

Introduction and Motivation

Natural systems optimize nutrient transport by growing microvasculature or other fluidic networks. Growth of these fluidic networks is driven by external signals of chemical, gravitational, thermal, and electromagnetic field gradients.

Replication of this process used in applications for:

- Biotechnology and Biocircuits
- Minuturization of Circuits and Microsatellites
- Sensors
- Microreactors
- Modeling of Complex Microvasculature: Tree Roots, Tumor Growth, and Cardiovasculature

Goals:

- Grow wires from nanoparticle-colloidal suspension
- Capture wires in a solid matrix
- Remove wires to allow fluid flow

Dielectrophoresis is employed to grow wires:

- Particles form dipoles along field gradient
- Aggregation of neighboring particles to each other and to electrodes
- Net translational motion toward the field intensity maxima caused by the generated dielectric force,

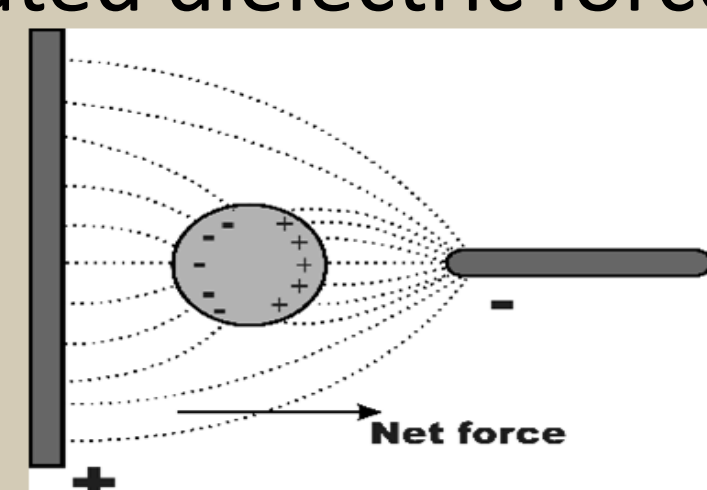
$$F_{DEP} = 2\pi\epsilon R^3 \nabla(E^2)K$$

E = Electric field intensity

R = Radius of the Nanoparticles

ϵ = Dielectric Permittivity of the Medium

K = Effective Polarizability of Particles in Solution.

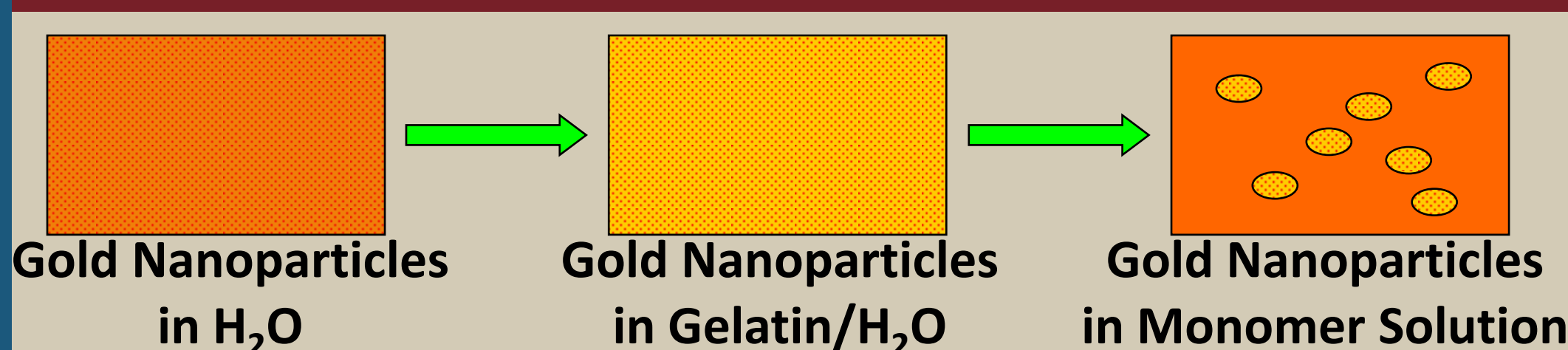


Current Focus is on Characterizing the Wire Growth:

