4CeeD Lecture Series

Lecture #1: Introduction and Overview

March 21st, 2023

Use of 4CeeD Services for Material Scientists

Leah Espenhahn (leahe2@Illinois.edu), Robert Kaufman (rbkaufm2@Illinois.edu)
Beitong Tian (beitong2@illinois.edu), and Klara Nahrstedt (klara@illinois.edu)

A timely and trusted curator and coordinator of scientific data

MRL FREDERICK SEITZ MATERIALS RESEARCH LABORATORY

MNTL micro+nanotechnology lab

CSL: COORDINATED SCIENCE LAB

Lecture Series Learning Objectives

- Lecture 1 (3/21): Overview of 4CeeD
  - Introduction to 4CeeD
    - Breakout Session #1: Log-In and Explore
  - Key 4CeeD Features: Templates for Fast Storage
    - Breakout Session #2: Creating and Using Templates

- Lecture 2 (3/23): Workshop (Cont.) & Advanced Features
- Lecture 3 (3/28): 4CeeD Backend Services
- Lecture 4 (3/30): SENSELET/MAINTLET

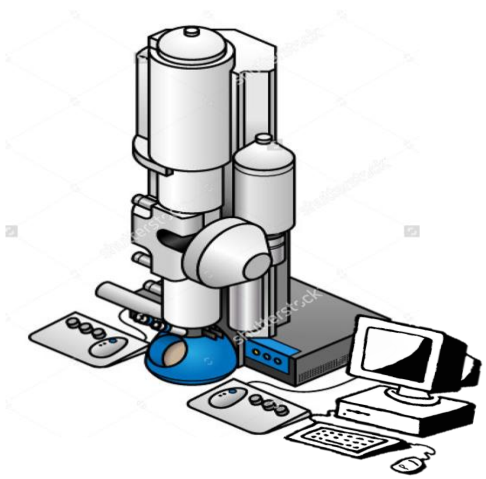
Introductory Questionnaire

- Do you describe yourself more of a computer scientist or a material scientist?

- Do you conduct your research primarily on modeling/simulation or experimental research?

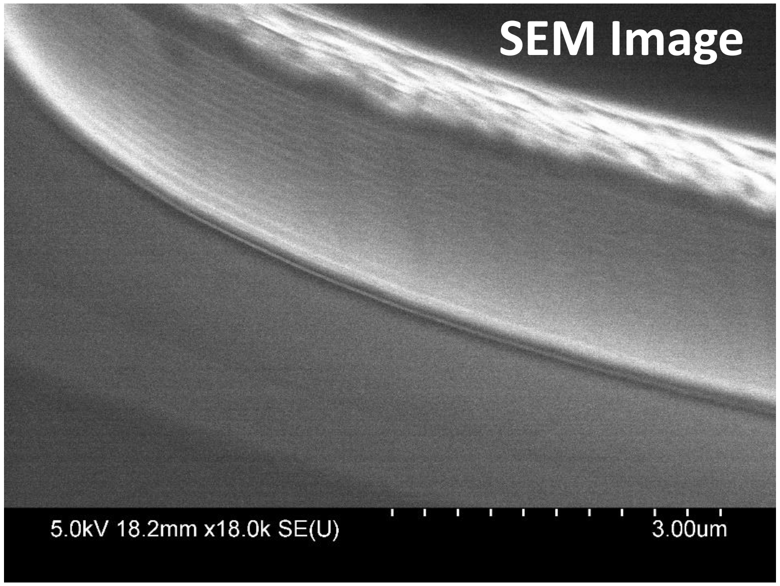
What is 4CeeD and its goals?

- Address Scientific Digital Data Acquisition, Curation and Sharing prior to Scientific Publication of Results via Private Cloud Storage Facility



Instrument

(in MRL/HMNTL/BI)



Sidewall View of AlGaAs DBR
Hitachi S4800 SEM

Experimental Setting
Time: 30 min
Temp: 425°C

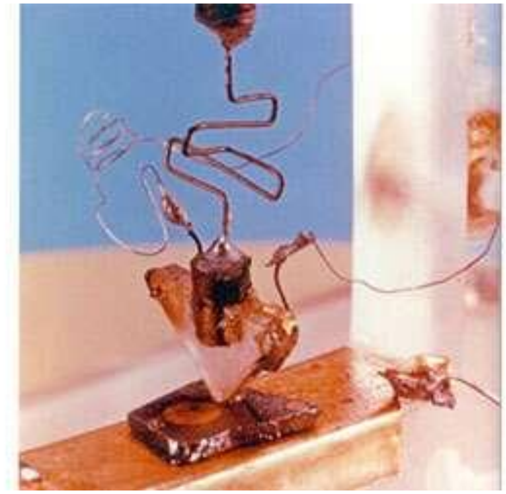
Observation Notes:
Oxidation depth is 12 um
Oxidation layer is $Al_{0.98}GaAs$
N_2 bubbler flowing steam
2” Quartz tube furnace

Sample Experimental Dataset from SEM Imaging

Why is current data collection an issue?

- Consideration of National Academy Studies: **20-year gap** from discovery of new materials to implementation of next-generation devices
- Necessitates **real-time** and **trusted** processing from **materials –to-devices digital data**

Red LED (1962) Holonyak, Jr.
Blue LED (1993) Nakamura



Transistor (1947) Bardeen

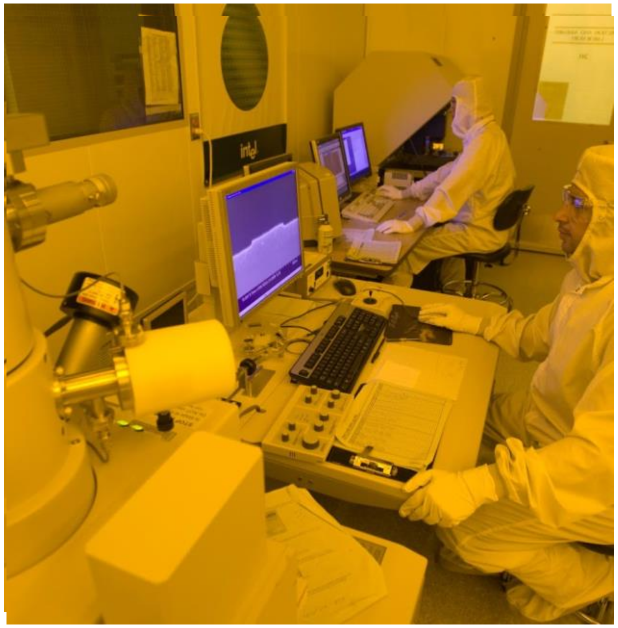
Graphene(2004) Geim and Novoselov

Why is University data collection unique?

- Industry concentrates on scaling and improving reliability and manufacturability to deliver an end product (smartphone, cars)

- Academia concentrates on diverse and riskier research using older equipment to prove innovative ideas and concepts

Industrial Wafer Fabrication Cleanroom

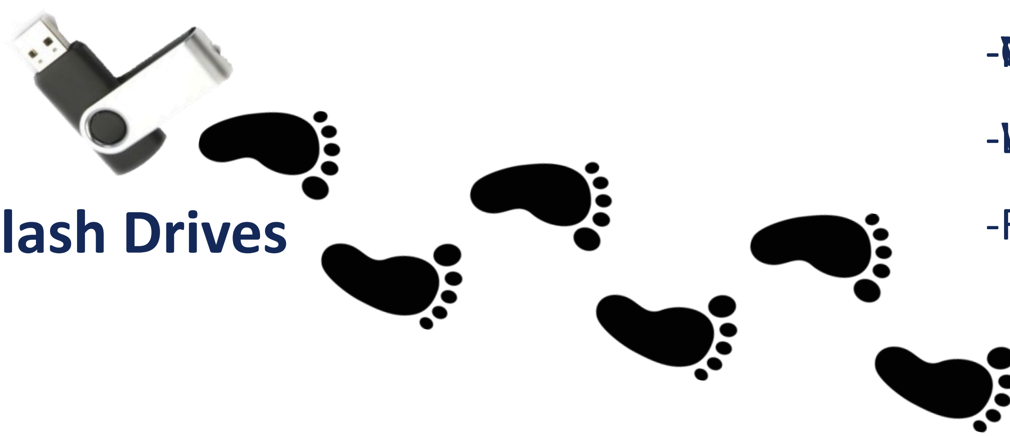


University Cleanroom (HMNTL)

