

4CeeD Lecture Series

Use of 4CeeD Services for Material Scientists

Lecture #2: 4CeeD for Collaboration and Data Processing

March 23rd, 2023

Robert Kaufman (rbkaufm2@Illinois.edu), Leah Espenhahn (leahe2@illinois.edu)

Beitong Tian, and Prof. Klara Nahrstedt (Klara@Illinois.edu)



A timely and trusted curator and coordinator of scientific data

Lecture Series Learning Objectives

- Lecture 1 (3/21): Overview of 4CeeD
- Lecture 2 (3/23): Workshop (Cont.) & Advanced Features
 - Reviewing 4CeeD Structure
 - Introducing Data Sharing and Extractors
 - Visualizing Trends with Jupyter
 - **Breakout:** *Analyzing an Experiment with 4CeeD and Jupyter*
- Lecture 3 (3/28): 4CeeD Backend Services
- Lecture 4 (3/30): SENSELET: Sensory Network Infrastructure for Scientific Lab Environments

Lecture Series Learning Objectives

- Lecture 2: Demonstration of 4CeeD
 - Reviewing 4CeeD Structure
 - Introducing Data Sharing and Extractors
 - Visualizing Trends with Jupyter
 - **Breakout:** *Analyzing an Experiment with 4CeeD and Jupyter*

4Ceed Review

Space

Owner

Shared User

Shared User

Shared User

Shared User

Shared User

Shared User

Collection

Datasets

10. Base Zinc Diffusion

Process of diffusing Zn into the base region of the TI-QCL to increase doping and improve contact resistance.

Note: Due to instability of SiNx, the hardmask was redone with 100 nm SiO₂.

Process (See detailed process on sheet in 2111):

1. Prepare tubes...

Owner: Robert Kaufman
Created on Apr 12, 2019

9. SiNx Diffusion Mask Definition Etch

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Open etch to define the diffusion mask.

Process (On Oxford Fraun RIE):

1. Recipe session (Dateless-SiNx-Etch)
- 2 min...

Owner: Robert Kaufman
Created on Mar 26, 2019

8.b Diffusion Mask Lithography Exposure & Development

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Alignment, exposure, and development step of the lithography to define the emitter hard mask.

Process:

1. Align mask # 4 on MUB...

Owner: Robert Kaufman
Created on Mar 26, 2019

8.a Diffusion Mask Lithography Spin On

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Spin on process for the lithography to define the Zn-diffusion hard mask.

Process:

1. Clean and O₂ desum...

Owner: Robert Kaufman
Created on Mar 26, 2019

7. SiNx Deposition for Diffusion Hard Mask

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Deposition of SiNx using the STS to act as the hard mask for base Zn diffusion. The Zn diffusion is necessary to improve contact resistance but must only be in the base region to avoid shorting. Includes all TiQCL samples (P14, #27, and KC#1). #14 is in quadrant "HP 1" in the photos...

Owner: Robert Kaufman
Created on Mar 26, 2019

Collection

Datasets

10. Base Zinc Diffusion

Process of diffusing Zn into the base region of the TI-QCL to increase doping and improve contact resistance.

Note: Due to instability of SiNx, the hardmask was redone with 100 nm SiO₂.

Process (See detailed process on sheet in 2111):

1. Prepare tubes...

Owner: Robert Kaufman
Created on Apr 12, 2019

9. SiNx Diffusion Mask Definition Etch

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Open etch to define the diffusion mask.

Process (On Oxford Fraun RIE):

1. Recipe session (Dateless-SiNx-Etch)
- 2 min...

Owner: Robert Kaufman
Created on Mar 26, 2019

Sub-Collection

10. Base Zinc Diffusion

Process of diffusing Zn into the base region of the TI-QCL to increase doping and improve contact resistance.

Note: Due to instability of SiNx, the hardmask was redone with 100 nm SiO₂.

Process (See detailed process on sheet in 2111):

1. Prepare tubes...

Owner: Robert Kaufman
Created on Apr 12, 2019

9. SiNx Diffusion Mask Definition Etch

NOTE! For future diffusions, do not use SiNx on iHP lattice matched materials as the mask does not hold up.

Open etch to define the diffusion mask.

Process (On Oxford Fraun RIE):

1. Recipe session (Dateless-SiNx-Etch)
- 2 min...

Owner: Robert Kaufman
Created on Mar 26, 2019



10. Base Zn Diffusion

Process of diffusing Zn into the base region of the TI-QCL to increase doping and improve contact resistance.

Process (See detailed process on sheet in 2111):

1. Prepare tubes
2. Flame off and dimple
3. Load diffusant (Zn3As2); load sample
4. Seal off...

Owner: Robert Kaufman
Created on Aug 21, 2019

★ Follow

↓ Download All Files

✕ Remove

4CeeD Review

GUI Dashboard

- Dashboard View of 4CeeD

The screenshot displays the 4CeeD GUI Dashboard. At the top, there is a navigation bar with the 4CeeD logo, user information (You), and menu options (Shared, Create, Trash, Help). A search bar and 'Jupyter Hub' and 'Logout' links are also present. The main content area is divided into two panels. On the left is the 'File Tree Viewer', which shows a hierarchical list of files and folders. A context menu is open over the file '8.b Diffusion Mask Definition Etch', showing options like 'Create...', 'Attach Template', 'Add files...', 'Download', and 'Delete'. On the right is the 'Data Preview' window, which displays a green-tinted image of a semiconductor wafer with various patterns and labels. Below the image, there is a 'Metadata' section with the text 'No metadata available for this resource' and a 'Tags' section with an empty input field. A black box with the text 'File Tree Viewer' and an arrow points to the left panel, and another black box with the text 'Data Preview' and an arrow points to the right panel.