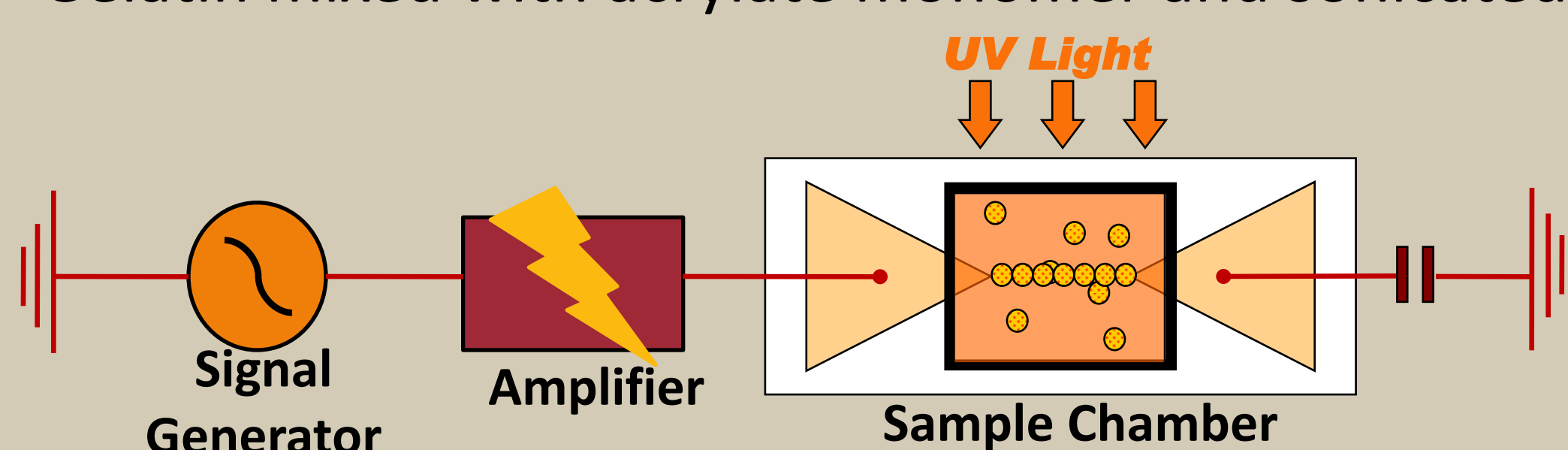
- Electrode Geometry
- Field Properties of Voltage and Frequency
- Duration of Applied Field
- Relative Concentration of Gold Nanoparticles
- Ease of Wire Removal

Within a particular electrode geometry, these parameters will be organized into a concise phase diagram to better understand the effects of said growth parameters.

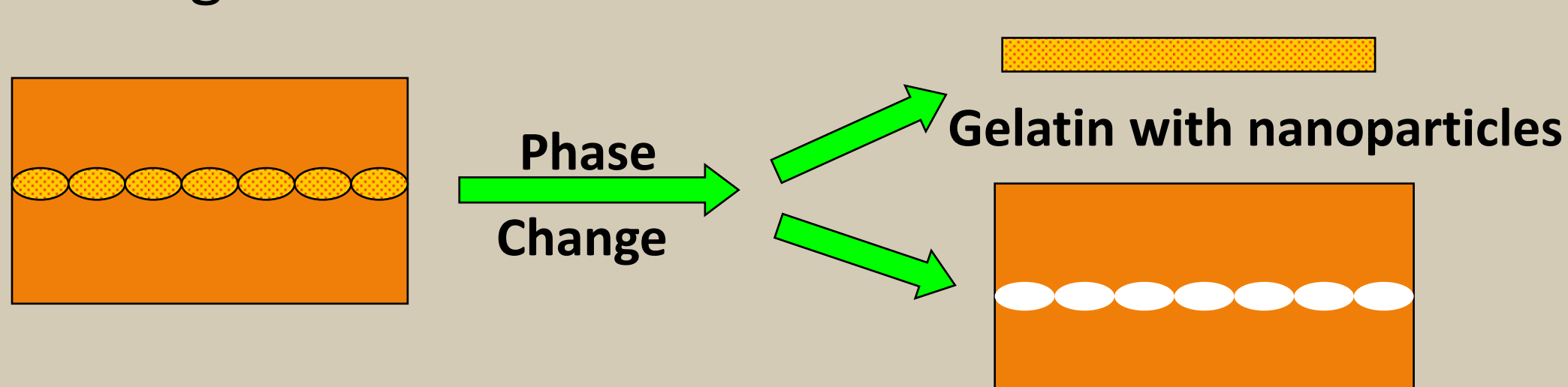
Method



- Gold nanoparticles mixed with gelatin and solidified
- Gelatin mixed with acrylate monomer and sonicated

