Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (NSEC) Award # 0749028 (CMMI)

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Overview and Mission

In the 21st century, discoveries and inventions at the nanoscale have the potential of profound and enduring changes on the most basic of human needs: health and well-being, security and knowledge. To realize this potential, methods for manufacturing devices with nanoscale features quickly, reliably and **cost-effectively** are essential. The mission of the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) is, therefore, to develop the science and technology knowledge base, the methodologies and tools, a diverse human resource base and the necessary industrial connections to make manufacturing at the nanoscale a common-place industrial activity.

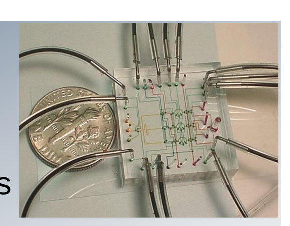
With major funding from the National Science Foundation, Nano-CEMMS Center's activities span six campuses: the University of Illinois, Stanford University, North Carolina Agricultural and Technological State University, University of Notre Dame, University of California – Irvine, and Northwestern University. They involve faculty, research staff, and students from mechanical, industrial, chemical, biomolecular, electrical, computer, and materials engineering, applied physics, chemistry, and molecular and cell biology.

Program Organization

To address its mission, the Nano-CEMMS Center's activities are integrated into three programs:

Research

Addressing:



Control of composition at the nanoscale
- Chemical, electrical, and mechanical properties
- Integrated dissimilar materials and processes

Placement of nano-structures in 3-D
- Resolution, tolerances, metrology

Knowledge of the state of matter at the nanoscale
- Composition, geometry, molecular structure

To manufacture with scalability, repeatability, robustness, economic viability

Education and HRD

Developing and delivering educational programs and materials to a diverse audience of:

University (undergraduate and graduate) students
- Courses, research, laboratories, REU program

High school students
- Camps, teaching modules, NanoChallenge after-school research program

Middle school students
- Camps, teaching module inclusion in *Project Lead the Way* curriculum, *Benjamin Banneker* and *TAP-IN* after-school programs

Teachers
- Workshops, hands-on labs, RET program
- To develop a diverse human resource for nanomanufacturing

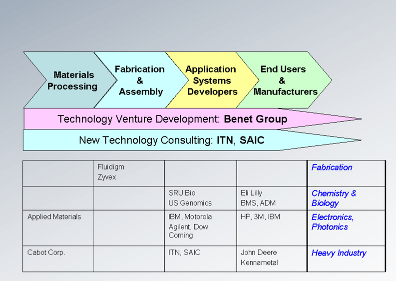
Industrial Outreach

Engaging industrial partners from across the nanotechnology value-chain to:

Collaborate on Research and HRD
- Joint research programs, teaming
- Student internships