4CeeD Review

Dataset Page

TI-QCL (RBK) / 10. Base Zn Dif...

10. Base Zn Diffusion

Created by Robert Kaufman

All Rights Reserved Robert Kaufman

Created on Aug 21, 2019

Access: Space Default (Private) Private

Public

Process of diffusing Zn into the base region of the TI-QCL to increase doping and improve contact resistance.

Process (See detailed process on sheet in 2111):

1. Prepare tubes
2. Flame off and dimple
3. Load diffusant (Zn3As2); load sample
4. Seal off
5. Heat in furnace
-560C for 10-20 min

Notes:

- Test with GaAs dummy samples first (try and verify rate with KOH-KFe(CN) stain and SEM)
- Steps 7-11 are not necessary if skipping Zn diffusion.

[+ Add Files](#) [Download All Files](#) [Delete](#) [Collaborators](#)

Files [Metadata](#) [Comments \(0\)](#)



02-13-2020_TIQCL007_ZnDiff_Longside.png

image/png

Feb 13, 2020

1.8 MB

[Download](#)

[★ Follow](#)

Space containing the Dataset



TI-QCL (RBK)

27 datasets | [✕ Remove](#)

Select a Space

[+ ADD](#)

Collections containing the Dataset



TI-QCL 007 Process

15 datasets | [✕ Remove](#)

Select a collection

[+ ADD](#)

Tags

[TAG](#)

Detailed Data Description

Access Files, Template Data and Comments

Quickly Modify Dataset Location

4CeeD Review

Dataset Page

TI-QCL (RBK) / 10. Base Zn Dif... Space containing the Dataset

10. Base Zn Diffusi

Created by **Robert Kaufman**
Created on Aug 21, 2019
Access: Space Default (Private) Private Public

Process of diffusing Zn into the base region of

Process (See detailed process on sheet in 211)


1. Prepare tubes
2. Flame off and dimple
3. Load diffusant (Zn3As2); load sample
4. Seal off
5. Heat in furnace

-560C for 10-20 min

Notes:
-Test with GaAs dummy samples first (try an
-Steps 7-11 are not necessary if skipping Zn di

[+ Add Files](#) [Download All Files](#)

Files **Metadata** Comments (0)



02-13-2020_TIC
image/png
Feb 13, 2020
1.8 MB

0 0 0

Dataset Metadata

Select a template:
--Select One--

Key:	Value	Units:	
Time	13	min	REMOVE
Tempearture	425	C	REMOVE
Oxide Depth	12	um	REMOVE
Oxide Layer	99	%	REMOVE
Oxide Thick.	30	nm	REMOVE

[ADD NEW](#) [SUBMIT](#) [CLOSE](#)

Lecture Series Learning Objectives

- Lecture 2: Demonstration of 4CeeD
 - Reviewing 4CeeD Structure
 - **Introducing Data Sharing and Extractors**
 - Visualizing Trends with Jupyter
 - ***Breakout: Analyzing an Experiment with 4CeeD and Jupyter***

Effective Collaboration: Data Sharing

Fabrication Development Dallesasse

Fabrication Development Space for Professor John Dallesasse Group:

Creator: Patrick Su

Viewers: Rob Kaufman, Kevin Pikul, John Carlson


 Delete  Create Dataset  Create Collections


All Data **Public Data**

Datasets in the Space

Viewing most recent datasets

 View All Datasets

 Manage Users

 Edit Space

 Manage Metadata Terms & Definitions

 Extractors


 Follow

External Links

Edit Space to add links

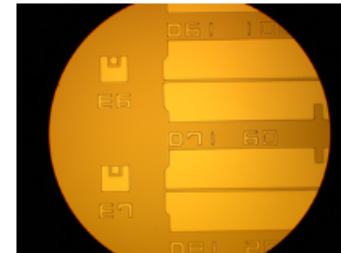
03-11-2019 CLU-LF

Purpose: Stain-Etch Mask
Time: 12 minutes
Thickness: 432.2 nm
Rate: 36 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 380 KHz

 0  0  0  0 

03-11-2019 CLU-10HF

Purpose: Diffusion Mask for
TI-QCL006 (600C for 12.5
mins)
Time: 20 minutes
Thickness: 178.82 nm
Rate: 8.9 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 13.56 MHz



Silicon Sample 2

Effective Collaboration: Data Sharing

Fabrication Development Dallesasse

Fabrication Development Space for Professor John Dallesasse Group:

Creator: Patrick Su

Viewers: Rob Kaufman, Kevin Pikul, John Carlson

 Delete

 Create Dataset

 Create Collections

Fabrication Development Dallesasse



Fabrication Development Space for Professor John Dallesasse Group:

Creator: Patrick Su

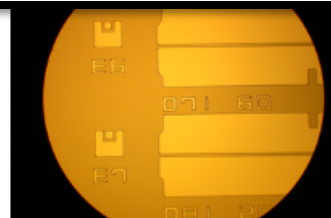
Viewers: Rob Kaufman, Kevin Pikul, John Carlson

[Data Terms & Definitions](#)

