valuable skills in studying physical phenomena from first-principles, experimentation characterization methods, analog hardware design, and/or modeling of the process at the atomic scale. Fundamental research skills will be covered including literature review, presentation, and report writing. The undergraduate student will also be encouraged to begin building a professional body of research work by presenting the work at either a conference and/or preparing a paper for journal publication.