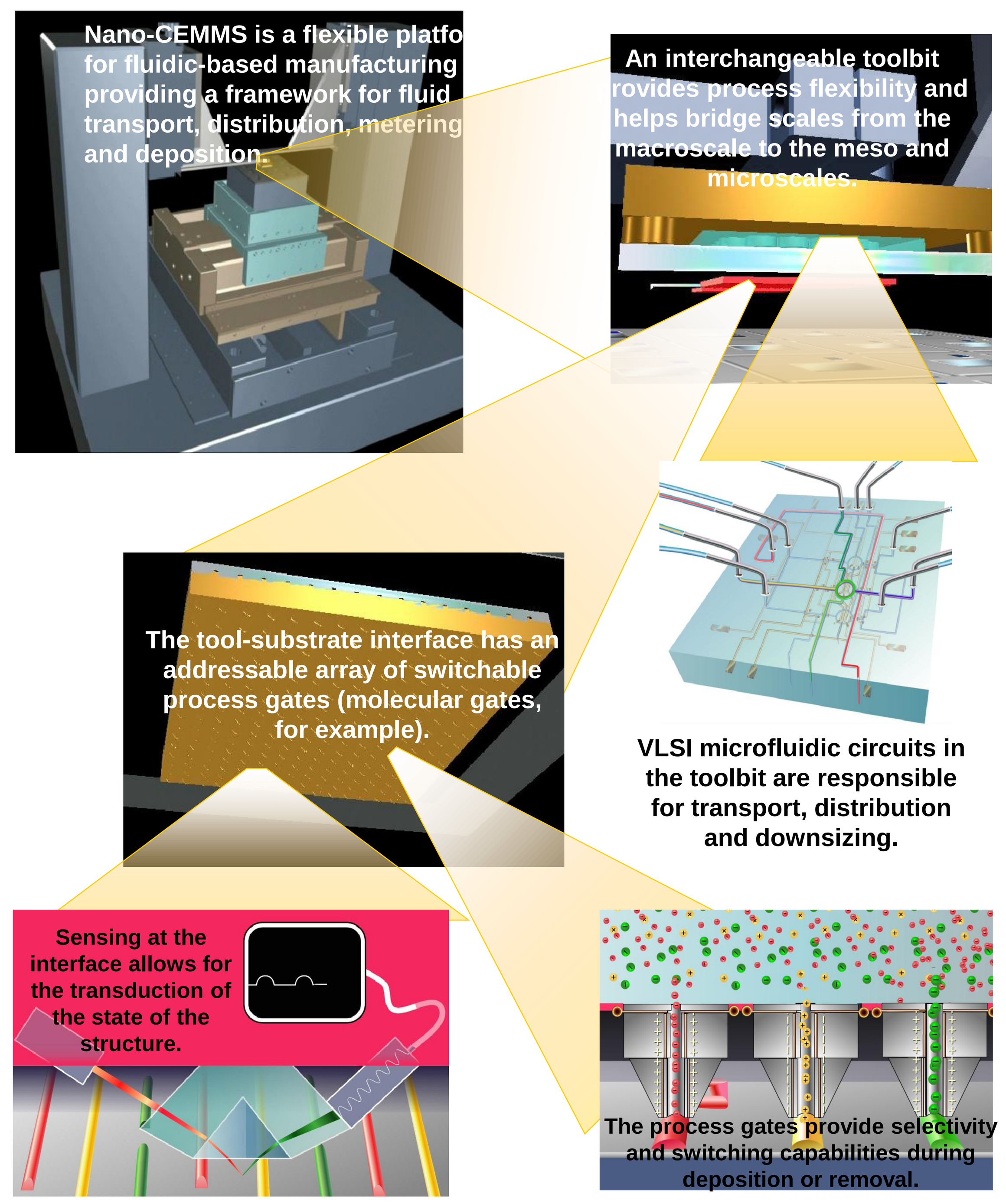
Maintain Industrial Viability
- Industrial Advisory Board

Create channels for deployment
- Industrial affiliates programs
- Intellectual property issues