Current State of Data Capture

Instrument
(MRL/HMNTL)

- Fabricate experimental sample
- Prepare analytical sample
- Bring sample to instrument for analysis
- **Extract data (File conversion)**
- **Transport data to office computer**
- **Analyze data**



Flash Drives

[illegible] analysis

-[illegible]

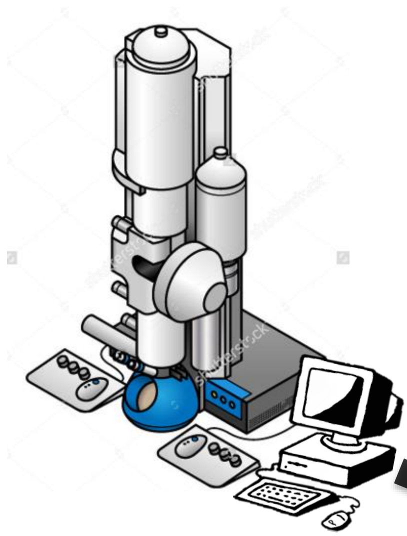
-[illegible] space

-[illegible]?

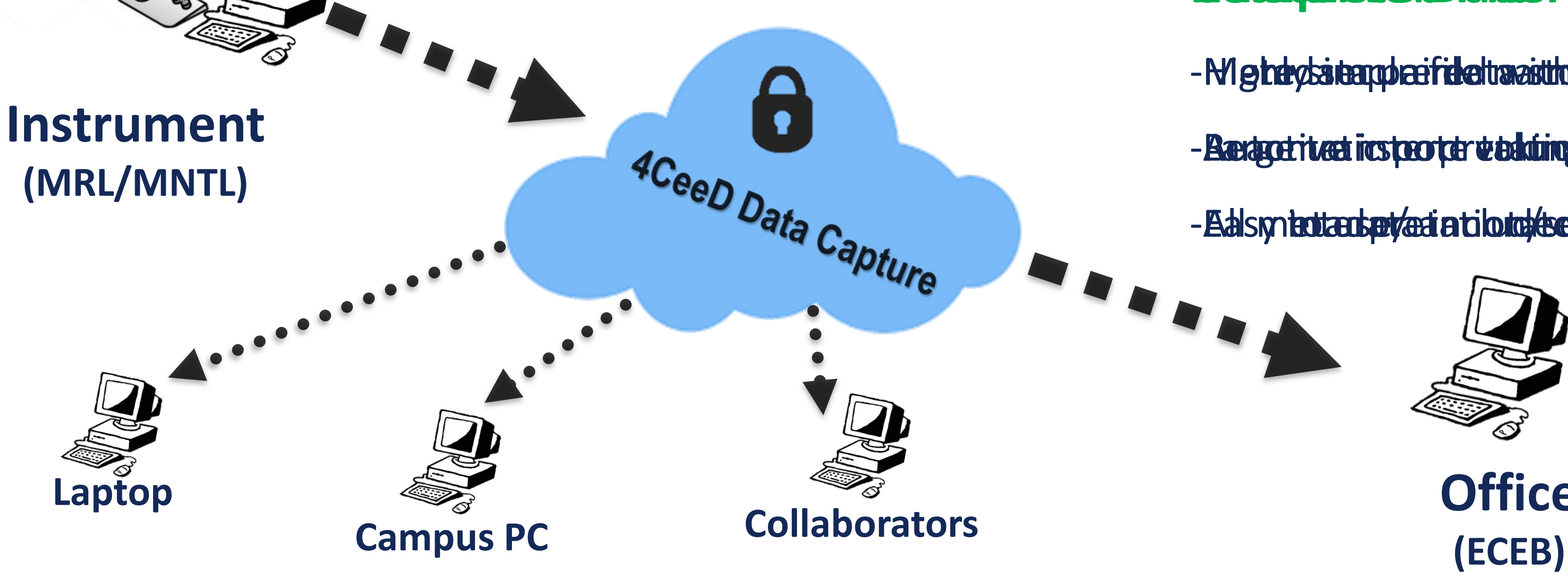
-Retroactive not reactive

Office
(MRL/MEB/MNMS)

Scenario with 4CeeD Integration

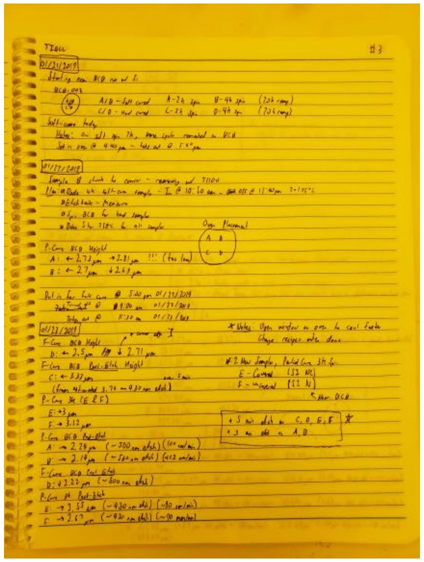


- Fabricate experimental sample
- Prepare analytical sample
- Bring sample to instrument for analysis
- **Extract data (NO FILE CONVERSION)**
- **Transport data to office computer (DIRECT)**
- **Analyze data (REAL TIME)**
- Repeat per iteration



How is Metadata Currently Stored?

- Manual notetaking of complex experiments can lead to inconsistent or inadequate documentation

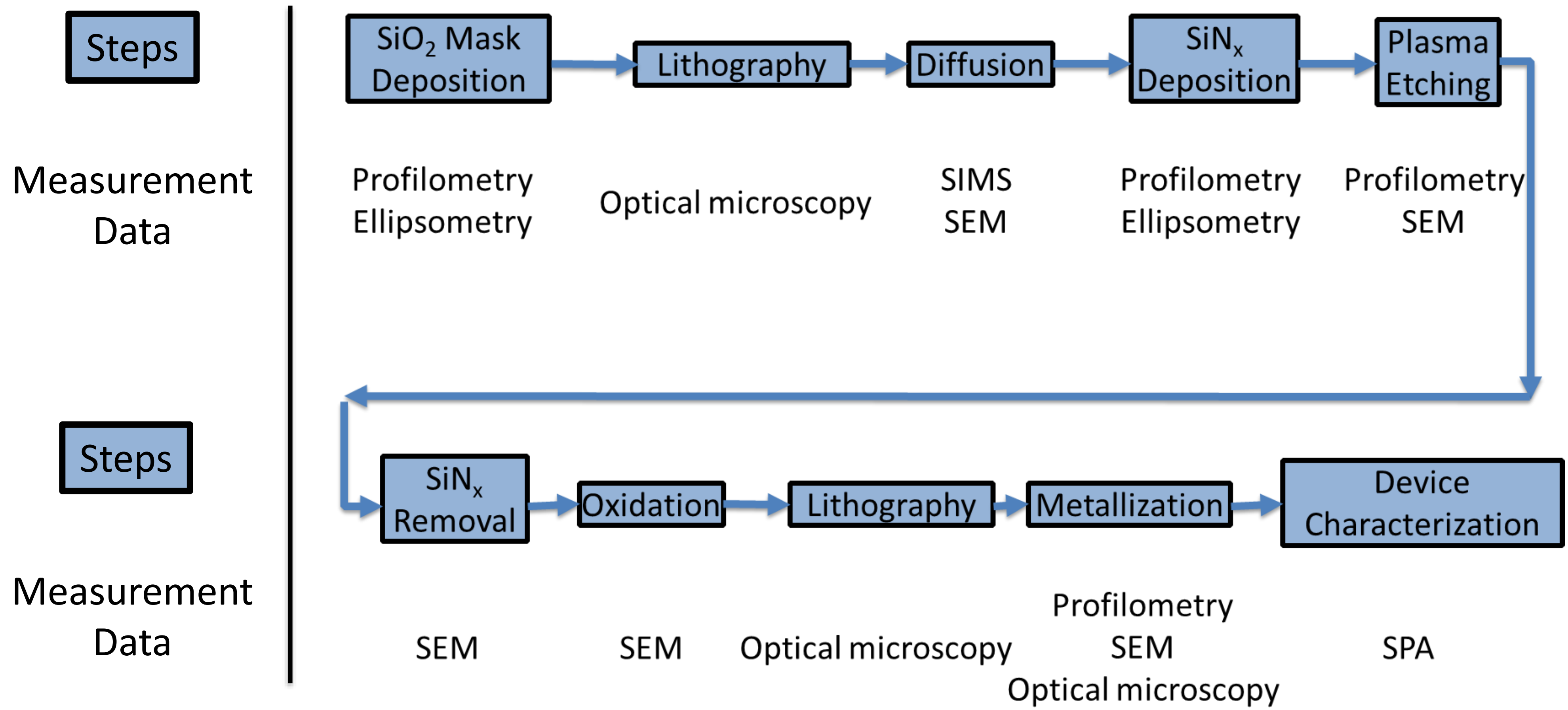


- Data transfer from tools is often done using flash-drive or emails that carry limitations and security risks