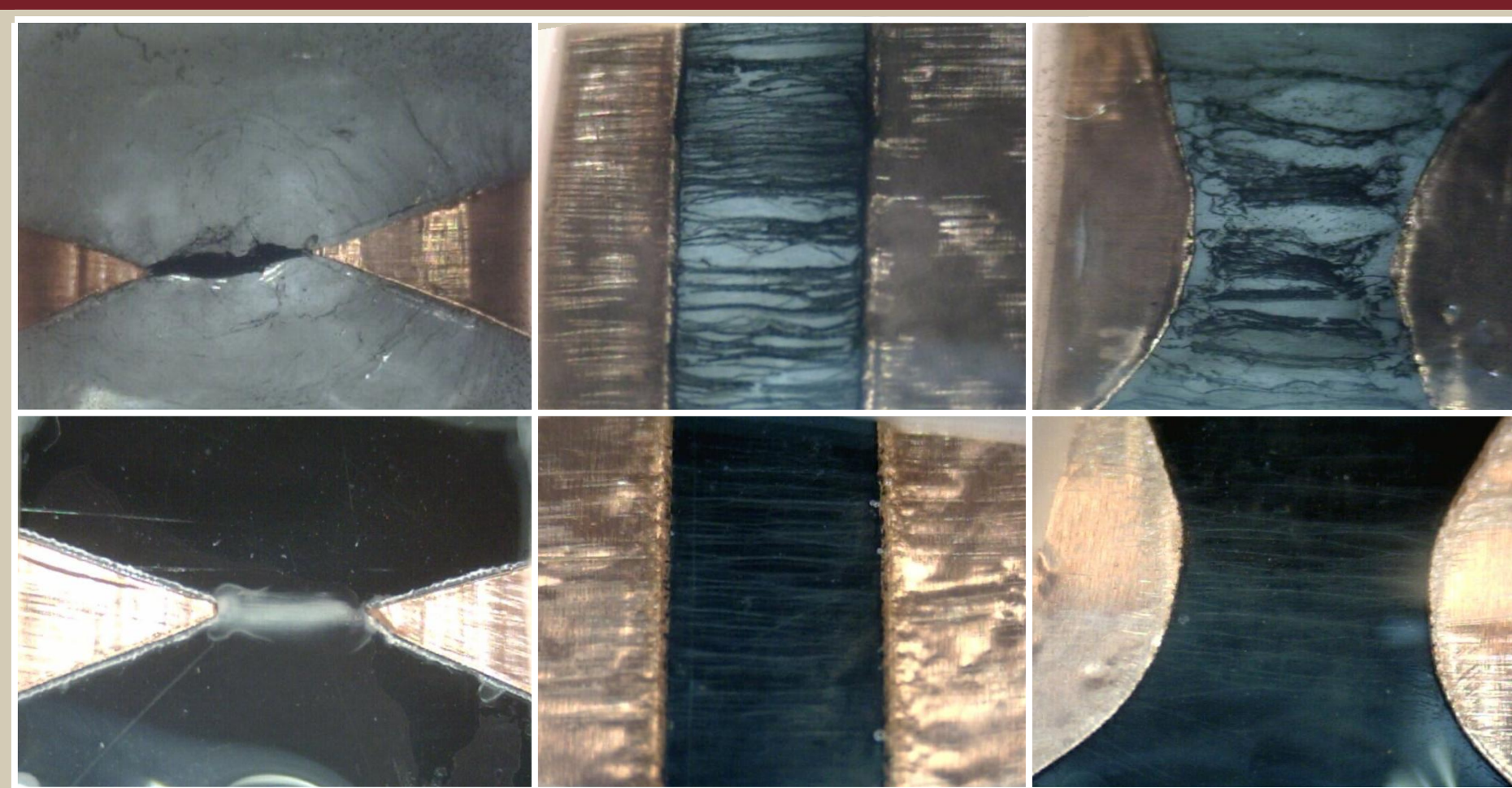


- Electric field generated and connected to electrodes
- F_{DEP} causes aggregation of nanoparticles
- UV Light is used to cure monomer into solid matrix



Heating liquefies the wires, allowing them to flow out of the microvasculature with applied pressure.