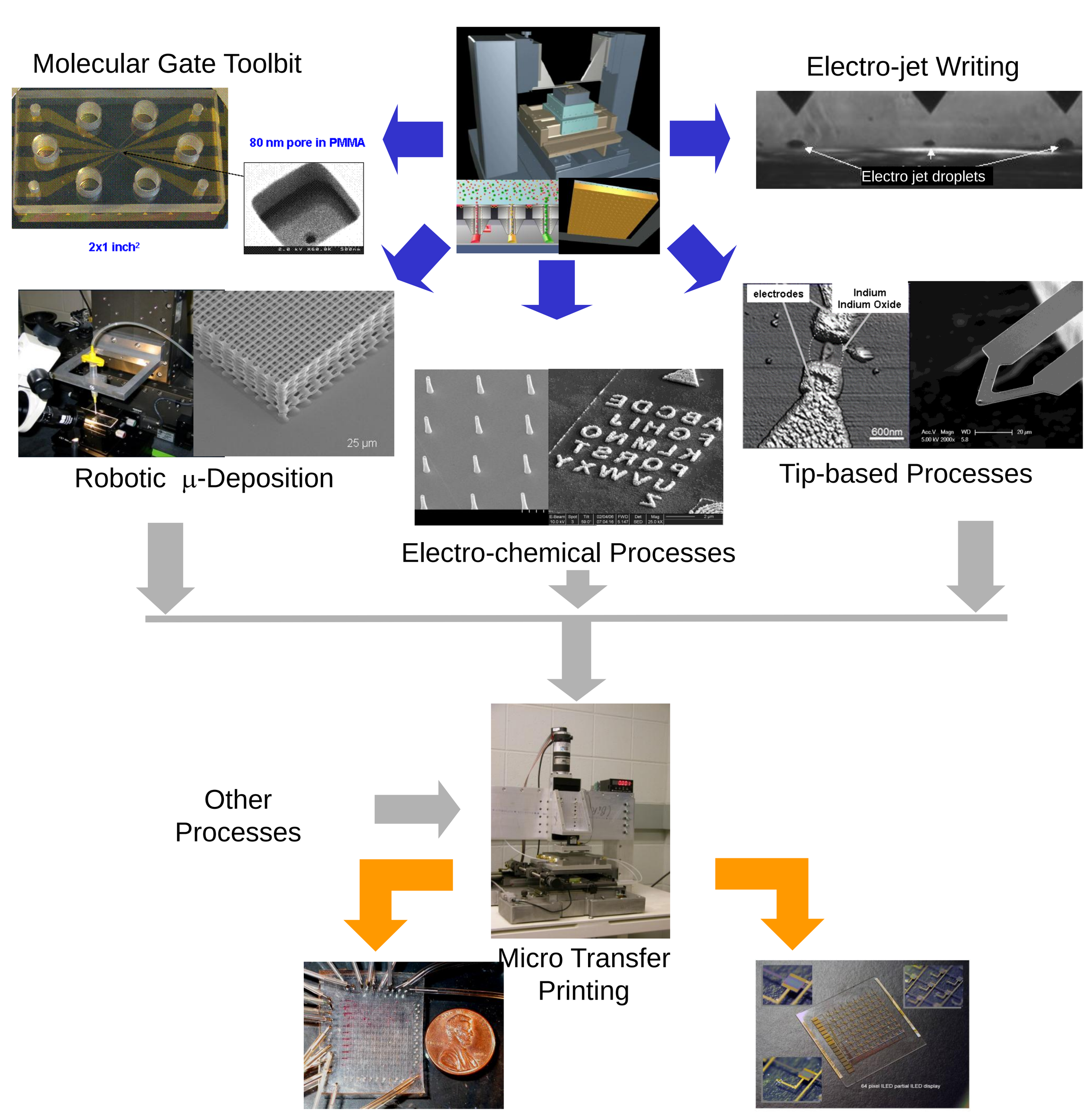
To make nanomanufacturing industrially viable and pervasive

Nano-CEMMS' Process Strategy



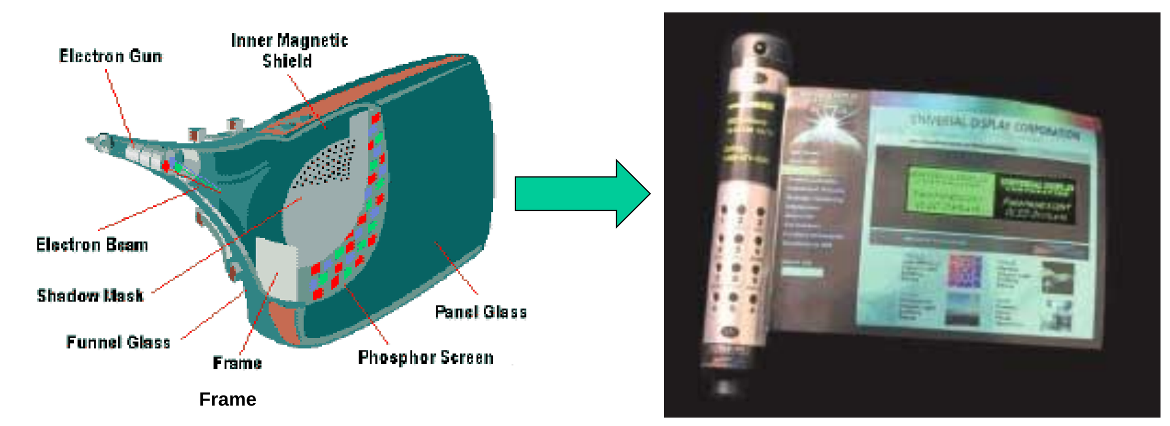
Nano-CEMMS' Process Strategy allows for flexibility through the use of addressable process elements, controllable microfluidic, positioning systems and tool-bit interchangeability; process scalability through the use of arrays of process elements; and robustness through embedded sensing.