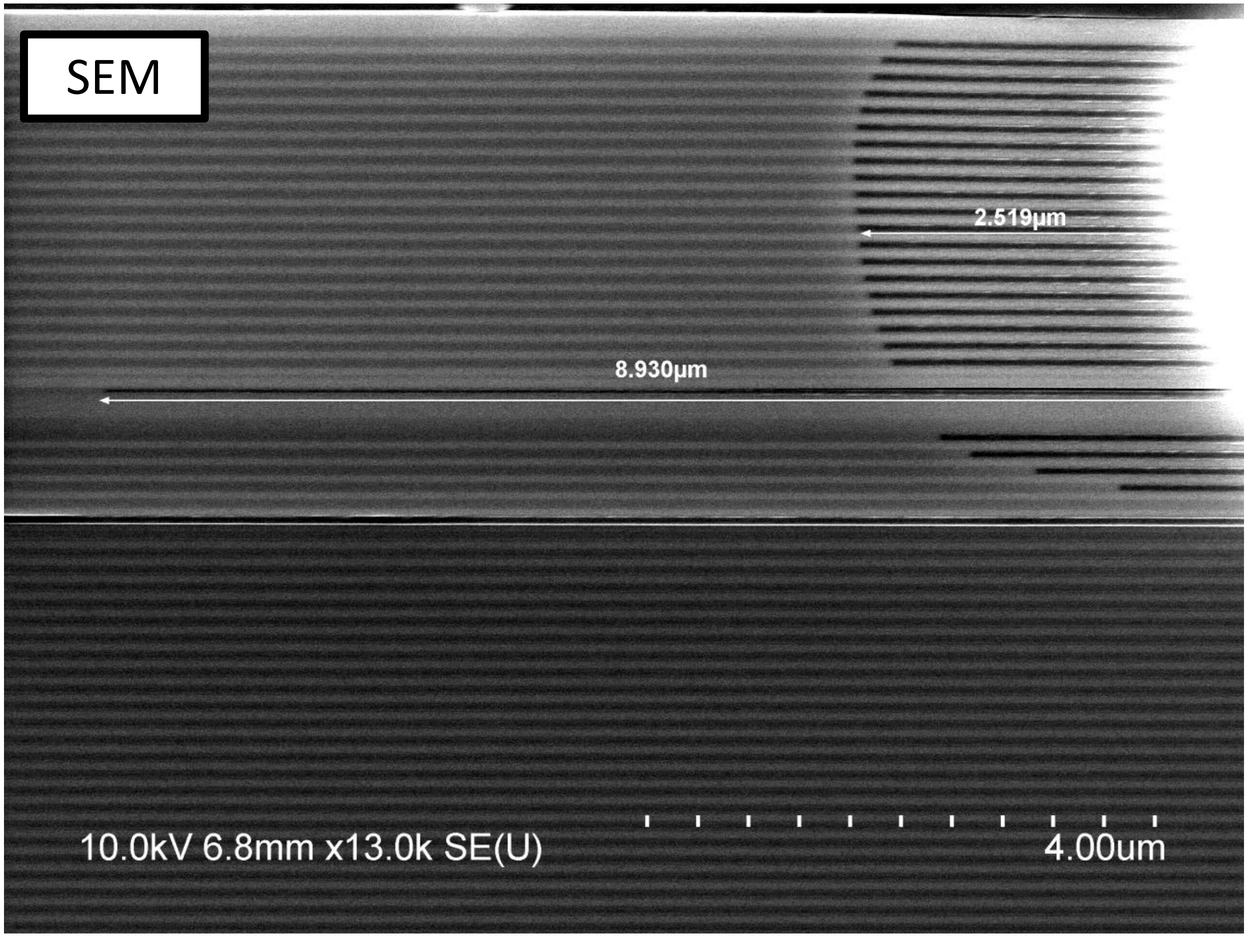
- Material research data is expensive and time intensive
    - Publication data is often documented well but remaining data is discarded

Metadata of Device Development Process

- Experiments can have multiple steps where each step is verified for success by various metrology methods



How is Metadata Currently Stored?



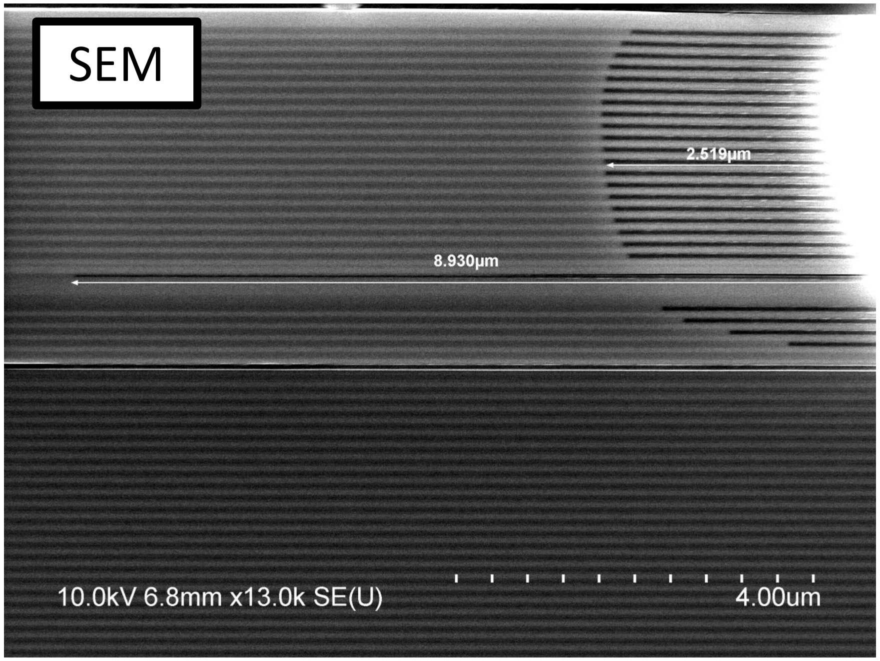
Experimental Setting:
Time: 11 minutes
Temperature: 425°C

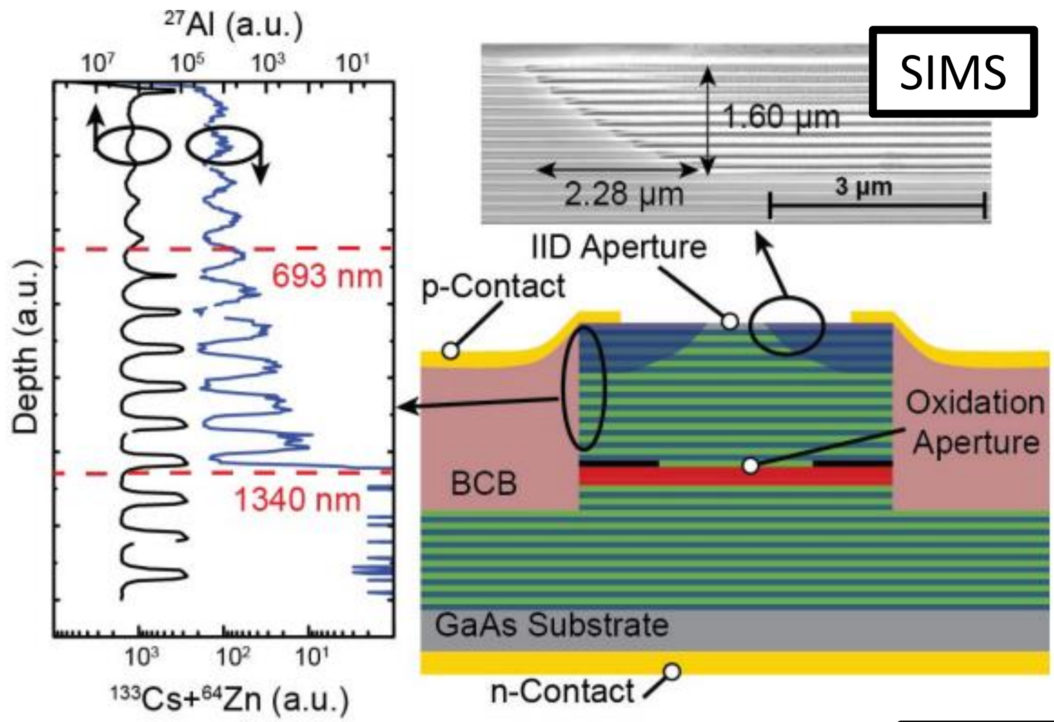
Material Analaysis:
Oxidation Depth: 8.93 µm
Oxidation Layer: $Al_{0.98}Ga_{0.02}As$
Furnace: N_2 Ambient, 2” Quartz

