

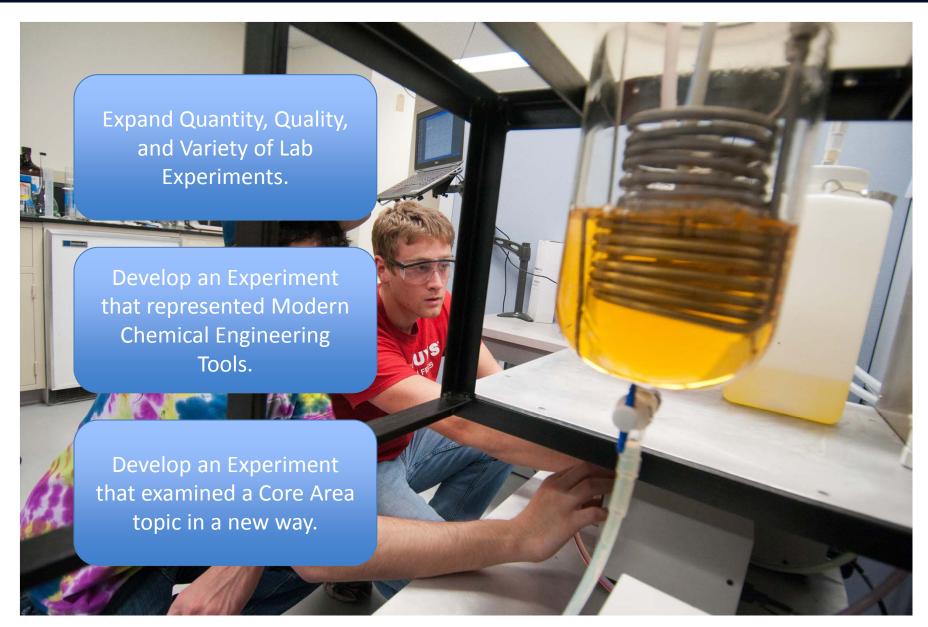
Initiated Chemical Vapor Deposition (iCVD) as a New Take on a Kinetics Lab

Daniel D. Burkey, Daniel Anastasio, & Aravind Suresh Department of Chemical and Biomolecular Engineering University of Connecticut, Storrs CT 428c – Wednesday November 6th, 2013 Union Square 25 (Hilton)



- 2.0 Experimental Setup
- 3.0 Experimental Design

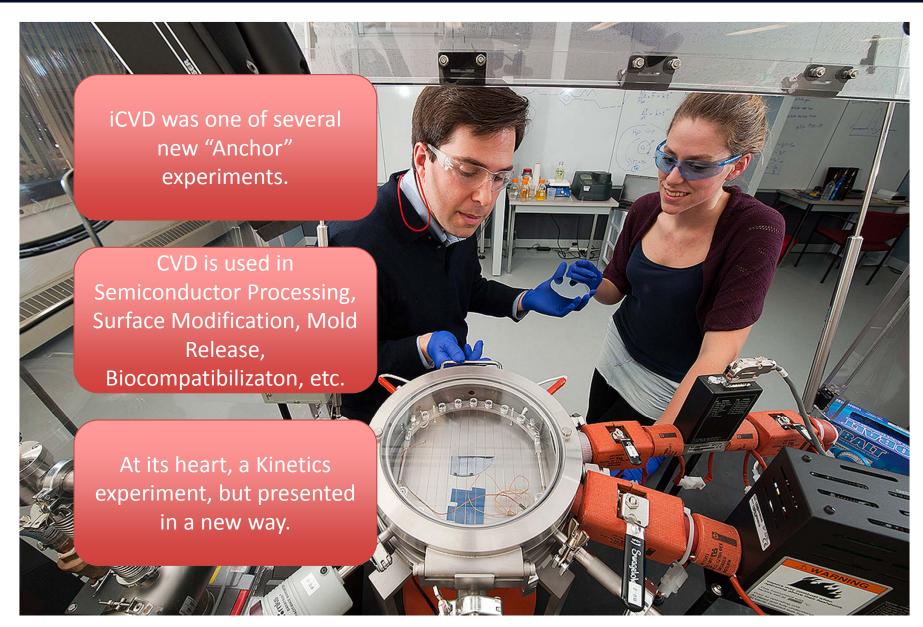
4.0 Student Generated Results5.0 Student Reception and Feedback6.0 Other Observations