Nano-CEMMS' Manufacturing Systems Strategy

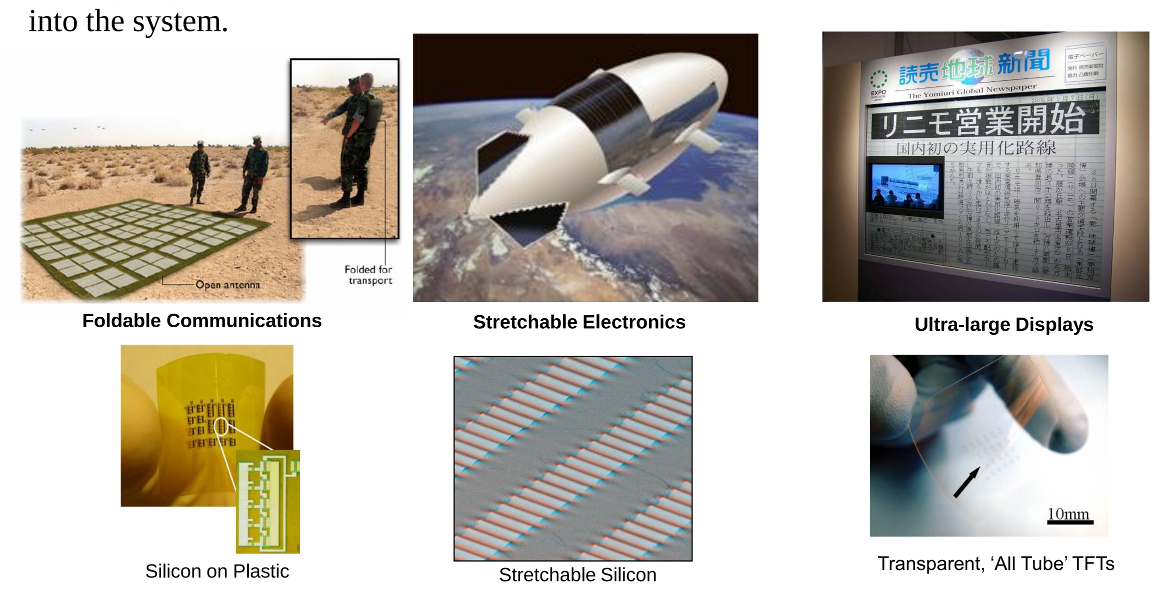


Nano-CEMMS' Manufacturing Strategy involves different embodiments of its process scheme, exploiting different transport phenomena to address building nano structures from different materials. These structures are integrated into devices using micro transfer printing.