Purpose: Stain-Etch Mask
Time: 12 minutes
Thickness: 432.2 nm
Rate: 36 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 380 KHz

 0  0  0  0 

Purpose: Diffusion Mask for
TI-QCL006 (600C for 12.5
mins)
Time: 20 minutes
Thickness: 178.82 nm
Rate: 8.9 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 13.56 MHz



Silicon Sample 2

 Follow

External Links

Edit Space to add links

Effective Collaboration: Data Sharing

Fabrication Development Dallesasse

Fabrication Development Space for Professor John Dallesasse Group:

Creator: Patrick Su

Viewers: Rob Kaufman, Kevin Pikul, John Carlson

 Delete  Create Dataset  Create Collections

All Data **Public Data**


Datasets in the Space

Viewing most recent datasets

 View All Datasets

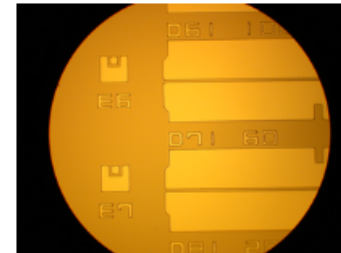
03-11-2019 CLU-LF

Purpose: Stain-Etch Mask
Time: 12 minutes
Thickness: 432.2 nm
Rate: 36 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 380 KHz


 0  0  0  0 

03-11-2019 CLU-10HF

Purpose: Diffusion Mask for
TI-QCL006 (600C for 12.5
mins)
Time: 20 minutes
Thickness: 178.82 nm
Rate: 8.9 nm/min
N2: 1960 SiH4: 40 NH3: 55
Power: 20 Freq: 13.56 MHz



Silicon Sample 2

 Manage Users

 Edit Space

 Manage Metadata Terms & Definitions

 Extractors

 Follow

External Links

Edit Space to add links

Effective Collaboration: Data Sharing

Manage Users of Space Fabrication Recipe Bank

Users Invites Requests (0)

Owner: Patrick Su

Admins

Admin Admin Role

- Patrick Su (psu8@illinois.edu) [Local Account] ✕

Select Users for this Level...

Admin

Admin Role

- Patrick Su (psu8@illinois.edu) [Local Account] ✕

Select Users for this Level...

Collaborator

A collaborator can add datasets and files to a space. They cannot delete anything

- Robert Kaufman (rbkaufm2@illinois.edu) [Local Account] ✕
- Thomas O'Brien (tobrien3@illinois.edu) [Local Account] ✕
- John Carlson (jcarls21@illinois.edu) [Local Account] ✕
- Maanav Ganjoo (ganjoo2@illinois.edu) [Local Account] ✕
- Kevin Pikul (kpikul2@illinois.edu) [Local Account] ✕

Select Users for this Level...

Collaborators

Effective Collaboration: Communication

Highlight and annotate parts of image files

SEMExample.tif
Add a description

Tag:
Comment:

SUBMIT CLOSE

This screenshot shows a file viewer for 'SEMExample.tif'. A blue rectangular box highlights a portion of the image. Overlaid on this box is a comment form with fields for 'Tag' and 'Comment', and two buttons: 'SUBMIT' (with a checkmark icon) and 'CLOSE' (with a close icon).

Leave comments on Datasets and Files

#	Thumbnail	Position	Description	Find
		x: 0.55, y: 0.02, width: 0.37, height: 0.59	<input checked="" type="checkbox"/> EDIT	Similar

This screenshot shows a gallery view of image files. The top part shows a large image with navigation arrows and a zoom icon. Below it is a table listing the files. The first entry is highlighted, showing its position and an 'EDIT' button.

Files Metadata Comments (1)

POST

Robert Kaufman • Jul 20, 2020 17:18:01

Completed on July 14th, 2020.
Dev Notes:
-L1: 25s w/shake at 10s + 1s dip - pretty good
-L2: 22s w/shake at 5, 12s + 3s dip - really good
-L3: 29s w/shake at 22s - better than L4
-L4: 31s - looked under + over dev'd (expose issue?) + 3s dip
-InP1: 50s over dev'd
-InP2: 35s really good, hair over dev'd

[Reply](#) [Edit](#) [Delete](#)

This screenshot shows the 'Comments' tab for a file. It features a 'POST' button and a single comment from Robert Kaufman. The comment includes a timestamp and detailed 'Dev Notes' with specific parameters and observations. At the bottom, there are 'Reply', 'Edit', and 'Delete' options.

