



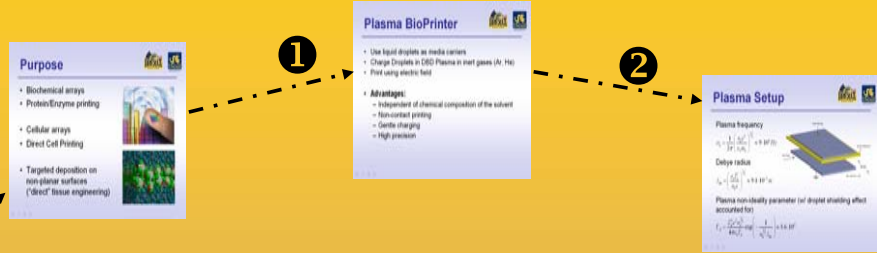
# NON-THERMAL PLASMA BIO-PRINTER WITH NANO SCALE PRECISION

Anne Kimani, Carmen Baez, Eric Irwin, Greg Fridman, Alexander Fridman & Bio Applications Group - Drexel Plasma Institute  
Drexel University, Philadelphia PA 19104 USA



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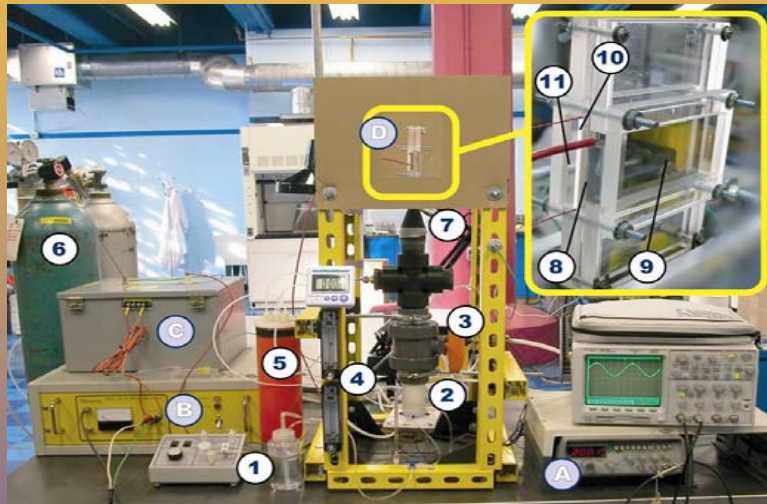
Dr. Mary Poats



### Targeted Deposition

- Idea is to design a system for targeted bioactive substance deposition, or "printing"
- Issues to be addressed:
  - Micro and sub-micrometer precision
  - Operating at room temperature and pressure
  - Varying liquid chemical compositions
  - Minimal mechanical strain

## Experimental Setup



### Plasma BioPrinter

- Reaction to liquid droplets
- Electric Baric Discharge to create Plasma
- Printing High resolution Direct Cell Printing

### Dielectric Barrier Discharge

DBD plasma in Argon at room conditions (300K, 1atm)

DBD plasma in Helium at room conditions (300K, 1atm)

### "Wet" plasma

### Plasma Generation

RF Power Generator parameters: 100-1500 W, 10-100 kHz, 10-100 Torr, 10-100 cm

### Experimental Setup

- Liquid supply (via variable flow pump)
- Ultrasonic Nebulizer
- Droplet flow control valve
- Flow converter
- Liquid Nitrogen cooler
- Carrier Gas Supply
- Flow conversion nozzle
- Quartz Dielectric Barrier
- High Voltage Electrode
- Grounded Mesh Electrode
- Target Substrate

### Droplet Generation

Ultrasonic Nebulizer produces 1 to 4 micrometer droplets (measured by Sonosizer Cx1) at the rate of 130 ml per hour

Droplet concentration:  $7.8 \cdot 10^{10} \text{ cm}^{-3}$

Droplet size:  $9.2 \cdot 10^3 \text{ m}$

$T = 300\text{K}, \rho = 1 \text{ gm}^{-3}$

### Droplet Charge

Water droplets will charge to "floating potential" of  $4 \text{ mV}$  due to plasma behavior and characteristics and due to water's electro-negativity

Droplet charge:  $4.4 \cdot 10^{-11} \text{ C}$  (2775 electrons)

Time to charge a droplet:  $1.2 \cdot 10^{-6} \text{ sec}$  (droplet will charge after passing  $0.4 \cdot 10^3 \text{ meters}$  in plasma)

### Droplet Deposition

Droplet deposition speed is independent of droplet diameter

$F_{\text{net}} = F_{\text{drag}} - F_{\text{buoy}} - F_{\text{gravity}}$

$F_{\text{drag}} = 6\pi\eta r v$

$F_{\text{buoy}} = \rho_{\text{medium}} V g$

$F_{\text{gravity}} = \rho_{\text{droplet}} V g$

$\rho_{\text{droplet}} = 10^3 \text{ kg m}^{-3}$

$\rho_{\text{medium}} = 10^3 \text{ kg m}^{-3}$

$\eta = 0.01 \text{ Pa s}$

### History

#### InkJet Printing

- Binding: Inkjet technology, comparably large liquid ink droplets are sprayed onto the substrate
- Problems:
  - Large droplets
  - Color-mixing problems
  - Low precision

#### Electro-Spray

- Binding: Inkjet technology
- Inkjet spraying, droplets are "spilled" off the nozzle by high electric fields
- Problems:
  - Splashing problems
  - Low precision, high droplet speed
  - High Droplet Charge

#### Laser Printing

- Binding: Inkjet technology
- Blank paper and toner are charged separately. Toner on paper surface and "baked" to form. Toner is laid onto the surface by the drum unit.
- Problems:
  - Particle sticking
  - High temperature
  - Mechanical strain
  - Solid state deposition

### Applications

#### Applications

- Improved BioChip manufacturing process

#### Tissue Engineering

#### Applications

- Tissue Engineering: control adhesion of cells and tissue assembly

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|--|---|--|
| <b>Plasma Generation</b><br>10KV 20KHz AC is generated by:<br>A. Signal generator (sine, triangle, square waveform)<br>B. High frequency current amplifier<br>C. Power transformer<br>Voltage is then applied to:<br>D. Printer head | <b>Experimental Setup</b> <ol style="list-style-type: none"> <li>Liquid supply (bottle and variable flow pump)</li> <li>Piezoelectric "Ultrasonic Nebulizer"</li> <li>Droplet flow control valve</li> <li>Carrier gas flow control amplifier</li> <li>Liquid Nitrogen cooler</li> <li>Carrier gas supply</li> <li>Flow conversion nozzle</li> </ol> | <b>Printer Head</b> <ol style="list-style-type: none"> <li>Quartz dielectric</li> <li>High voltage electrode</li> <li>Grounded mesh electrode</li> <li>Target substrate</li> </ol> |
|--|---|--|