Motivation: Heterogeneous Integration



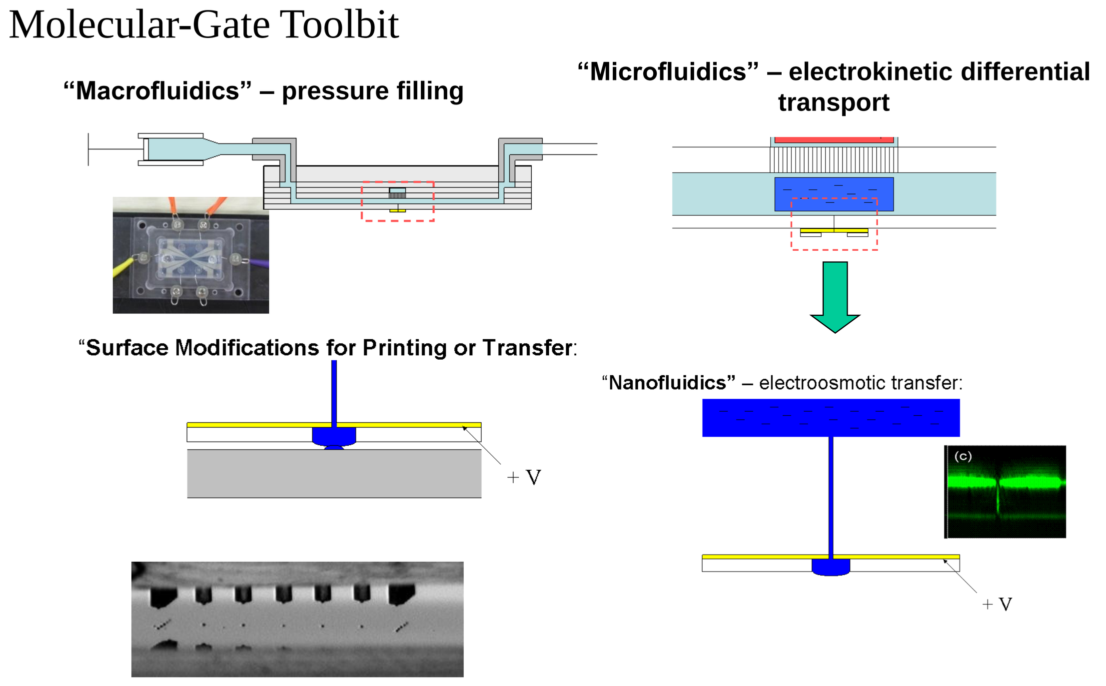
Each pixel has the display element (OLED), the gate (TFT), interconnects, touch sensor, computation, communication functions. So each volume element is responsible for electronic, photonic/optical, thermal, mechanical and chemical functions to integrate sensing, logic, computation, communication, energy generation/collection capabilities into the system.



* Some figures above have been taken without permission from web pages to demonstrate the concept of heterogeneous and its possible applications.