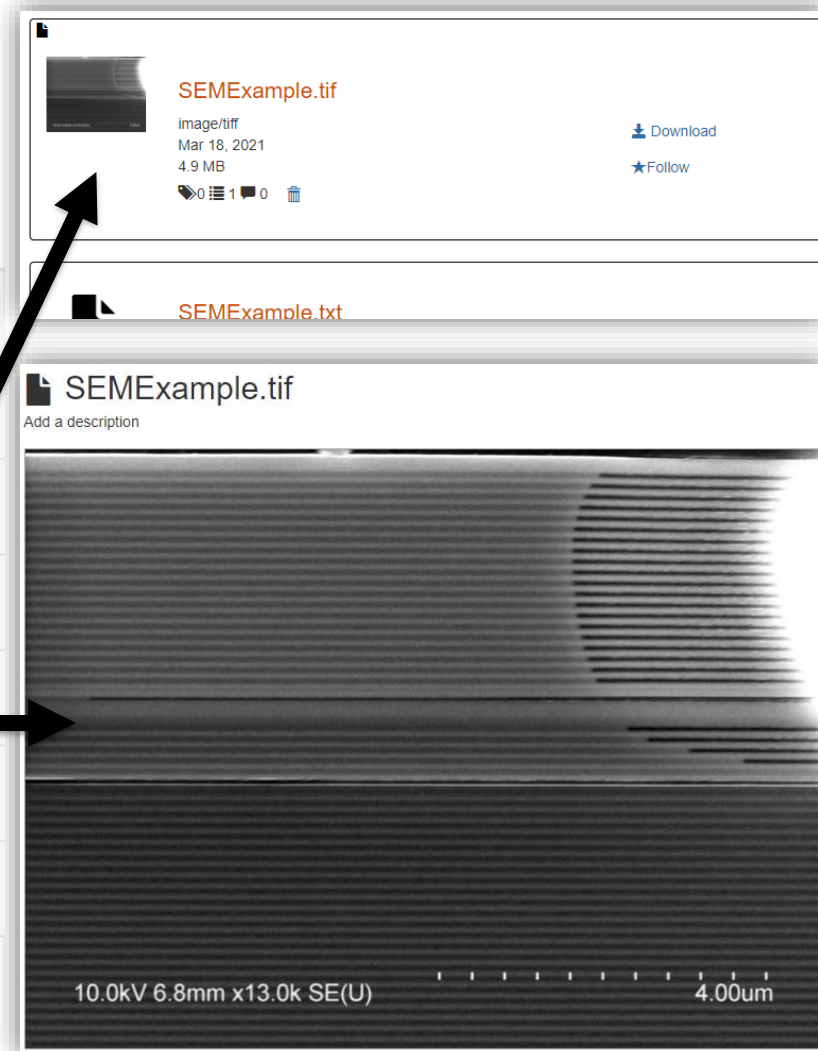
Efficient Data Collection: Extractors

- Extractors automatically log pertinent information of uploaded data
- Basic Example: Image Thumbnails

Extractions

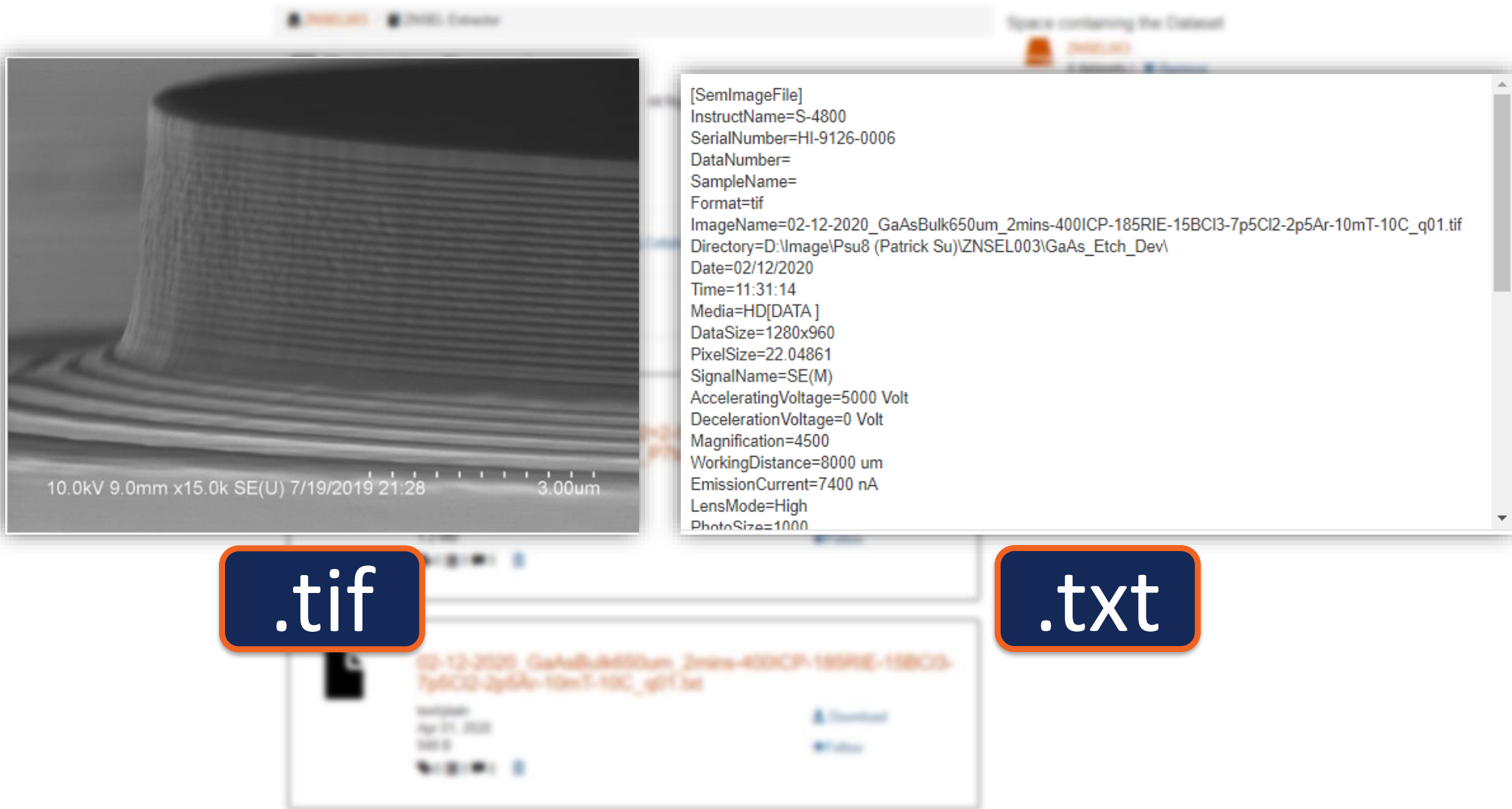
[List extraction events](#) [Submit file for extraction](#)