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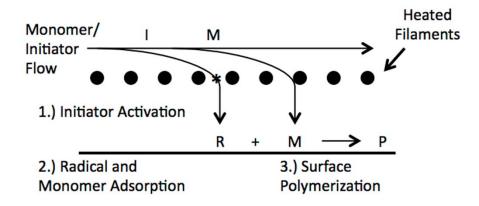
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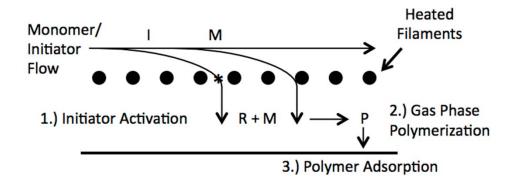
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A. Adsorption Limited/Surface Polymerization



B. Gas Phase Polymerization



iCVD = Initiated Chemical Vapor Deposition

- Heated Filaments or other Initiation Source (e.g. UV light)
- Decomposition of Initiator
- Polymerization of Monomer
- High structural fidelity to traditionally polymerized materials.

Figure adapted from Lau, et al. "Initiated Chemical Vapor Deposition of Poly(alkyl acrylates): An Experimental Study". Macromolecules, 39. 3688-3694 (2006).

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Photo courtesy of GVD Corporation

Turn-key system from GVD Corporation.

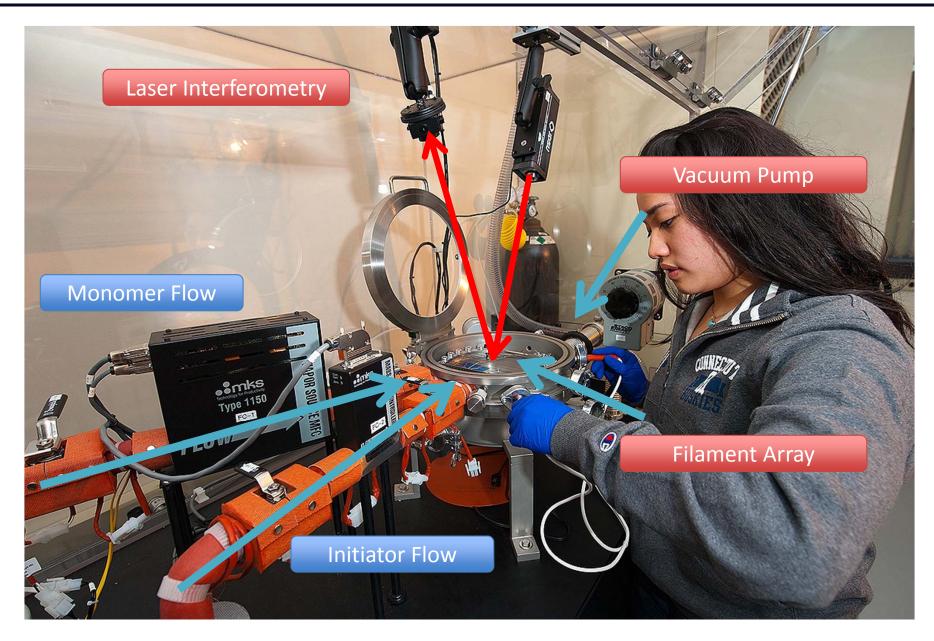
- Vacuum System
- Laser Metrology
- Source containers, heaters, flow controllers
- Filament Array
- Computer Control and Monitoring

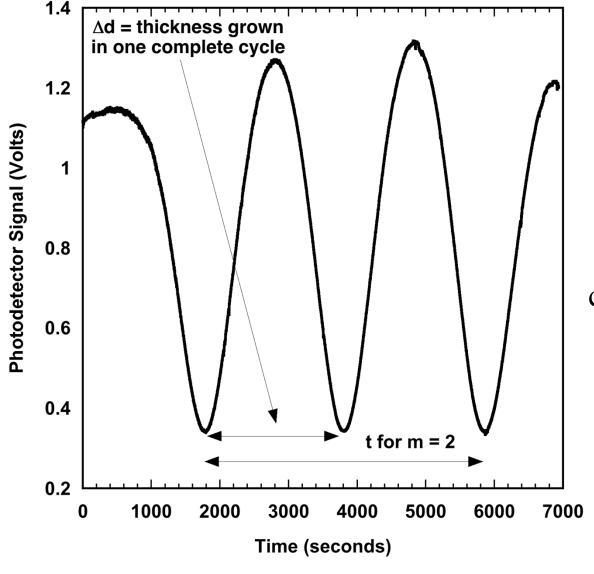


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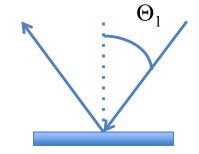




$$rate = \frac{m\Delta d_{film}}{t}$$

$$\Delta d_{film} = \frac{\lambda}{2n\cos(\theta_2)}$$

$$\cos(\theta_2) = \sqrt{1 - \left[\frac{\sin(\theta_1)}{n}\right]^2}$$





3.0 Experimental Design

 "What can you tell me kinetically and mechanistically about the polymerization reaction you are going to carry out?