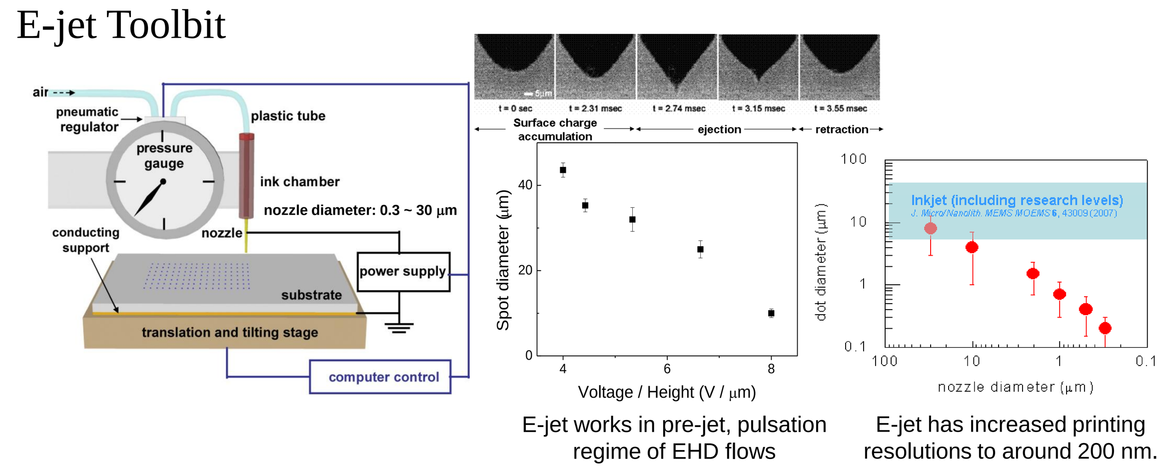
Process Research

Molecular-Gate Toolbit



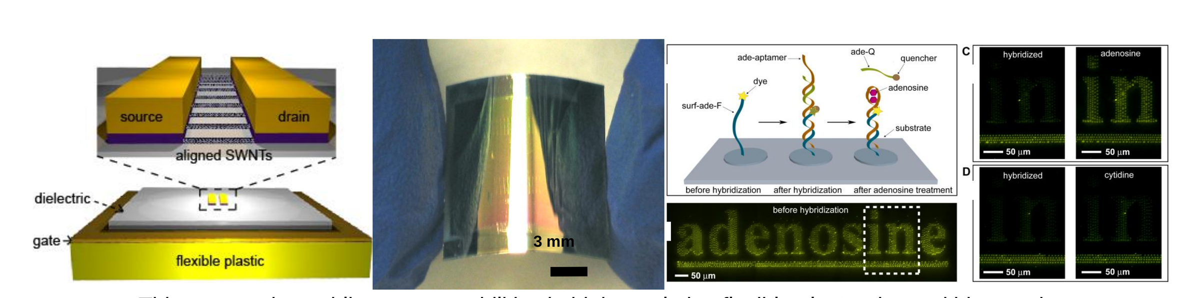
The molecular-gate toolbit uses fluidic transfer through molecular gates until the eventual printing-like transfer to a substrate. Electrokinetic pumping across a gate array is used to build a charged fluid body. Electroosmotic transfer through addressable pores ink the toolbit surface. Control of surface geometry and wetting properties is used to control the transfer to a substrate. Pico-liter resolution transfer has been demonstrated.

E-jet Toolbit



E-jet works in pre-jet, pulsation regime of EHD flows

E-jet has increased printing resolutions to around 200 nm.

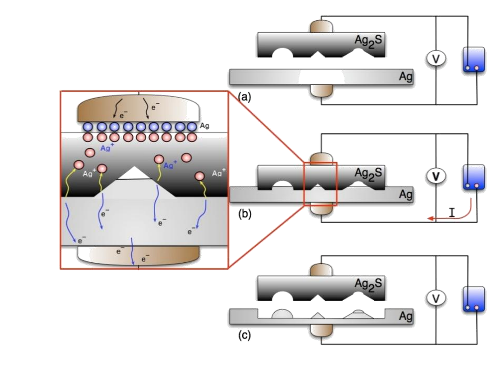


This process is enabling new capabilities in high resolution flexible electronics and bio-sensing.

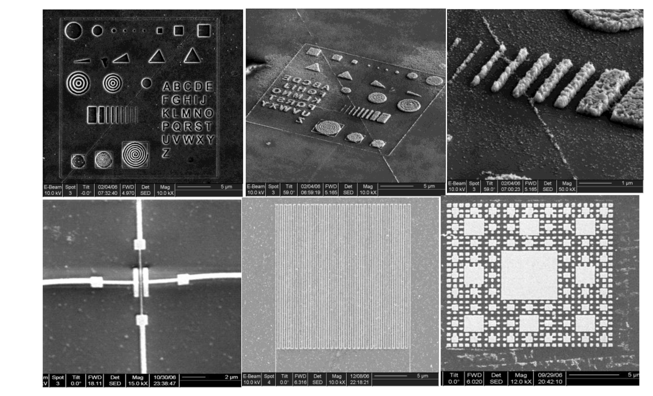
The electro jet toolbit uses electrohydrodynamic (EHD) fluid transfer to write sub-micron structures with polymers, nanoparticle suspensions and inks. The process uses the pre-jet pulsation regime in a dot-matrix-like printing mode. The focusing effect of the jet allows for the writing of structures far smaller than the nozzle orifice diameter. Sub-micron resolutions have been achieved and working electronic devices have been built. Work continues on multi-nozzle e-jet toolbits, modeling of the pre-jet kinetics, and novel micro-fabricated tool-bit configurations