Extractor	Start	End	Status
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	StatusMessage.start: Started processing
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	StatusMessage.processing: Downloading file.
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	StatusMessage.processing: Uploaded thumbnail of type png
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	StatusMessage.processing: Uploading file preview.
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	StatusMessage.processing: Uploaded preview of type png
nrsa.image.preview	Thu Mar 18 00:54:10 GMT 2021	N/A	DONE



Efficient Data Collection: Extractors

- A more useful example is with SEM metadata



The screenshot shows a scanning electron microscope (SEM) image of a cylindrical structure on the left. The image includes technical details at the bottom: "10.0kV 9.0mm x15.0k SE(U) 7/19/2019 21:28 3.00um". On the right, a metadata extraction window displays the following information:

```
[SemImageFile]
InstructName=S-4800
SerialNumber=HI-9126-0006
DataNumber=
SampleName=
Format=tif
ImageName=02-12-2020_GaAsBulk650um_2mins-400ICP-185RIE-15BCI3-7p5CI2-2p5Ar-10mT-10C_q01.tif
Directory=D:\Image\Psu8 (Patrick Su)\ZNSEL003\GaAs_Etch_Dev\
Date=02/12/2020
Time=11:31:14
Media=HD[DATA ]
DataSize=1280x960
PixelSize=22.04861
SignalName=SE(M)
AcceleratingVoltage=5000 Volt
DecelerationVoltage=0 Volt
Magnification=4500
WorkingDistance=8000 um
EmissionCurrent=7400 nA
LensMode=High
PhotoSize=1000
```

Below the image and metadata, two blue boxes with orange borders contain the file extensions ".tif" and ".txt", indicating the output formats for the image and its metadata, respectively.

Efficient Data Collection: Extractors

ZNSEL003 / ZNSEL Extractor

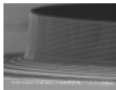
Extractor Example

Created by Patrick Su
Created on Apr 01, 2020
Access: Space Default (Private) Private
 Public

Add a description

[+ Add Files](#) [Download All Files](#) [Delete](#) [Collaborators](#)


Files Metadata Comments (0)



07-17-2019_BCI3=7-5_CI2=2-5_Ar=3-5_RIE=185W_ICP=375W_P7to2mT_10C_II-VIEpi_Sidewall_q05.tif

image/tiff
Apr 01, 2020
1.2 MB

[Download](#)
[Follow](#)



02-12-2020_GaAsBulk650um_2mins-400ICP-185RIE-15BCI3-7p5CI2-2p5Ar-10mT-10C_q01.txt

text/plain
Apr 01, 2020
949 B

[Download](#)
[Follow](#)

Space containing the Dataset
ZNSEL003
4 datasets | [Remove](#)

Select a Space [+ ADD](#)

Collections containing the Dataset
Select a collection [+ ADD](#)

Tags
 [TAG](#)

SEM Image Captures

Corresponding .txt of SEM capture conditions

Efficient Data Collection: Extractors

Extracted Text File

```
[SemImageFile]
InstructName=S-4800
SerialNumber=HI-9126-0006
DataNumber=
SampleName=
Format=tif
ImageName=02-12-2020_GaAsBulk650um_2mins-400ICP-185RIE-15BCI3-7p5CI2-2p5Ar-10mT-10C_q01.tif
Directory=D:\Image\Psu8 (Patrick Su)\ZNSEL003\GaAs_Etch_Dev\
Date=02/12/2020
Time=11:31:14
Media=HD[DATA ]
DataSize=1280x960
PixelSize=22.04861
SignalName=SE(M)
AcceleratingVoltage=5000 Volt
DecelerationVoltage=0 Volt
Magnification=4500
WorkingDistance=8000 um
EmissionCurrent=7400 nA
LensMode=High
PhotoSize=1000
```

Corresponding 4CeeD Metadata

Metadata

— Extracted by <http://clowder:9000/extractors/sem.extractor/2.0.0> on Mar 18, 2021 

ColorPalette:

Media: HD[DATA]

SerialNumber: HI-9126-0006

Directory: D:\Image\Psu8 (Patrick Su)\ZNSEL003\Oxidation_Calib\

Magnification: 13000

DataDisplayCombine: 1

KeyWord2:

KeyWord1:

CalibrationScanSpeed: 25

SubMagnification: 0

Format: tif

Vacuum:

Date: 02/24/2020

Data Size: 2560x1920

WorkingDistance: 6800 um

Condencer1: 5000

LensMode: High

SubSignalName:

EmissionCurrent: 7800 nA

Lecture Series Learning Objectives

- Lecture 2: Demonstration of 4CeeD
 - Reviewing 4CeeD Structure
 - Introducing Data Sharing and Extractors
 - Visualizing Trends with Jupyter
 - **Breakout:** *Analyzing an Experiment with 4CeeD and Jupyter*

4CeeD Integrated Jupyter Notebook

- Access metadata from datasets
- Uses pandas DataFrames to store info
 - Quick table views
 - Create custom columns
 - Easy data retrieval and sorting
- Quick plotting and visualization through matplotlib

Select Metadata to Read from 4Ceed

```
In [5]: py4ceed.read_datasets_metadata()
```

Retrieving datasets ...