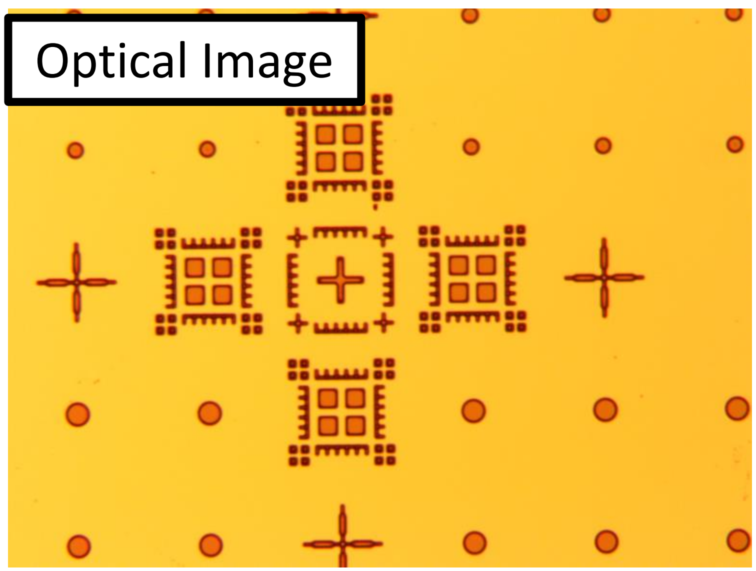
SEM Image Settings
Scale: 4 µm (10 divisions)
Acceleration Voltage: 10.0 kV
Working Distance: 6.8 mm

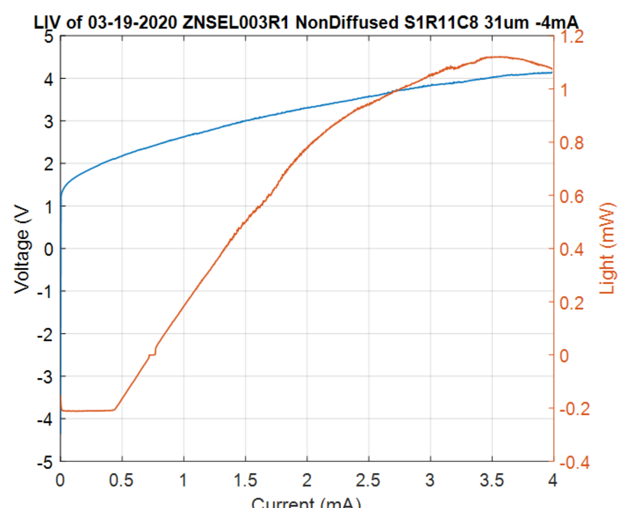
- Multiple text and image files are necessary to capture all the pertinent data of a single experiment

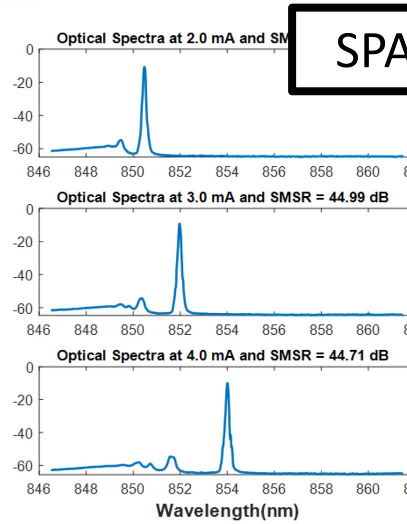
Example of Metrology Data (SIMS, SEM, OM, SPA)