Process Research

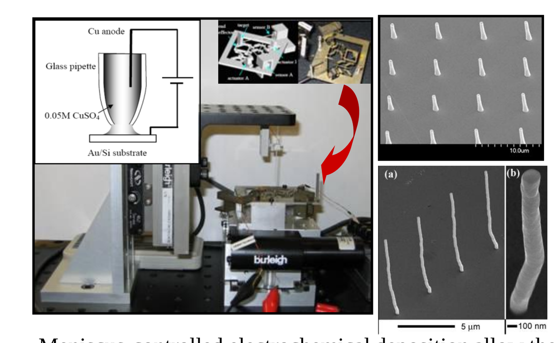
Electrochemical Toolbit



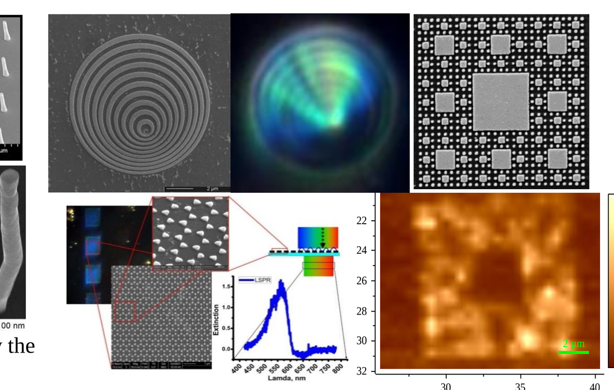
Solid-State Superionic Stamping (S^4) is a all-solid electrochemical etching process that directly patterns metals



Examples of a stamp and different metallic structures built in a single step by the S^4 process



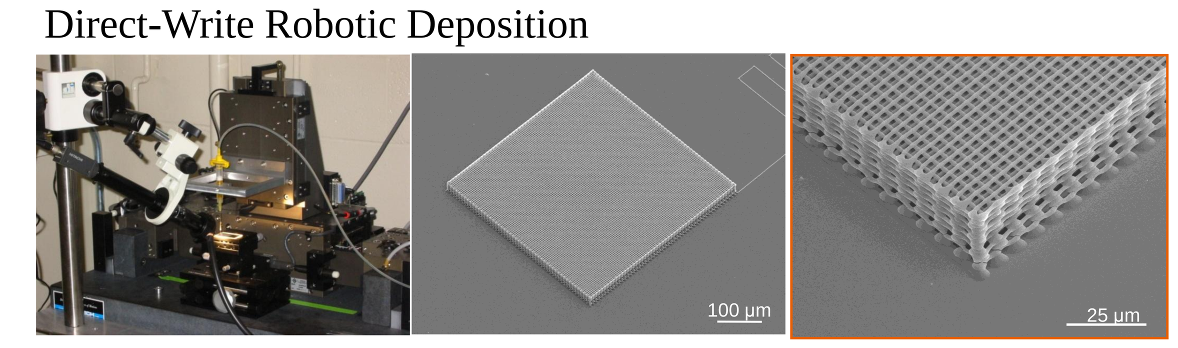
Meniscus-controlled electrochemical deposition allow the creating of out-of-plane structures



Metallic structures made by these processes find application such as plasmonic sensing and Raman spectroscopy

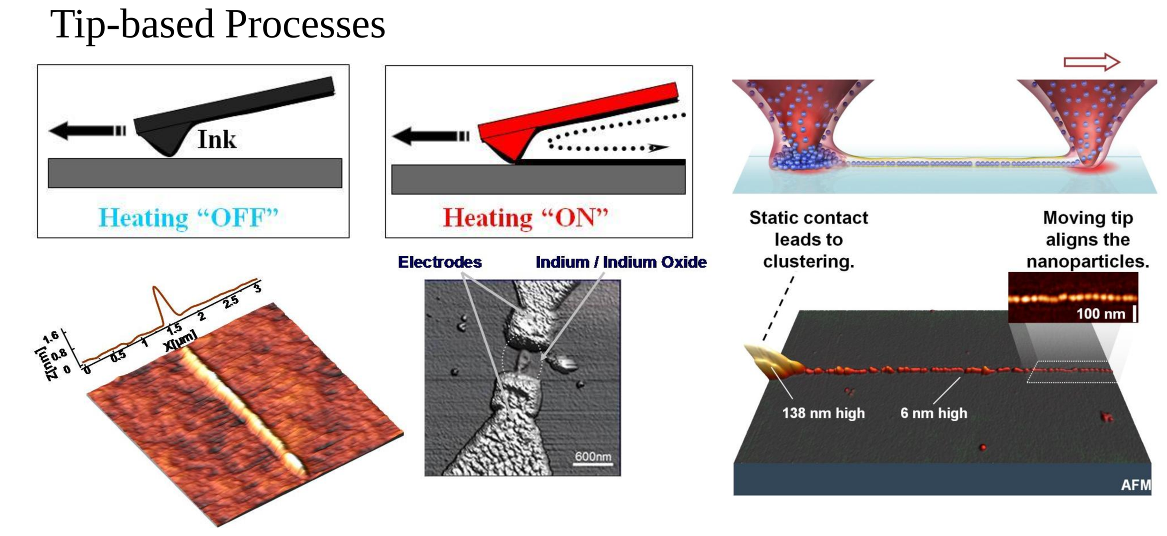
The electrochemical toolbits provide the Center with a nanoscale metalworking platform. Using both solid-state electrochemistry and liquid-based systems, these toolbits directly pattern in-plane and out-of-plane metal structures with resolutions down to 50 nm in silver, copper and platinum.