- ▶ Fabrication Development Dallasius Group (Space)
- ▶ Classroom Demos (Space)
- ▼ 4CeeD Demo: GaN Etch Recipe Optimization Figure 2 (Space)
 - ▼ datasets
 - GaN Etch Pressure 9 mTorr
 - GaN Etch Pressure 7 mTorr
 - GaN Etch Pressure 5 mTorr
 - GaN Etch Pressure 3.5 mTorr
- ▶ 4CeeD Demo: GaN Etch Recipe Optimization Figure 1 (Space)
- ▶ TI-QCL 006B (Collection)
- ▶ TI-QCL 005-006 (Collection)

Submit

GaN Etch Pressure 7 mTorr	280.0	49.0	21.0	1000.0	150.0	7.0	25.0
GaN Etch Pressure 5 mTorr	300.0	49.0	21.0	1000.0	150.0	5.0	25.0
GaN Etch Pressure 3.5 mTorr	280.0	49.0	21.0	1000.0	150.0	3.5	25.0

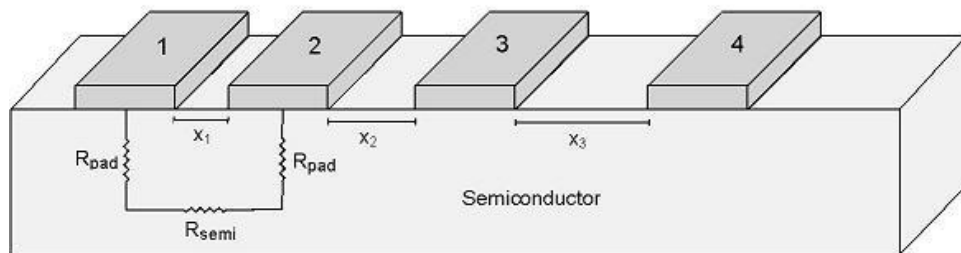
Plot Metadata

```
In [4]: metadata = py4ceed.get_metadata()
metadata.plot(x='Pressure', y='Etch_Rate')
plt.show()
```

Pressure	Etch_Rate
4	280
5	300
7	280
9	220

4CeeD Integrated Jupyter Notebook

- Jupyter environment is hosted on 4CeeD servers
- Allows for remote access and processing of custom scripts



The screenshot shows a Jupyter Notebook interface with the following content:

```
jupyter TLM (autosaved) Logout Control Panel
File Edit View Insert Cell Kernel Widgets Help Trusted Python 3 O
+ - % < > Run C >> Markdown
f.write('Contact Resistivity: '+str(r_pad*pad_area)+' [ohms-cm2]\n')
f.write('Best-fit Line: y = ('+str(fit_slope)+'x + '+str(fit_int)+'\n')
f.write('\tR = '+str(r_val)+'\n')
f.write('\nDistance(um)\tResistance(ohms)\n')
for d in range(len(dist)):
    f.write(str(l_dist[d])+'\t'+str(res_list[d])+'\n')

#Return Rpad
return r_pad*pad_area
```

Iterate through data and perform TLM measurements for each trial

```
In [7]: resistances = [[] for x in range(trials)]
r_pads = []
avg_res = [0 for d in range(len(dist))]
for t in range(trials):
    for d in range(len(dist)):
        resistances[t] += [1/(stats.linregress(voltages[t][d], currents[t][d])[0
        avg_res[d] += resistances[t][d]/trials
    r_pads += [fitPlotSaveResistances(resistances[t],t+1)]
r_pads += [fitPlotSaveResistances(avg_res,0)]

print("Pad Resistance: "+str(r_pads))
```

0.993471835645128
0.9876314375071126
0.9940794194313601
Pad Resistance: [1.0767903731516643e-05, 1.006055129797721e-05, 1.0414227514747174e-05]

The plot shows a scatter plot of resistance (y-axis, ranging from 1.0 to 3.0) versus distance (x-axis, ranging from 0 to 60). The data points are blue dots, and a dashed orange line represents a linear fit to the data. The data points are approximately at (20, 1.8), (25, 2.0), (30, 2.2), (35, 2.4), (40, 2.6), (45, 2.8), (50, 3.0), and (55, 3.2).

4CeeD and Jupyter Notebook

- `py4ceed.enter_key()`
 - Prompts entry of API Key to access 4CeeD account
- `py4ceed.read_datasets_metadata()`
 - Opens GUI to select metadata info
- `py4ceed.get_metadata()`
 - Returns selected metadata as a pandas DataFrame

4CeeD and Jupyter Notebook

■ enter_key()

The screenshot displays the 4CeeD user interface. At the top, a navigation bar includes the 4CeeD logo, user options (You, Shared, Create, Trash, Help), a search bar, and a 'Jupyter Hub' link. A user profile for Robert Kaufman is shown, including a placeholder image, name, profile source (Local Account, rbkaufm2@illinois.edu), and a section for 'User API Keys'. A table lists one key named 'rbkaufm2_key' with a redacted key value. A '+ Add' button is highlighted with a yellow box. A callout box points to the 'Jupyter Hub' link with the text 'Link to hosted Jupyter'. A yellow box highlights the 'Logout' and 'View Profile' buttons in the top right. An inset window titled 'Enter 4Ceed Key' shows a Jupyter Notebook cell with the code `py4ceed.enter_key()`, a 'User Key:' input field, and a 'Submit' button.