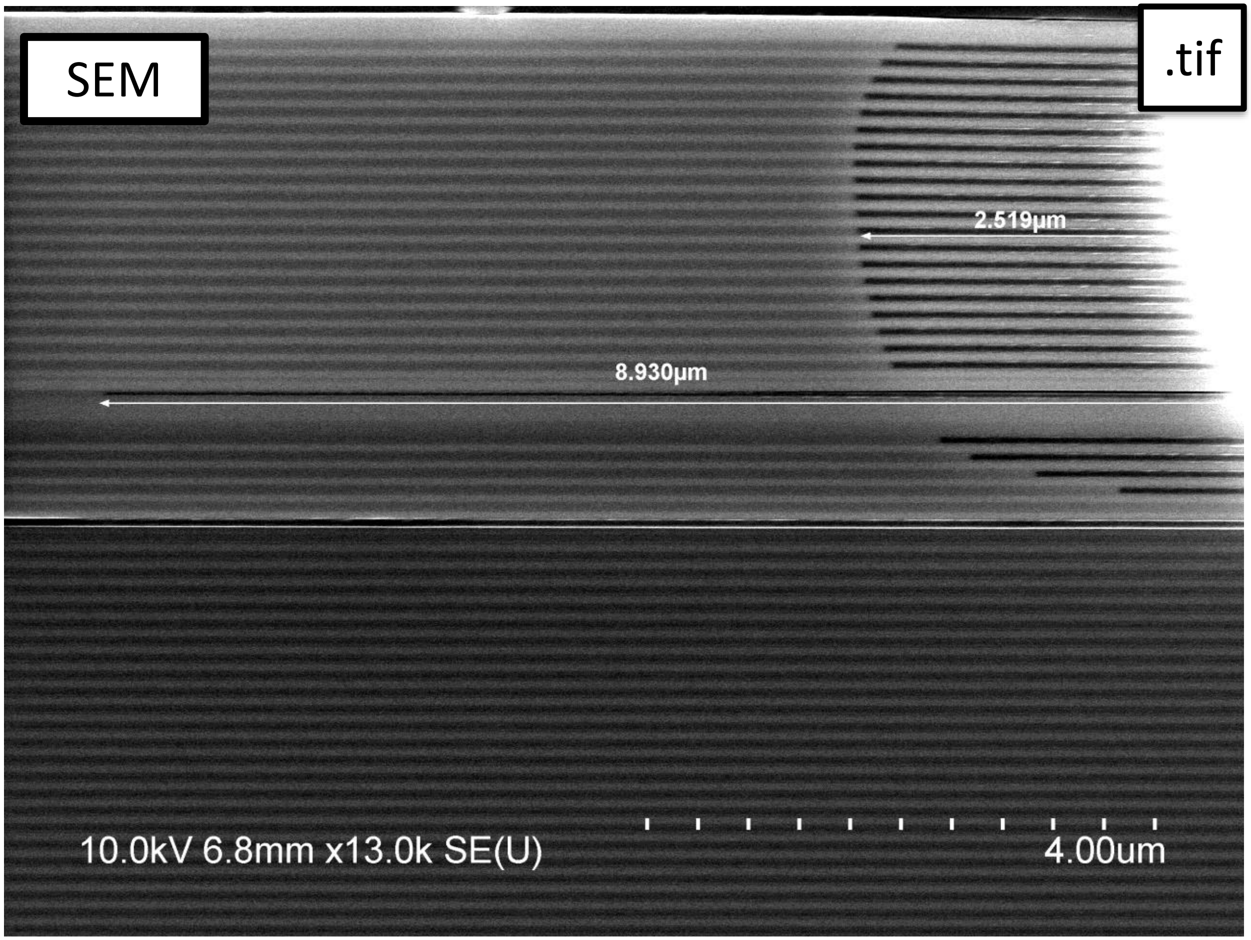






Vastly different data formats for same device

Storing Multiple File Types



Experimental Setting:
Time: 11 minutes
Temperature: 425°C

.txt

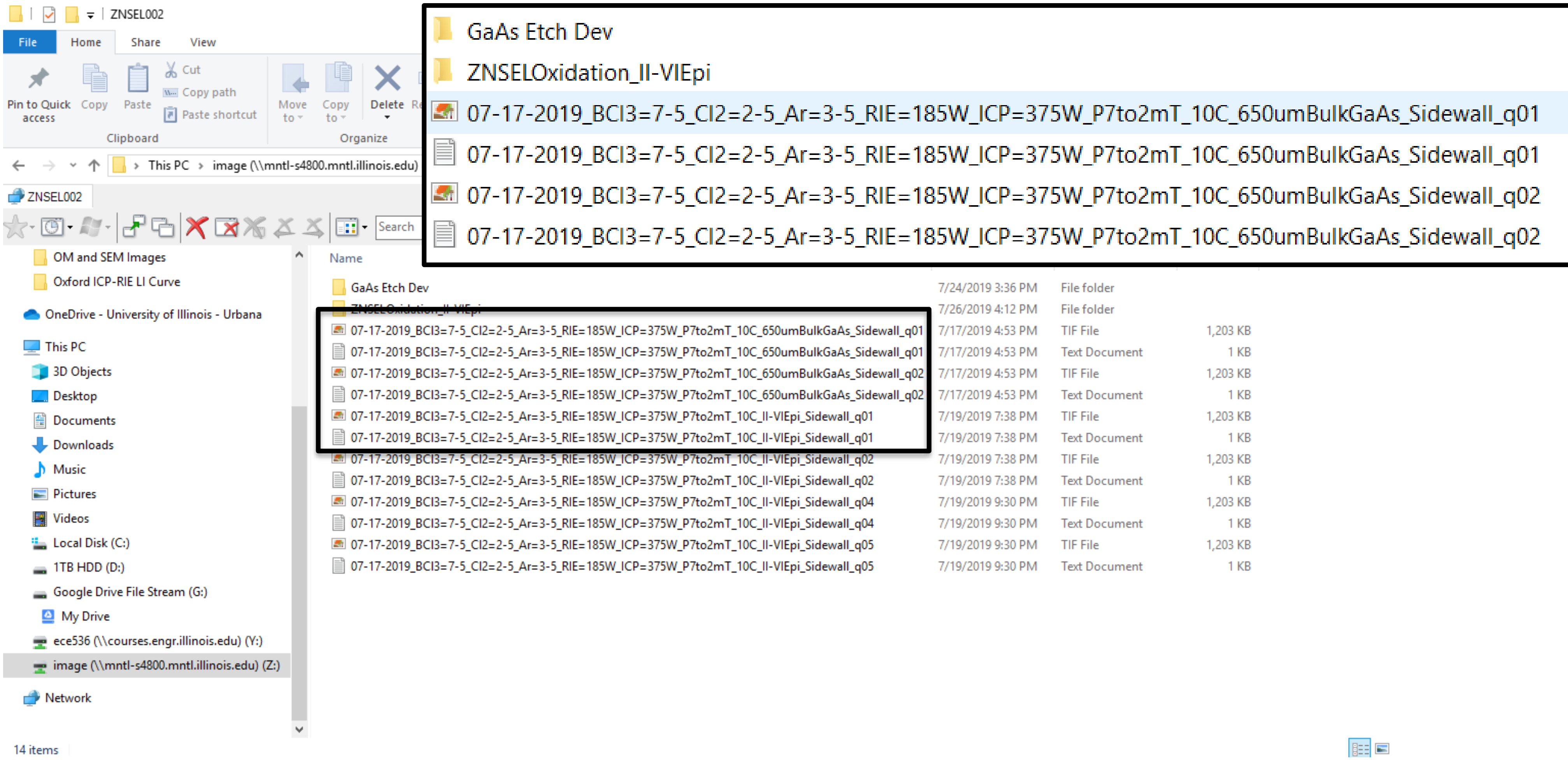
Material Analaysis:
Oxidation Depth: 8.93 μm
Oxidation Layer: $Al_{0.98}Ga_{0.02}As$
Furnace: N_2 Ambient, 2" Quartz

SEM Image Settings
Scale: 4 μm (10 divisions)
Acceleration Voltage: 10.0 kV
Working Distance: 6.8 mm

.txt

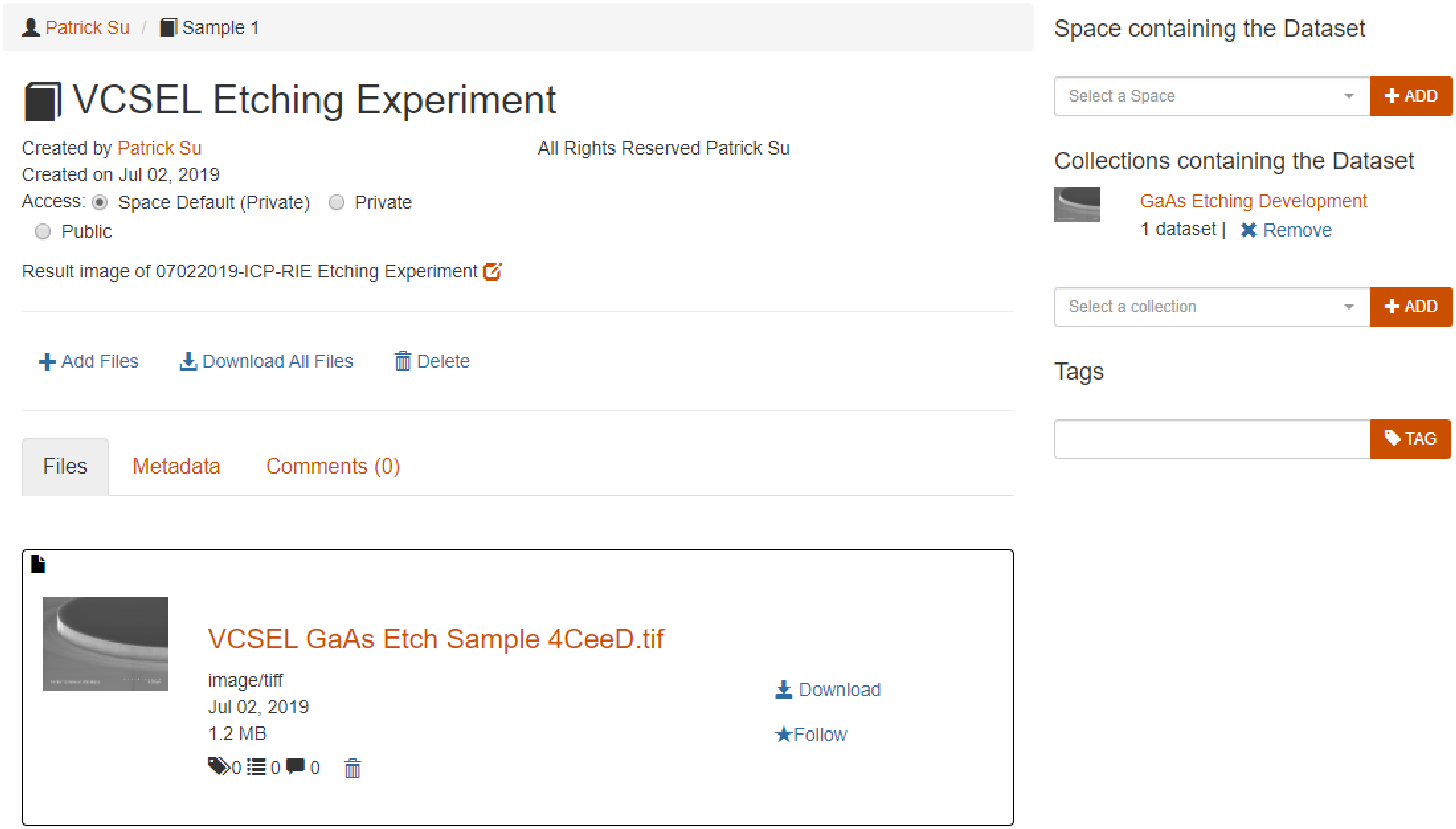
- Multiple text and image files are necessary to capture all the pertinent data of a single experiment