Investigation of Electrode Shape

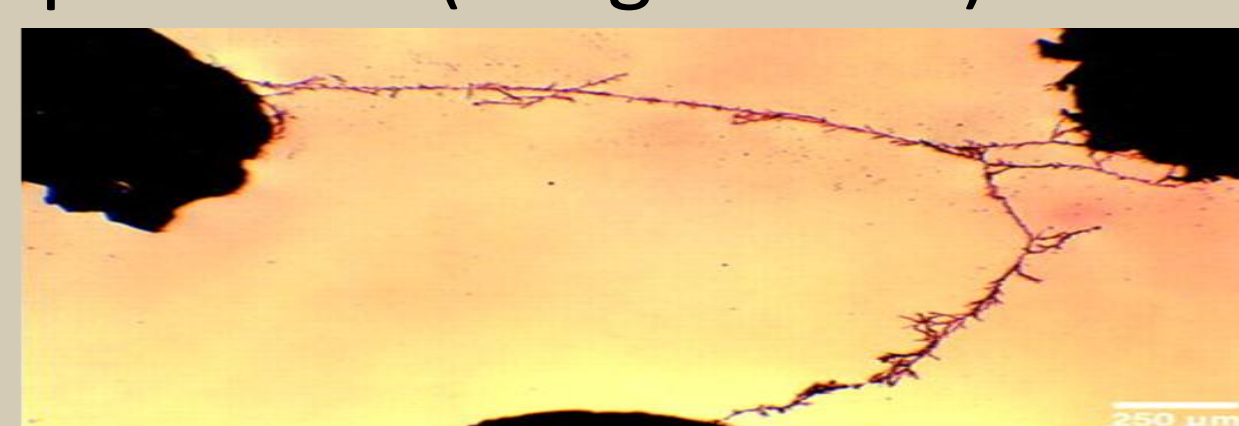


Top Three Images – Aqueous Carbon Black Solution
 “Proof of Concept”

Bottom Three Images – Gold Nanoparticle Solution

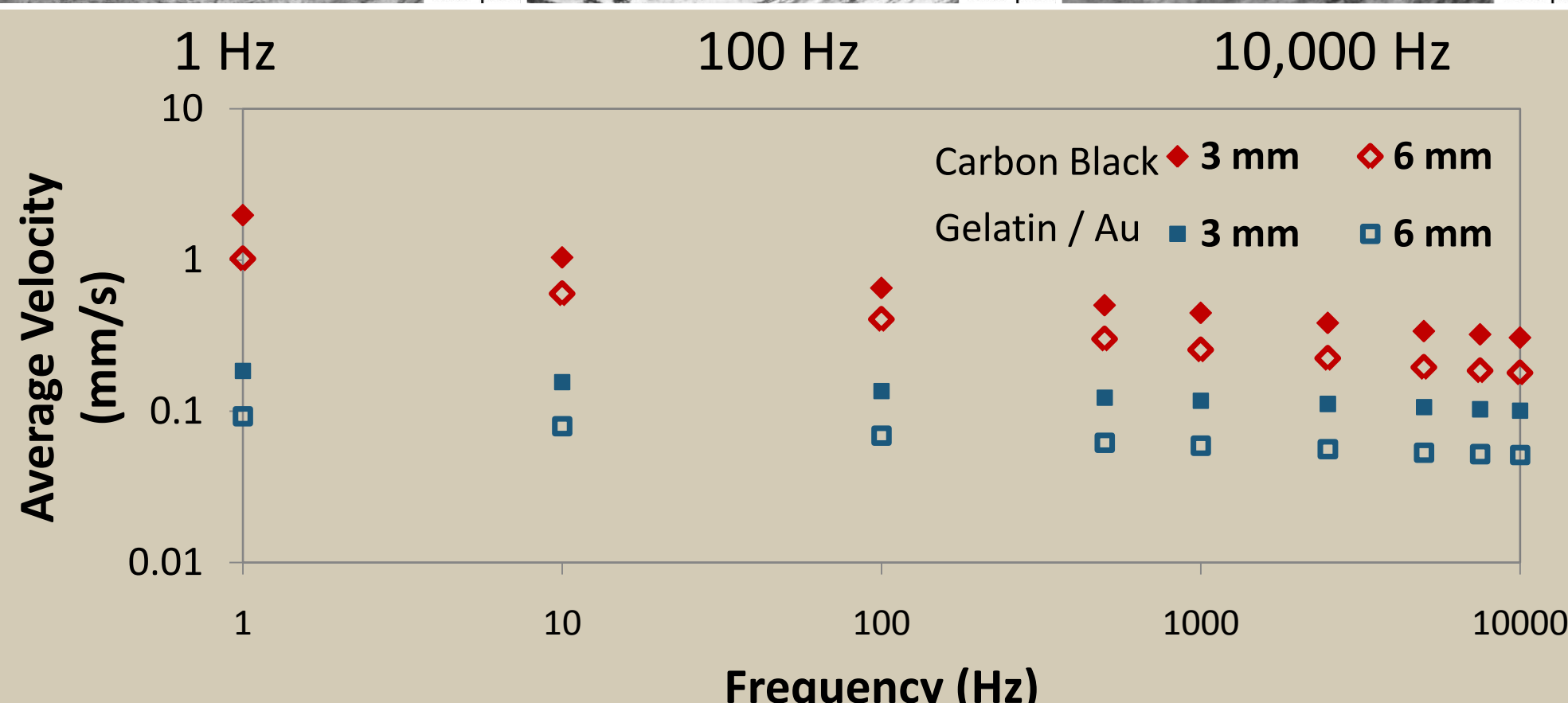
Conclusions:

- Wire growth follows electric potential gradient
- Increased electrode spacing decreases velocity
- Parallel Plates – Simplest electrode geometry with simplest gradient field lines to follow
- Triangle – Most direct and concentrated gradient
- Rounded Edges – Curvature and more complex growth patterns can be generated
- Conductive Islands – Other desired wire patterns can be produced (image below)



Hermanson, Kevin, et al. "Dielectrophoretic Assembly of Electrically Functional Microwires from Nanoparticle Suspensions" Science 2001, 294.

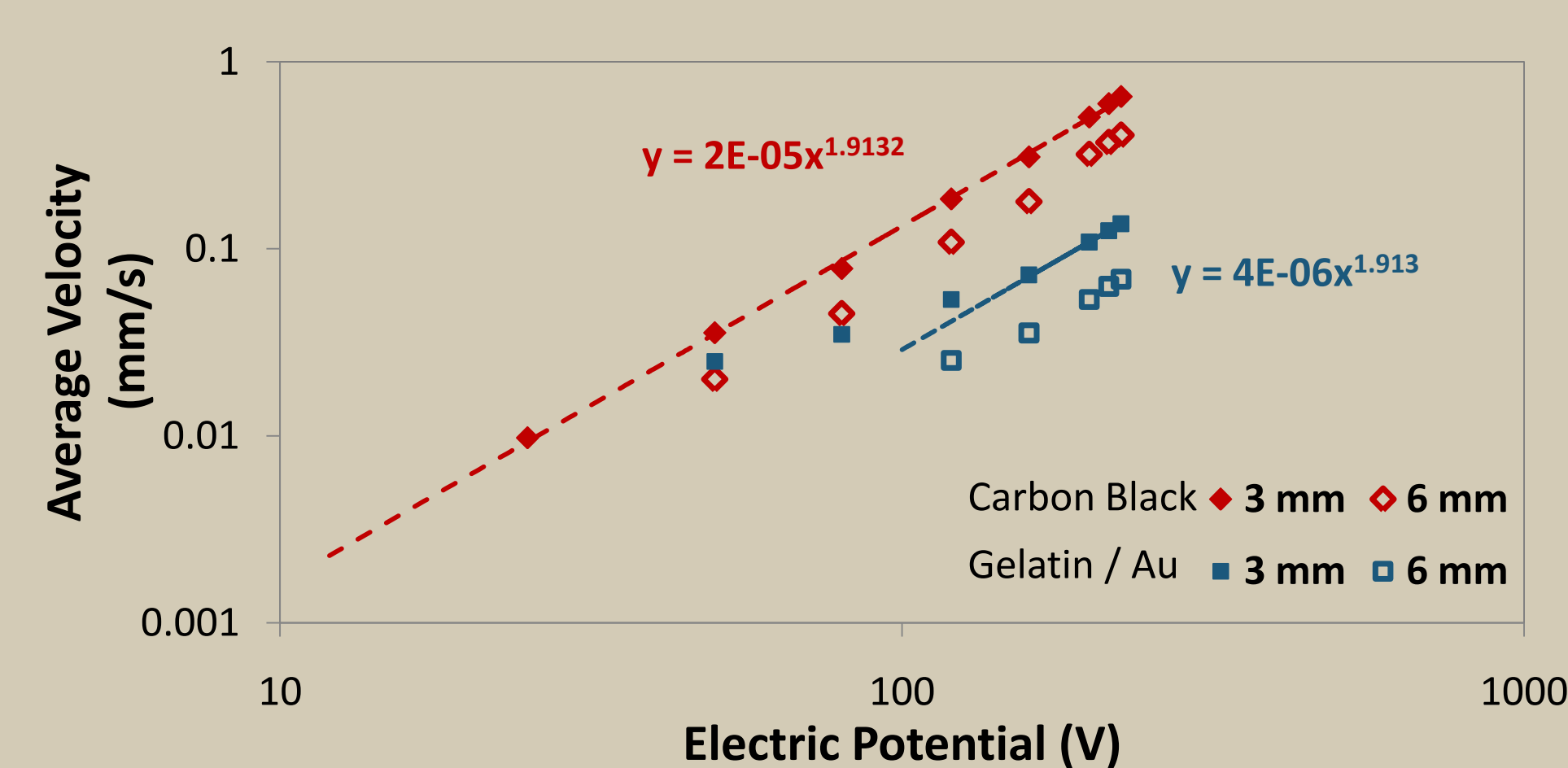
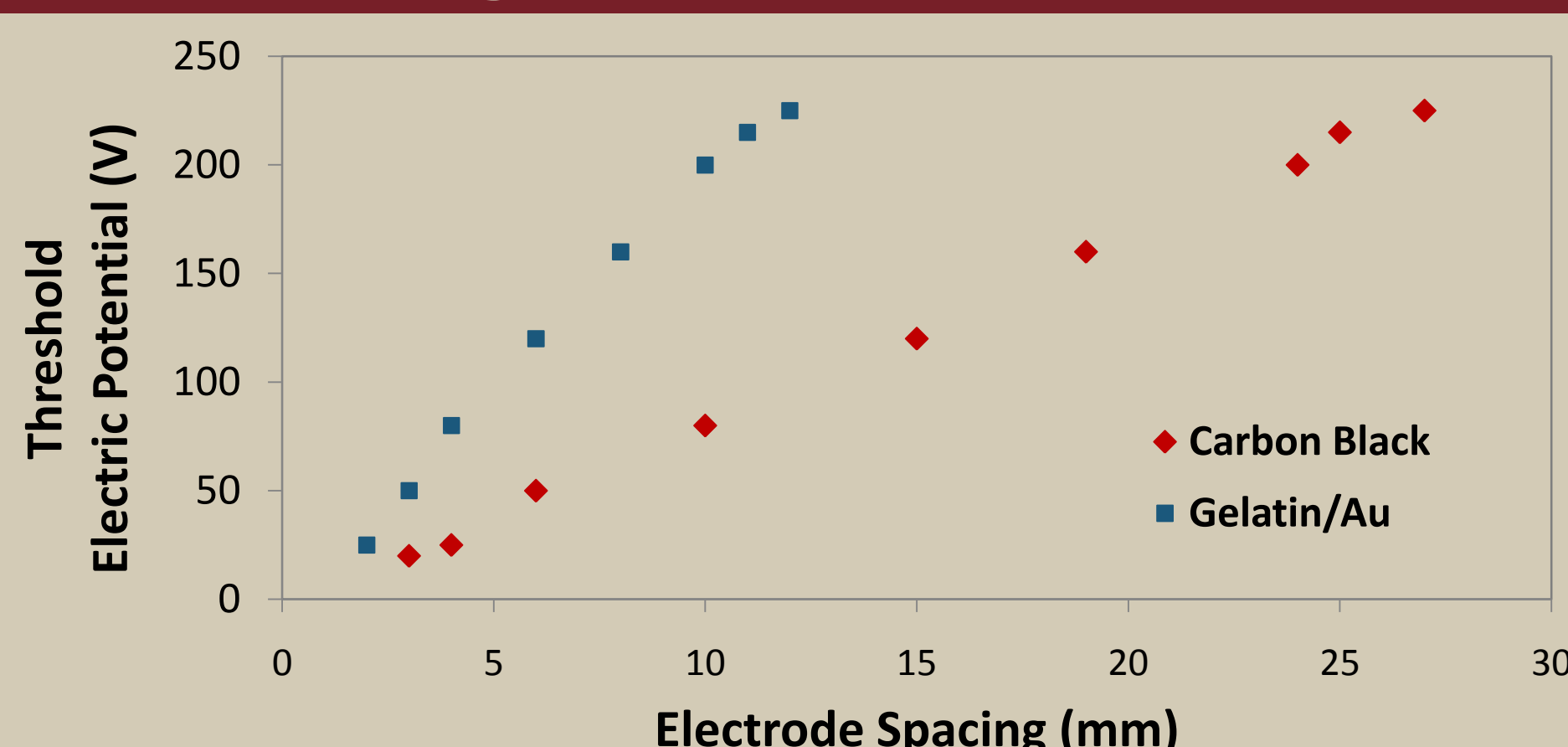
Investigation of Frequency