4CeeD You Shared Create Trash Help Search Jupyter Hub Logout View Profile Logout

Robert Kaufman
Profile Source : Local Account
rbkaufm2@illinois.edu

User API Keys
Create your personal API keys by providing a name for the key and clicking the Add button. Key names have to be unique per user.

Name	Key
rbkaufm2_key	[REDACTED]

+ Add

Followed by 0 people
[Edit Profile](#)

Link to hosted Jupyter

Enter 4Ceed Key

```
In [2]: py4ceed.enter_key()
```

User Key:

Submit

4CeeD and Jupyter Notebook

▪ `read_datasets_metadata()`

Select Metadata to Read from 4CeeD

```
In [3]: py4ceed.read_datasets_metadata()
```

Retrieving datasets ...

▶ Test Space (Space)

▶ 4CeeD Demos (Space)

▶ TIQCL007 (Space)

▶ **SENSELET Data (Space)**

▶ Growth Experiments (Space)

▶ collaborator role test space (Space)

▶ TI-QCL (RBK) (Space)

▼ 4CeeD Demo: GaN Etch Recipe Optimization Figure 2 (Space)

▼ datasets

GaN Etch Pressure 9 mTorr

GaN Etch Pressure 7 mTorr

GaN Etch Pressure 5 mTorr

GaN Etch Pressure 3.5 mTorr

▶ 4CeeD Demo: GaN Etch Recipe Optimization Figure 1 (Space)

▶ rbs (Collection)

▶ dm3 (Collection)

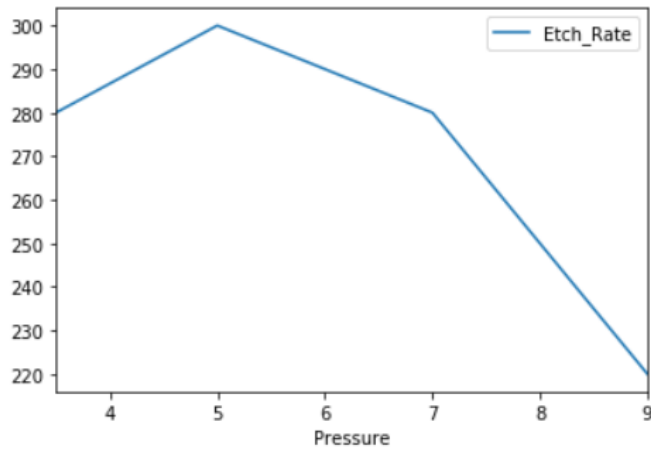
Submit

4CeeD and Jupyter Notebook

■ get_metadata()

Plot Metadata

```
In [5]: metadata = py4ceed.get_metadata()
metadata.plot(x='Pressure', y='Etch_Rate')
plt.show()
```



```
In [5]: metadata = py4ceed.get_metadata()
metadata.plot(x='Pressure', y='Etch_Rate')
plt.show()
```

Filter Metadata

```
In [6]: metadata[metadata['Pressure'] >= 7]
```

Out[6]:

	Etch_Rate	BCl3_Gas_Flow	Cl2_Gas_Flow	ICP_Power	RIE_Power	Pressure	Temperature
GaN Etch Pressure 9 mTorr	220.0	49.0	21.0	1000.0	150.0	9.0	25.0
GaN Etch Pressure 7 mTorr	280.0	49.0	21.0	1000.0	150.0	7.0	25.0

4CeeD and Jupyter Notebook

- **get_metadata()**

```
In [5]: metadata = py4ceed.get_metadeta()  
metadata.plot(x='Pressure', y='Etch_Rate')  
plt.show()
```

pandas.DataFrame

class **pandas.DataFrame**(data=None, index=None, columns=None, dtype=None, copy=False) [\[source\]](#)

Two-dimensional, size-mutable, potentially heterogeneous tabular data.

Data structure also contains labeled axes (rows and columns). Arithmetic operations align on both row and column labels. Can be thought of as a dict-like container for Series objects. The primary pandas data structure.

Lecture Series Learning Objectives

- Lecture 2: Demonstration of 4CeeD
 - Reviewing 4CeeD Structure
 - Introducing Data Sharing and Extractors
 - Visualizing Trends with Jupyter
 - ***Breakout: Analyzing an Experiment with 4CeeD and Jupyter***

Breakout: 4CeeD Jupyter Integration

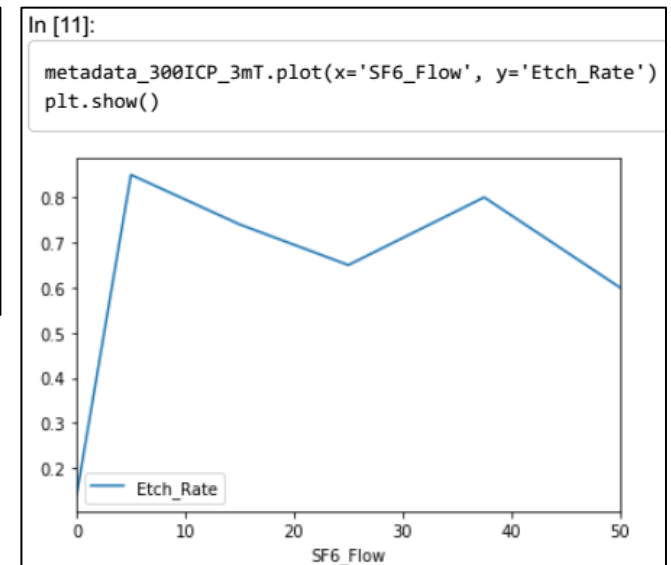
Activity Objectives

- Access the 4CeeD Jupyter server
- Extract stored 4CeeD metadata
- Quickly process that data in useful ways
- Save a snapshot of the notebook with the data