How this looks from File Explorer



- File explorer is limited to default "file list" where information is kept in long text names

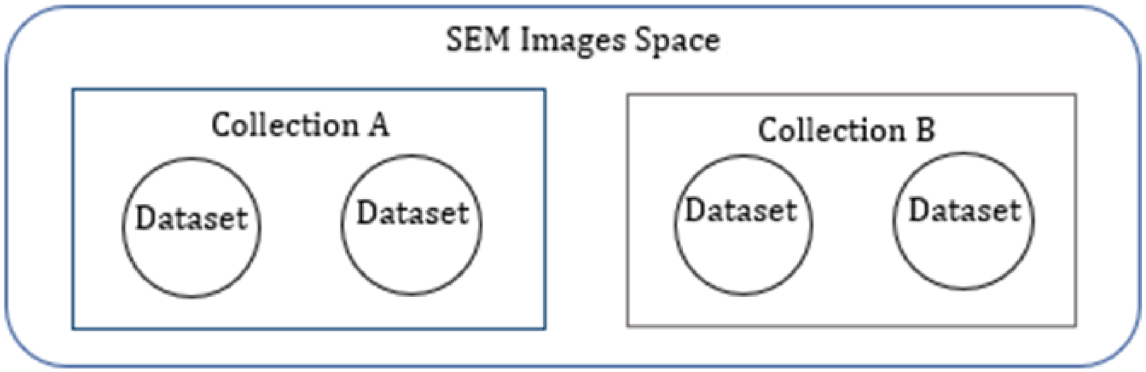
How this look from 4CeeD [Datasets]



- 4CeeD is designed to present only pertinent information for quick understanding of the experiment

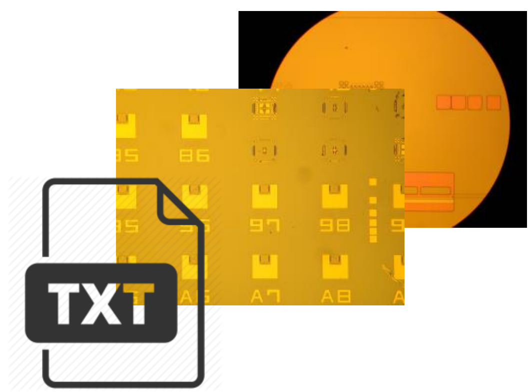
Data Hierarchy in 4CeeD

- "Spaces", "Collections", and "Datasets"

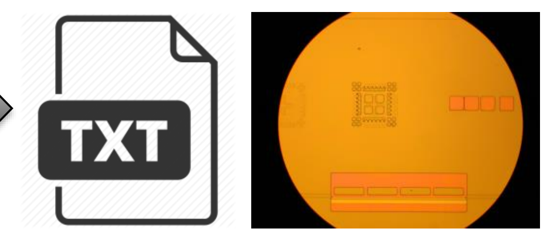


4CeeD Hierarchy

Space (Projects)

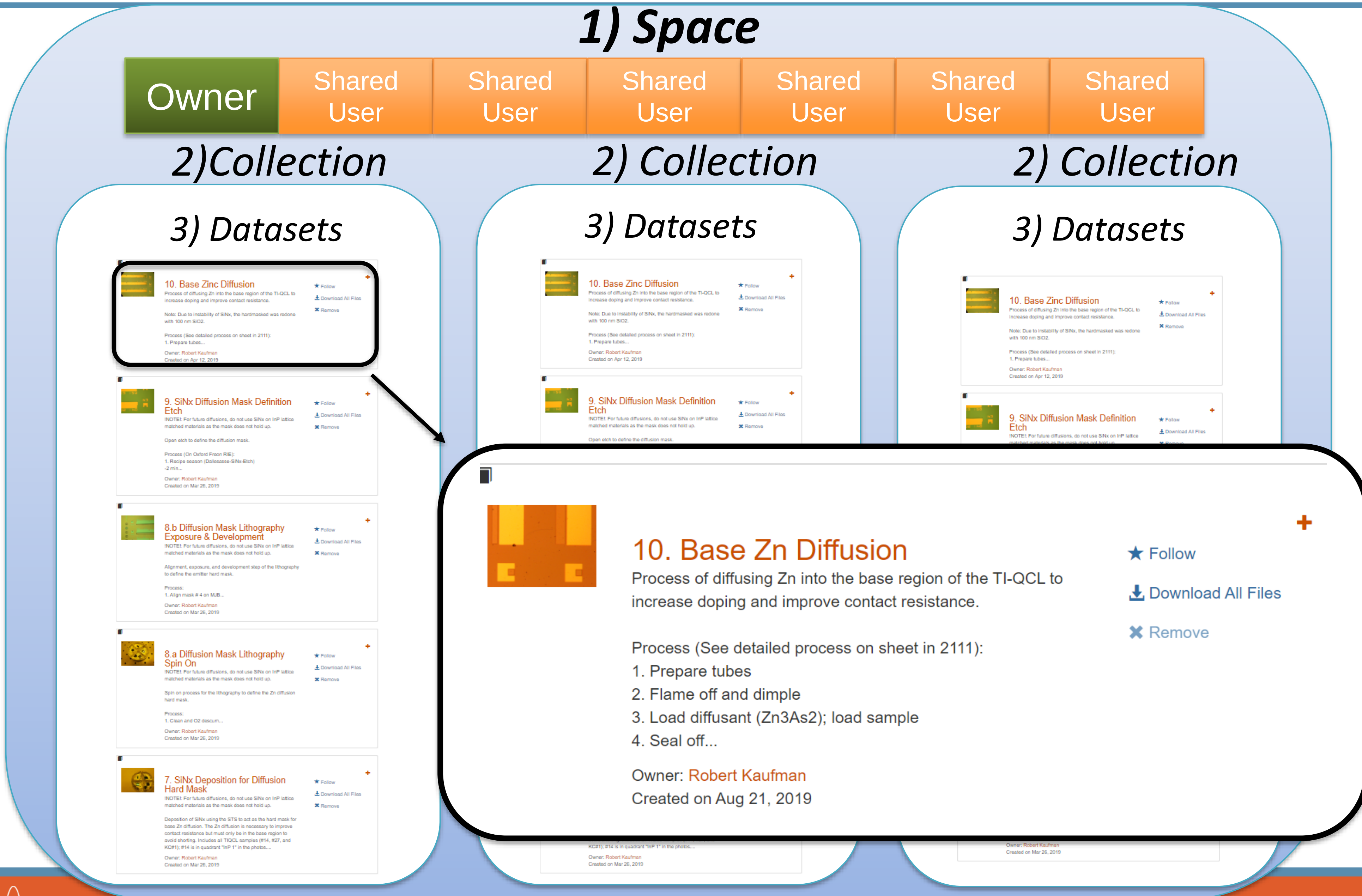


Collections (Experiments)



Datasets (Data)