Direct-Write Robotic Deposition

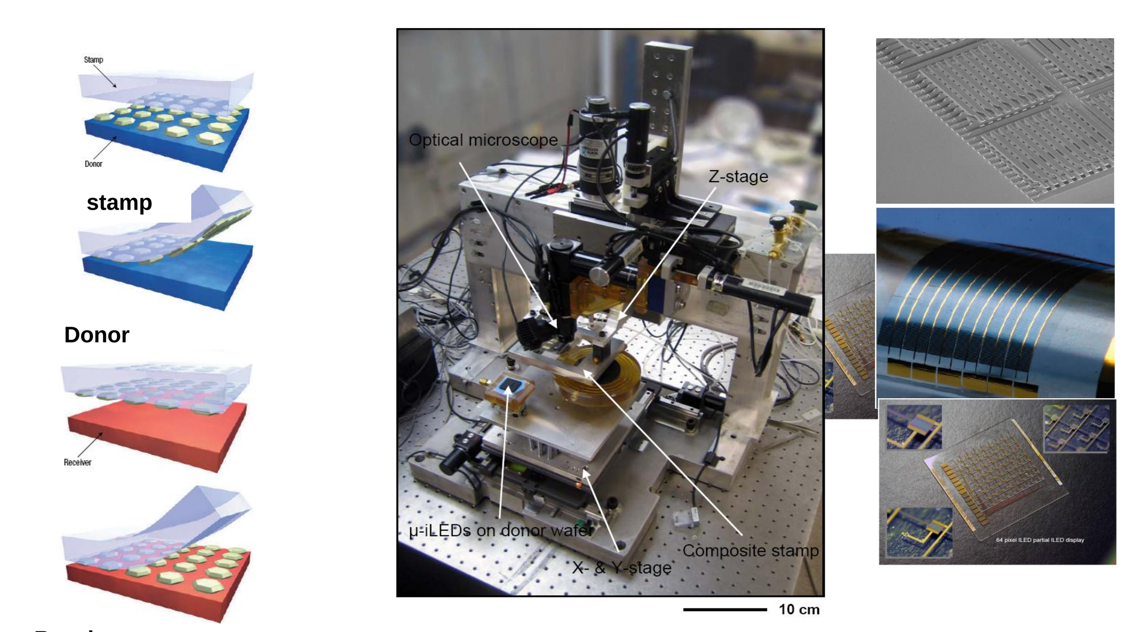


Direct-write robotic deposition, a pre-existing process from the Lewis lab, uses specially formulated sol gel inks with tailored viscoelasticity to build multi-level sub-micron structures at speeds of 400 microns per second with materials like titania and zirconia. Nano-CEMMS supports the parallelization of the process and the modeling of transport in the system to enhance its resolution and rate.

Tip-based Processes



Micro-Transfer Printing



Micro-transfer printing, developed by the Rogers laboratory, allows the transfer assembly of micro- and nano-structures onto different substrates. Exploiting the dependence of adhesion energy at an interface between the ink and the elastomeric stamp on the separation velocity, this adhesiveless transfer printing has been implemented on an automated printer to create multi-level heterogeneous structures.