1. **Description:** This non-contact printing process is an electrostatic based ink-jet print system capable of printing submicron dots, lines and patterns with a wide range of functional "ink" materials including polymers, nanoparticle suspensions, and biomaterials. The resolution of this system is approaching 25 nm vs. 1-2 microns for competing piezo and thermal processes. Also, this system is capable of printing charged liquids as patterns/templates with polarities selectively controlled by electric field directions that can provide the basis for micro-assembly.

As a way to promote the development of this technology, the Center is developing for interested companies a complete easy-to-use test unit with control software and commercially available micro-pipettes that is capable of 0.5 μm resolution and has a printing area of 100X100 mm. Contact David Hamman, dhamman@illinois.edu, if you would like to learn more about these test units.
2. Resolution:
   a. Demonstrated:
      i. Lines: ~ 400 nm min.
      ii. Dots: ~ 25 nm min. (can be controlled 10 \(\mu\)m to 0.1 \(\mu\)m with nozzle size)
   b. Estimated Limit: ~10 nm
3. Geometric capabilities: Dots, lines (can cover large areas)
4. Geometric Forms: 1D, 2D
5. “Ink” Materials (Tested):
   a. Metals (as nanoparticle suspensions): gold, silver
   b. Conducting/insulating/dielectric polymers: PEDOT, PSS, NDA, polyethylene
   c. Other: silicon rods, SWNTs, CNTs,
   d. Biomaterials: DNA, proteins
   e. Ink Parameters:
      i. Viscosity: 1 to 1,000 cp
      ii. Conductivity: \(10^{-6}\) to \(10^{-1}\) S/m
6. Process environment: ambient temperature and atmospheric pressure
7. Dimensional capabilities: very large area (potentially square meters)
8. Speed: >500 \(\mu\)m/s
9. Uniqueness:
   a. Submicron printing resolutions with superior resolution vs. existing thermal and piezoelectric ink jet processes
   b. Non-thermal process can print temperature sensitive materials/inks
   c. Wide variety of “ink” materials can be printed
   d. Capable of printing electrically charged liquids that retain the charge
10. vs. Competition:
   a. Ink-jet (piezo and thermal): higher resolution(by 10X) and non-heat
   b. Dip-Pen Nano-lithography (DNP): more versatility, higher rates, and large area capability
11. Limitations:
   a. Large area, multiple nozzle systems underdevelopment
   b. Complexity
12. IP Status: Patents applied for
13. Potential Applications:
   a. Fabricated flexible electronic devices (e.g., carbon nanotube transistors)
   b. Printed electronics, e.g. flexible transistors
   c. Biosensors (e.g., DNA-programmed microarrays and adenosine sensors)
   d. Fabrication of chem/bio-nano arrays
   e. Maskless lithography
   f. Printing of charged liquids with polarities selectively controlled by electric field directions
   g. Security patterning
   h. Interconnects
14. Current Research Focus:
   a. Multiple nozzle systems
   b. Downsizing droplet size
   c. Expanding “ink” materials printed
d. Potential applications for printed charges

e. Inexpensive self-contained integrated R&D test/demonstration E-jet unit for sale to other research groups

15. Examples:

a. E-Jet printing demonstration

b. E-jet Printing of DNA with 2 micron droplet size

Fluorescence micrographs of butterfly pattern, e-jet printed onto a Si wafer using an oligonucleotide(ssDNA, 5 μM) suspension, ~2 μm droplets spaced ~6 μm horizontal rows and ~4 μm vertical rows.

Nano Lett, 8, 4210 (2008)
c. E-Jet Printing – Applications for electronics

E-Jet printed photoresist and subsequent etching patterns capability of <1 μm resolution.
Heterogeneous fabrication of transistors using aligned SWNTs


E-jet printed silver interconnects
d. Aptamer-based biosensor for adenosine, patterned by e-jet printing.

(a) Schematic representation of the detection of adenosine using e-jet printed aptamer patterns. (b) Fluorescence micrograph of the letters printed with [surf-ade-F] and underline with [surf-no ade-F] as an internal control. (c) Fluorescence micrographs of the pattern after (i) hybridization with two complementary strands (ade-aptamer and ade-Q), and (ii) reaction with adenosine molecules. (d) Fluorescence micrographs of the pattern after (i) hybridization with the same two complementary strands and (ii) reaction with cytidine, for comparison with the adenosine case. Scale bars in (a-d) are 50 μm.

Nano Lett. 8, 4210-4216 (2008)

e. Charge printing with E-Jet
Below: Kelvin Force Microscope potential-mode images of e-jet printed charges. The white and black lines were printed with the nozzle positive and negative respectively.

16. Recent papers:
   b. 