Conclusions:

- Increasing frequency increases branching, mainly with carbon black solution (images above)
- Increasing frequency decreases velocity of growth

Investigation of Electric Potential



Conclusions:

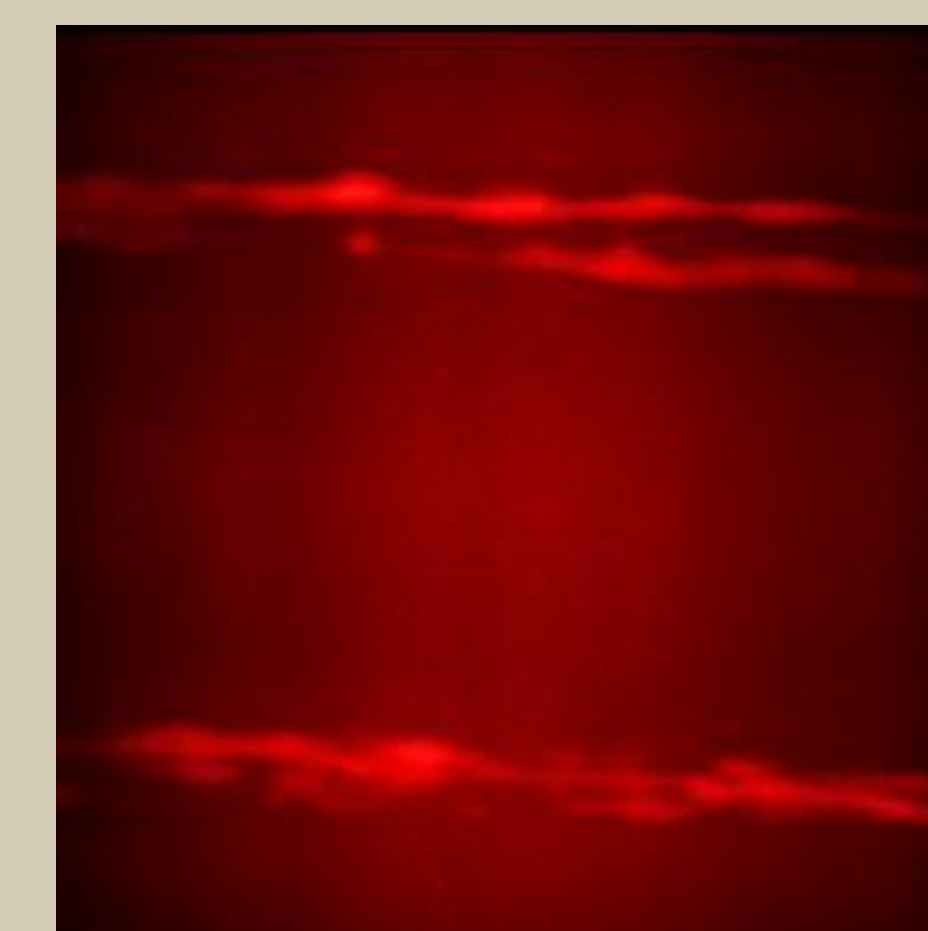
- There is a threshold voltage for any wire growth depending on electrode distance
- Increasing voltage increases velocity of growth

Summary of Wire Growth Effects

Parameter	Growth Rate	Branching	Thickness
Voltage ↑	↑	↓	↓
Frequency ↑	↓	↑	↓
Particle Conc. ↑	↑	Constant	↑
Particle Size ↑ (wt.%)	↓	↓	Constant
Particle Size ↑ (part conc)	↑	↓	↑
Electrolyte Conc. ↑	↑	Constant	↑

