

THE UNIVERSITY OF TEXAS AT AUSTIN

CHE384

From Data to Decisions: Measurement, Uncertainty, Analysis, and Modeling

## Lecture 3

### Data Example

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## Chemical Vapor Deposition Experiment

- Chemical vapor deposition (CVD) is used to deposit a tungsten film on a silicon wafer

Input gases

Zone heaters

Silicon wafers

Quartz tube

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## Deposition Rate vs. Temp Model

Deposition Rate (nm/min)

Diffusion-controlled

Reaction-controlled

1000/T

$$v = \frac{k_T}{N} \left( \frac{1}{kT} \right) P_g$$

$$k_T = \frac{h_g k_s}{h_g + k_s}$$

$$h_g = T^{\frac{3}{2}} \frac{P_g}{P_r}$$

$$k_s = A_r e^{-E_a/kT}$$

Goal: measure this activation energy

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## The Data

Deposition Rate (Å/min)

1000/T (K<sup>-1</sup>)

Fig. 2. Temperature dependence of tungsten deposition rate for several pressures (WF<sub>6</sub>-H<sub>2</sub> system).

E. K. Broadbent and C. L. Ramiller, "Selective Low Pressure Chemical Vapor Deposition of Tungsten", *J. Electrochem. Soc.*, **131**(6): 1427-1433 (1984).

What is missing from this data and analysis?

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## What is Data?

Data = the results of a measurement

- Definition of the thing being measured
- Measurement value (number plus units)
- Estimate of the uncertainty of each measurement
- Experimental context (measurement method + environment)
- Context uncertainty (uncertainty of controlled and uncontrolled input parameters)
- Measurement model (theory, assumptions and definitions used in making the measurement)

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## The Data and Data Analysis

Deposition Rate (Å/min)

1000/T (K<sup>-1</sup>)

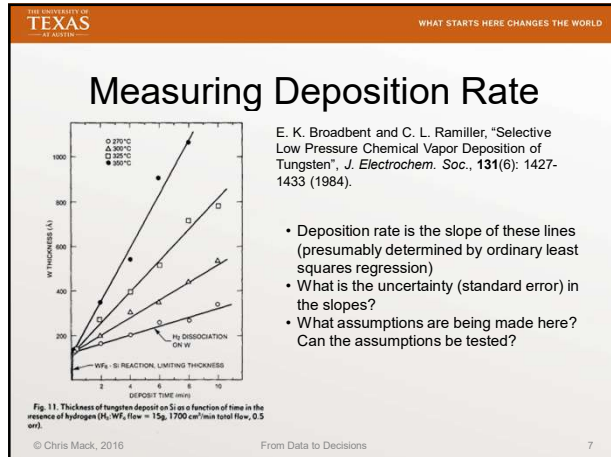
Fig. 2. Temperature dependence of tungsten deposition rate for several pressures (WF<sub>6</sub>-H<sub>2</sub> system).

E. K. Broadbent and C. L. Ramiller, "Selective Low Pressure Chemical Vapor Deposition of Tungsten", *J. Electrochem. Soc.*, **131**(6): 1427-1433 (1984).

In this paper...

- There is no mention of deposition rate measurement error
- "The temperature was controlled to within  $\pm 2^\circ\text{C}$  of the desired value within the deposition zone."
- The context of the experiment is well described
- There was no mention of context uncertainty (ex: pressure, flow rates)
- "From the Arrhenius plots an activation energy,  $E_a$ , of 0.71 eV/atom (69,000 J/mol) was calculated."

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WHAT STARTS HERE CHANGES THE WORLD

## Lecture 3: What have we learned?

- What are the six parts of the concept "data"?
- Which two parts can sometimes (but not always) be taken for granted?
- How often do you see data presented where the remaining four parts are carefully documented?

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