> T substrate

Preactor

| filament

Monomer (type and flow)

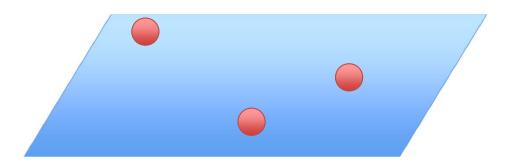
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Controlled by Reactor Pressure

$$\frac{P_{M}}{P_{sat}}$$

Controlled by Substrate Temperature



Surface 'Concentration' approaches zero; No reaction!

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- 2.0 Experimental Setup

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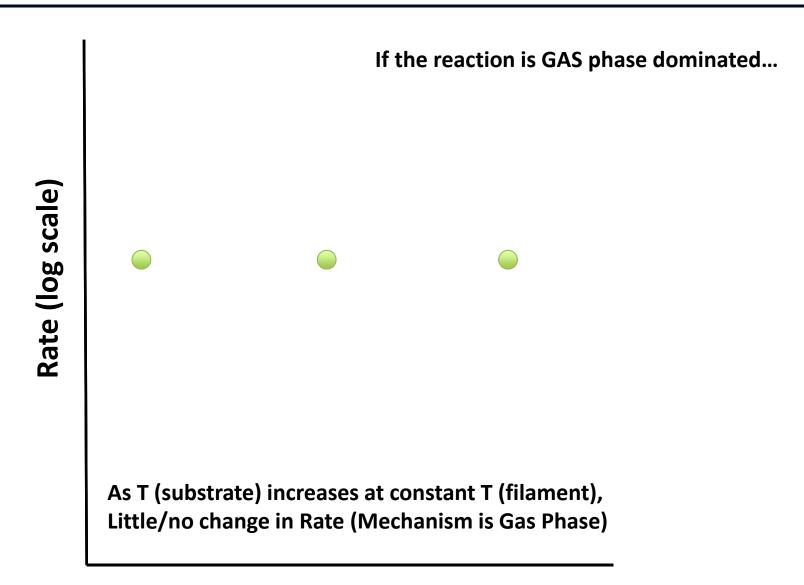
Controlled by Reactor Pressure $\frac{P_M}{P}$ Controlled by Substrate Temperature



Surface 'Concentration' approaches one; Condensation!

If the reaction is GAS phase dominated... Rate (log scale) As T (filament) increases at constant T (substrate), **Rate increases (Increased Activation)**

1/T_{filament} (K)



1/T_{substrate} (K)

If the reaction is SURFACE dominated... Rate (log scale) As T (filament) increases at constant T (substrate), Rate increases slightly (Increased Flux))

1/T_{filament} (K)

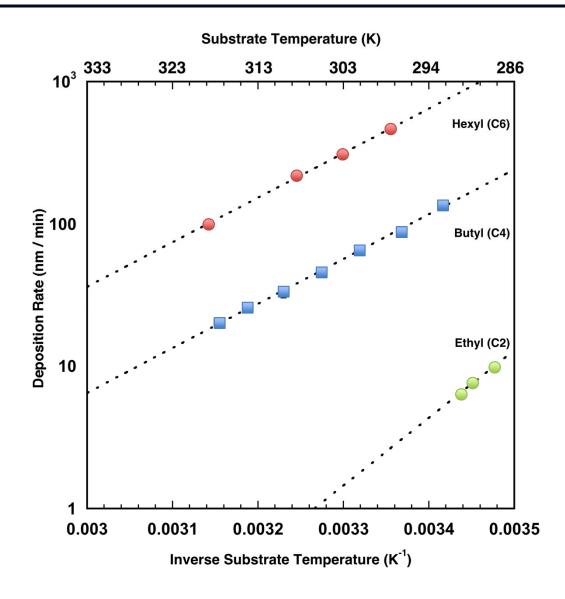
If the reaction is SURFACE dominated... Rate (log scale) As T (substrate) increases at constant T (filament),