Data Organization Structure



Breakout Session #1: Log-In & Explore 4CeeD

learn.4ceed.illinois.edu

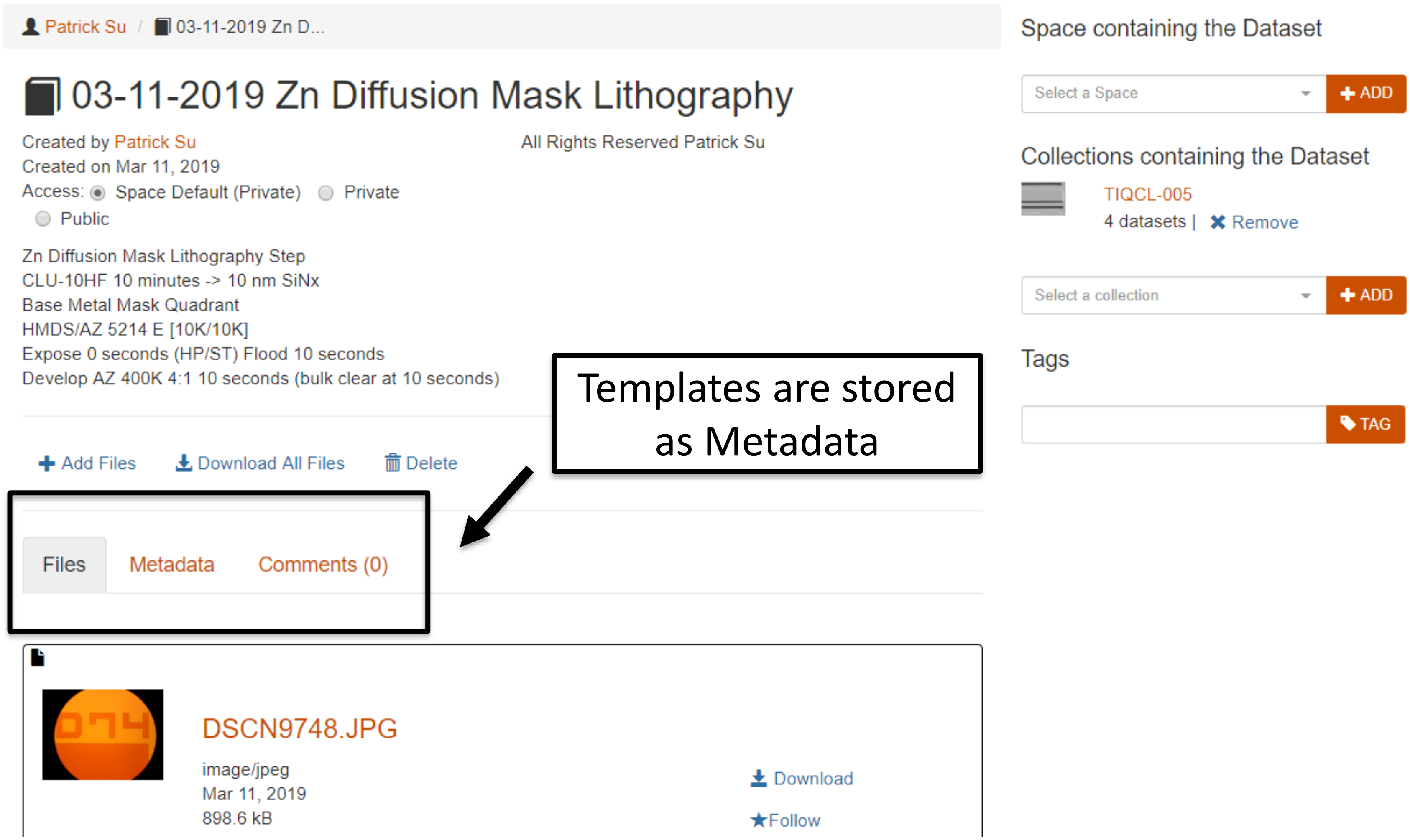
- "Sign Up" with Illinois email
- Note: Need to be on University connection to access (IllinoisNet or VPN)
- Try out 4CeeD yourself before next hands-on lecture
  - **Make an account**
  - Make a space, collection, dataset
  - Upload some image and add a template

Lecture Series Learning Objectives

- Lecture 1 (3/21): Overview of 4CeeD
  - Introduction to 4CeeD
    - Breakout Session #1: Log-In and Explore
  - Key 4CeeD Features: Templates for Fast Storage
    - Breakout Session #2: Upload your own data

Efficient Data Collection: Templates

- Templates and Extractors for Rapid Storage



Efficient Data Collection: Templates

Experimental setting:

Time 13min
Temp 425 C

(Structured meta data)

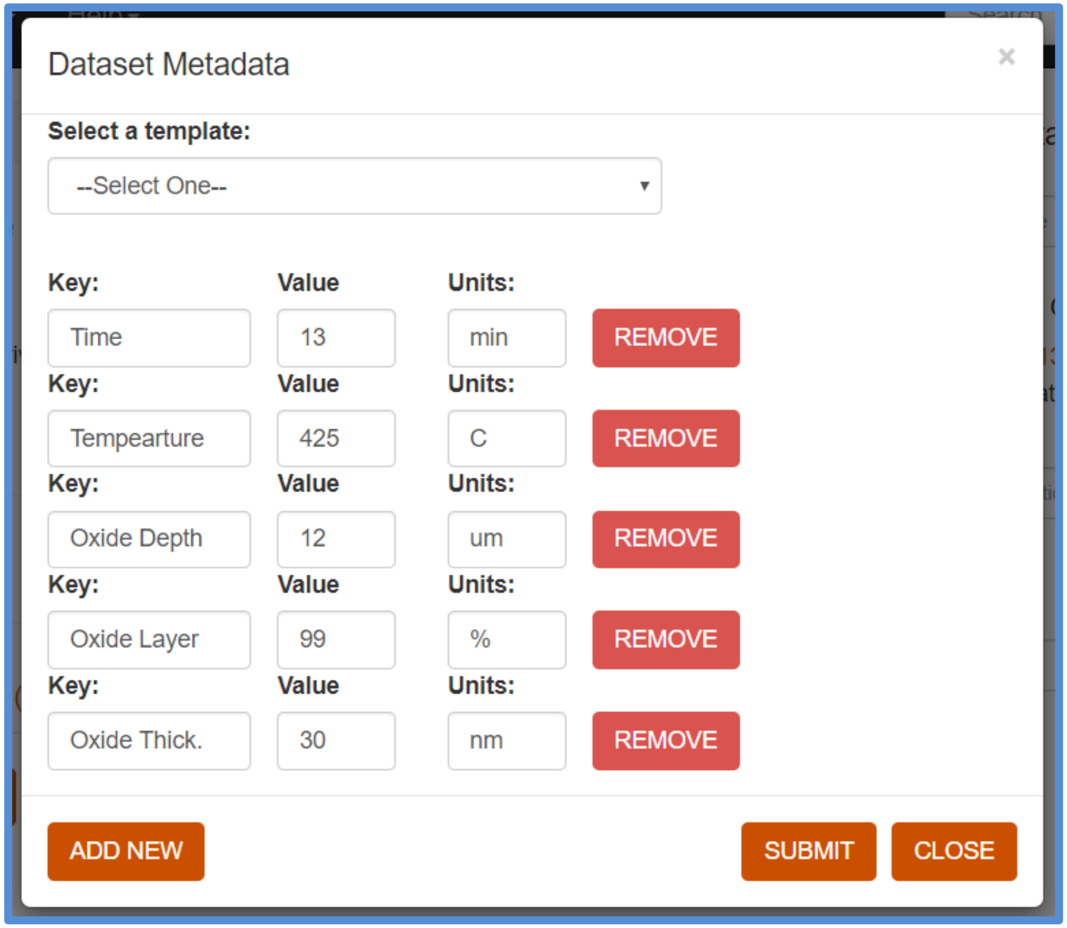
Notes:

Oxidation depth is about 12um. Oxidation layer composed of Al(0.98)GaAs with thickness of 30 nm. Furnace in 2111 MNT L, 2" diameter quartz.