Wire Removal Techniques

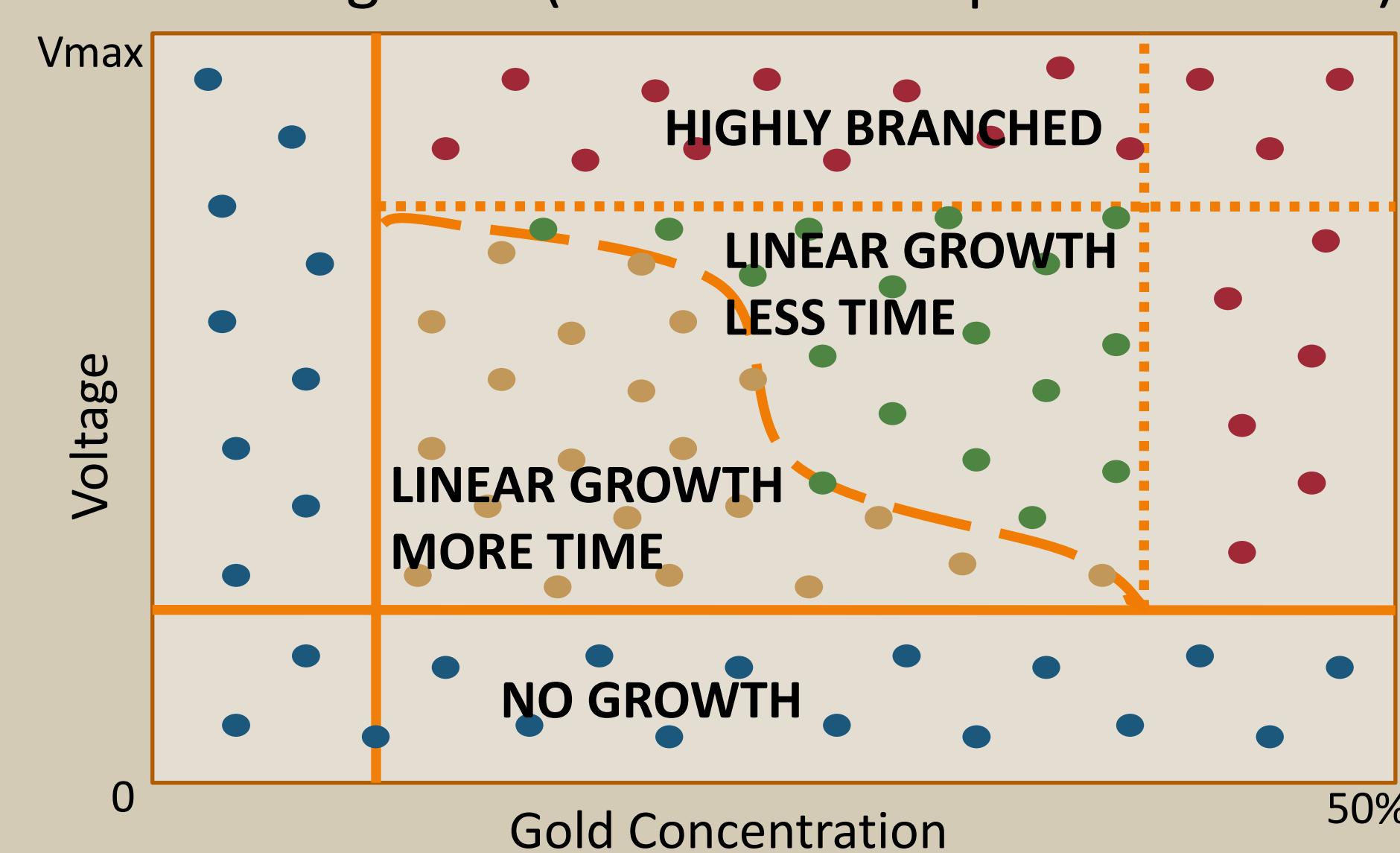
- Sample chamber is heated
- Plastic tubes connected to the ends of the wires
- Aqueous solution with fluorescent Rhodamine B forced through one of the tubes with a syringe
- With applied pressure, gelatin and gold flows out and Rhodamine B flows into the microchannels



- High-speed confocal laser scanning microscopy used for imaging and quantification

Future Work

- Continued characterization of growth
- “Phase Diagram” (below with expected results)



Effects of Voltage and Gold Concentration on:

- Branching
- Average Velocity of Wire Growth
- Distance Between Wires
- Number of Wires

Using Constant:

- Frequency
- Electrode Spacing
- Electrode Shape (parallel plates for simplicity)

Continued work on wire removal techniques to extend scope of functionalization and broaden possible uses and applications

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