1/T_{substrate} (K)

Rate DECREASES (Adsorption Limitations)

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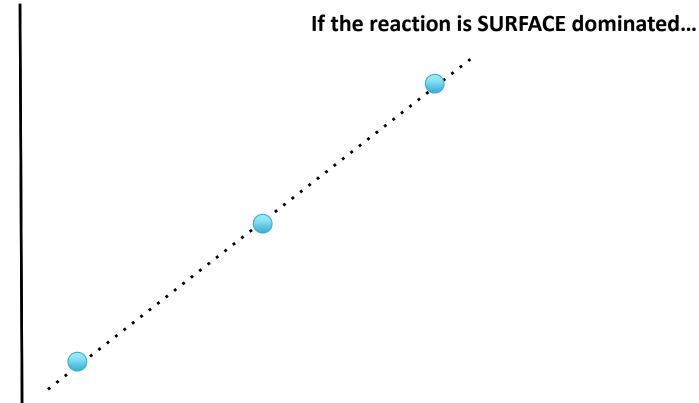
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D. D. Burkey, D. Anastasio, A. Suresh. "A New Take on Kinetics: Initiated Chemical Vapor Deposition as a Chemical Engineering Capstone Laboratory". *Chemical Engineering Education* (Accepted).

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Rate (log scale)

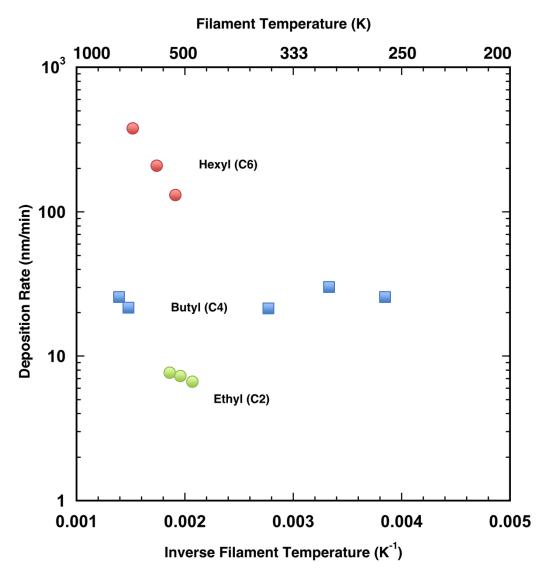


As T (substrate) increases at constant T (filament), Rate DECREASES (Adsorption Limitations)

1/T_{substrate} (K)

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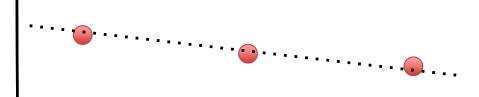


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If the reaction is SURFACE dominated...

Rate (log scale)

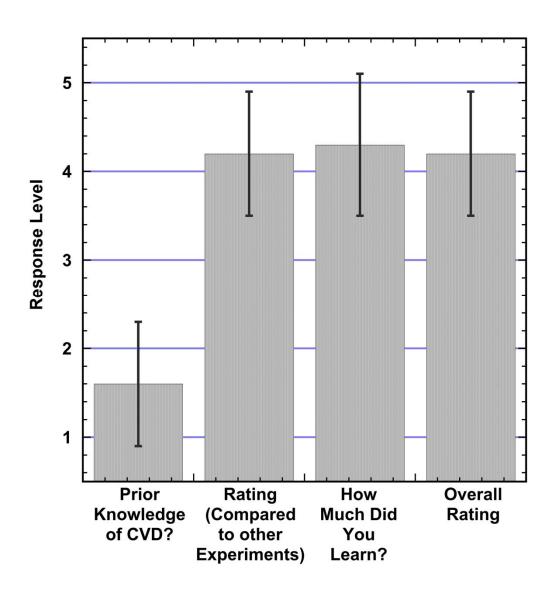


As T (filament) increases at constant T (substrate), Rate increases slightly (Increased Flux))

1/T_{filament} (K)

5.0 Student Reception and Feedback

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6.0 Other Observations



- Significant capital investment
 - Can 'roll your own', depending upon expertise
 - Additional use as a research tool
 - "Demonstration of Potential Opportunities in Photo-Initiated Chemical Vapor Deposition" – Gas Phase Deposition Processes; Friday 1:24 PM, Franciscan D; Aravind Suresh
- Some experimental conditions can be slow, leading to student disengagement
- Depending upon choice of reagents, can demonstrate mass-transfer limited as well as kinetically limited reactions.



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