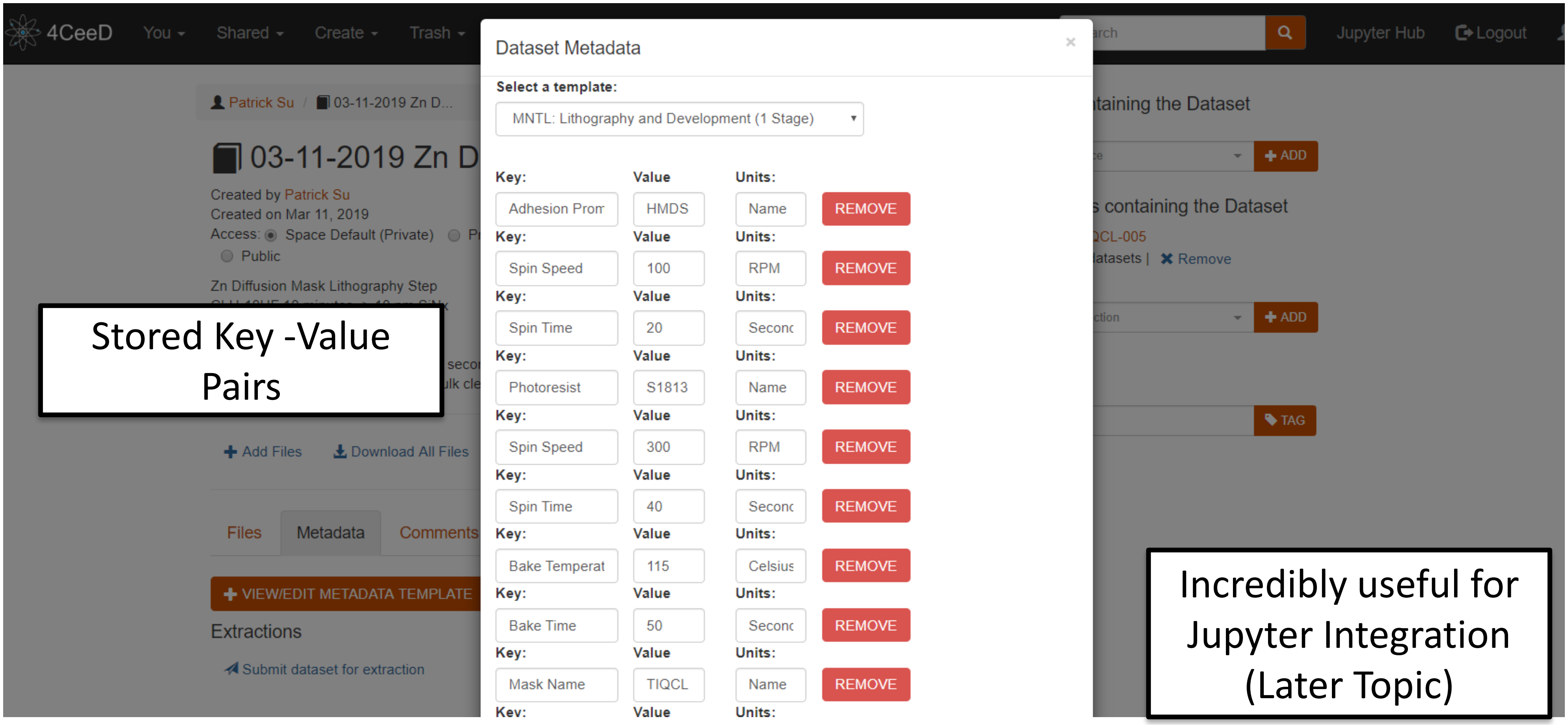
(Free text)

- Free-text view can be unorganized, hard-to-read, and difficult to compare results

- Templates provide consistency, accessibility, and enables digital processing (ex. Jupyter Notebook)



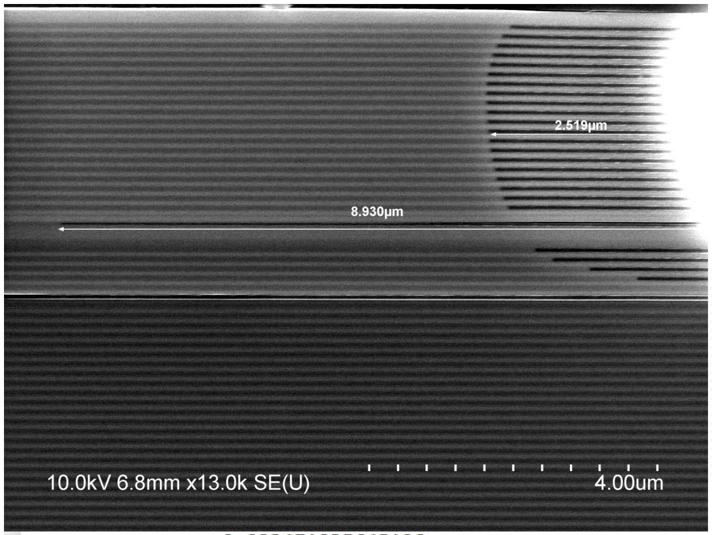
Breakout Session #2: Templates For Fast Storage

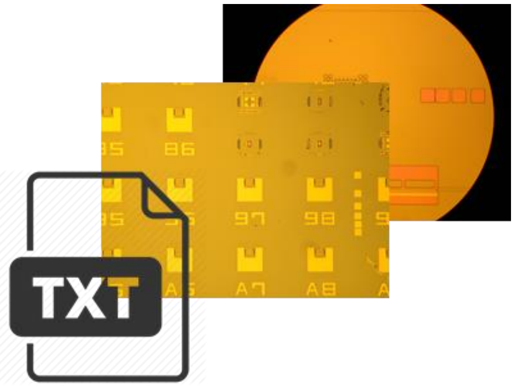


Stored Key -Value Pairs

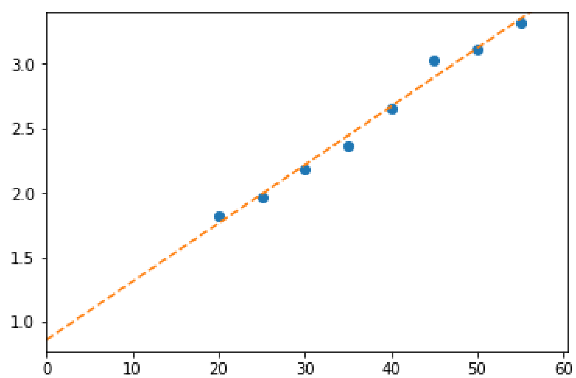
Incredibly useful for Jupyter Integration (Later Topic)

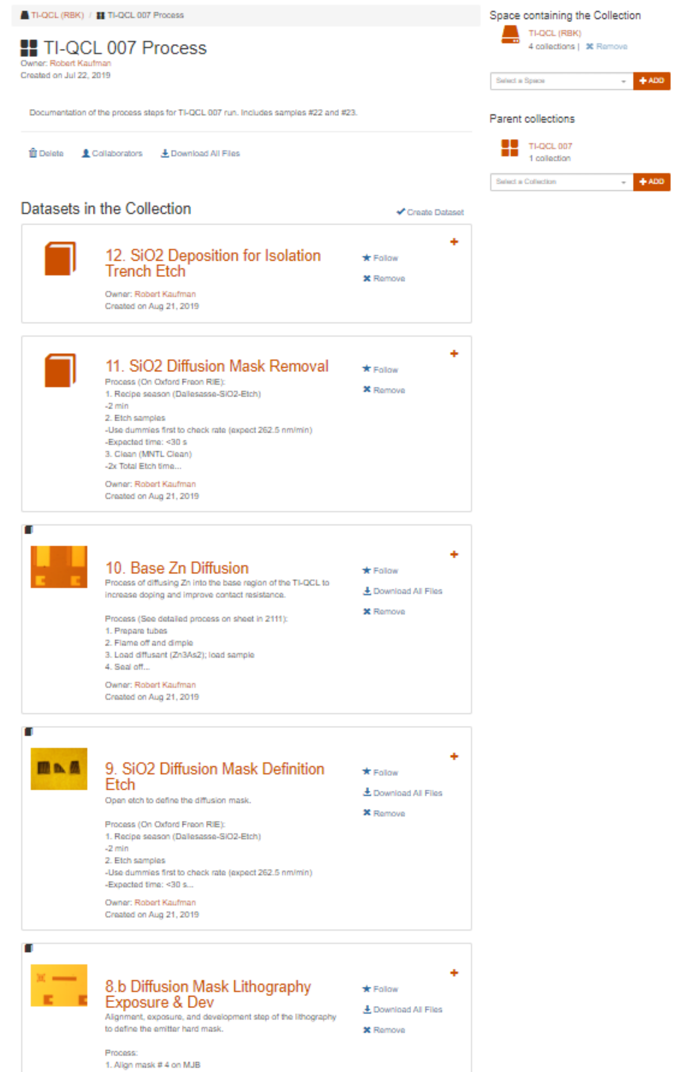
Questions?






```
0.993471835645128
0.9876314375071126
0.9940794194313601
Pad Resistance: [1.0767903731516643e-05, 1.0060551297977721e-05, 1.041422751474
7174e-05]
```





4CeeD NSF

MRL FREDERICK SEITZ MATERIALS RESEARCH LABORATORY | MNTL micro+nanotechnology lab | CSL: COORDINATED SCIENCE LAB