The screenshot shows the 4CeeD Jupyter interface. At the top, there are tabs for 'Files', 'Running', and 'Clusters'. Below the tabs, there is a section for file management with buttons for 'Upload', 'New', and 'Refresh'. A yellow arrow points to the 'Upload' button. Below this, there is a table of files in the '/ private' directory.

Name	Last Modified	File size
..	seconds ago	
TLM	2 years ago	
MSE598JupyterDemo.ipynb	2 minutes ago	7.44 kB
plot_metadata_tutorial.ipynb	9 months ago	60.4 kB

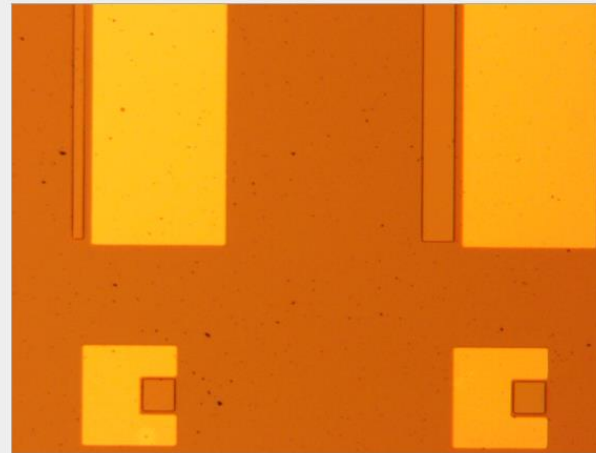


Questions?

Search...

Sort Delete

- 4CeeD Demos
 - TI-QCL (RBK)
 - TI-QCL 007 Process
 - 12. SiO2 Deposition for Isolation Trench Etch
 - 11. SiO2 Diffusion Mask Removal
 - 10. Base Zn Diffusion
 - 02-13-2020_TIQCL007_ZnDiff_Shortside.png
 - 02-13-2020_TIQCL007_ZnDiff_Longside.png**
 - 9. SiO2 Diffusion Mask Definition Etch
 - 8.b Diffusion Mask Lithography Exposure & Dev
 - 8.a Diffusion Mask Lithography Spin On
 - 7. SiO2 Deposition for Diffusion Hard Mask
 - 6. Emitter Hard Mask Removal
 - 5.b Emitter Mesa Wet Etch
 - 5.a Emitter Mesa Dry Etch
 - 4. SiO2 Emitter Mask Definition Etch



Metadata

No metadata available for this resource

Tags

In [8]: `metadata.describe()`

Out[8]:

	Etch_Rate	BCI3_Gas_Flow	Cl2_Gas_Flow	ICP_Power	RIE_Power	Pressure	Temperature
count	4.000000	4.0	4.0	4.0	4.0	4.000000	4.0
mean	270.000000	49.0	21.0	1000.0	150.0	6.125000	25.0
std	34.641016	0.0	0.0	0.0	0.0	2.393568	0.0
min	220.000000	49.0	21.0	1000.0	150.0	3.500000	25.0
25%	265.000000	49.0	21.0	1000.0	150.0	4.625000	25.0
50%	280.000000	49.0	21.0	1000.0	150.0	6.000000	25.0
75%	285.000000	49.0	21.0	1000.0	150.0	7.500000	25.0
max	300.000000	49.0	21.0	1000.0	150.0	9.000000	25.0

Select Metadata to Read from 4Ceed

In [5]: `py4ceed.read_datasets_metadata()`

Retrieving datasets ...

- Fabrication Development Databases Group (Space)
- Classroom Demos (Space)
- 4CeeD Demo: GaN Etch Recipe Optimization Figure 2 (Space)
- 4CeeD Demo: GaN Etch Recipe Optimization Figure 1 (Space)
- TI-QCL 006B (Collection)

datasets

- GaN Etch Pressure 9 mTorr
- GaN Etch Pressure 7 mTorr
- GaN Etch Pressure 5 mTorr
- GaN Etch Pressure 3.5 mTorr

	Etch_Rate	BCI3_Gas_Flow	Cl2_Gas_Flow	ICP_Power	RIE_Power	Pressure	Temperature
GaN Etch Pressure 9 mTorr	220.0	49.0	21.0	1000.0	150.0	9.0	25.0
GaN Etch Pressure 7 mTorr	280.0	49.0	21.0	1000.0	150.0	7.0	25.0
GaN Etch Pressure 5 mTorr	300.0	49.0	21.0	1000.0	150.0	5.0	25.0
GaN Etch Pressure 3.5 mTorr	280.0	49.0	21.0	1000.0	150.0	3.5	25.0

Plot Metadata

In [4]: `metadata = py4ceed.get_metadata()`
`metadata.plot(pw='Pressure', yw='Etch_Rate')`
`plt.show()`

