

MSE598sp21-Demo.html

Install the latest py4Ceed lib¶

In [1]:

```
!pip install ipywidgets
!pip install pandas
!pip install matplotlib
!jupyter nbextension enable --py widgetsnbextension --sys-prefix
!pip install py4ceedlib -U
```

Requirement already satisfied: ipywidgets in /opt/conda/lib/python3.7/site-packages (7.4.2)

Requirement already satisfied: traitlets>=4.3.1 in /opt/conda/lib/python3.7/site-packages (from ipywidgets) (4.3.2)

Requirement already satisfied: widgetsnbextension~=3.4.0 in /opt/conda/lib/python3.7/site-packages (from ipywidgets) (3.4.2)

Requirement already satisfied: nbformat>=4.2.0 in /opt/conda/lib/python3.7/site-packages (from ipywidgets) (4.4.0)

Requirement already satisfied: ipython>=4.0.0; python_version >= "3.3" in /opt/conda/lib/python3.7/site-packages (from ipywidgets) (5.1.0)

Requirement already satisfied: ipykernel>=4.5.1 in /opt/conda/lib/python3.7/site-packages (from ipywidgets) (5.1.0)

Requirement already satisfied: ipython_genutils in /opt/conda/lib/python3.7/site-packages (from traitlets>=4.3.1->ipywidgets) (0.2.0)

Requirement already satisfied: six in /opt/conda/lib/python3.7/site-packages (from traitlets>=4.3.1->ipywidgets) (1.12.0)

Requirement already satisfied: decorator in /opt/conda/lib/python3.7/site-packages (from traitlets>=4.3.1->ipywidgets) (4.3.2)

Requirement already satisfied: notebook>=4.4.1 in /opt/conda/lib/python3.7/site-packages (from widgetsnbextension~=3.4.0->ipywidgets) (4.4.1)

Requirement already satisfied: jsonschema!=2.5.0,>=2.4 in /opt/conda/lib/python3.7/site-packages (from nbformat>=4.2.0->ipywidgets) (2.6.0)

Requirement already satisfied: jupyter_core in /opt/conda/lib/python3.7/site-packages (from nbformat>=4.2.0->ipywidgets) (4.4.0)

Requirement already satisfied: setuptools>=18.5 in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (44.0.0)

Requirement already satisfied: jedi>=0.10 in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.17.2)

Requirement already satisfied: pickleshare in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.7.5)

Requirement already satisfied: prompt_toolkit<2.1.0,>=2.0.0 in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (2.0.10)

Requirement already satisfied: pygments in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (2.6.1)

Requirement already satisfied: backcall in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.2.0)

Requirement already satisfied: pexpect in /opt/conda/lib/python3.7/site-packages (from ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (4.7.0)

Requirement already satisfied: jupyter-client in /opt/conda/lib/python3.7/site-packages (from ipykernel>=4.5.1->ipywidgets) (5.2.4)

Requirement already satisfied: tornado>=4.2 in /opt/conda/lib/python3.7/site-packages (from ipykernel>=4.5.1->ipywidgets) (6.0.1)

Requirement already satisfied: Send2Trash in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (1.5.0)

Requirement already satisfied: prometheus-client in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (0.9.0)

Requirement already satisfied: pyzmq>=17 in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (19.0.0)

Requirement already satisfied: terminado>=0.8.1 in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (0.12.1)

Requirement already satisfied: jinja2 in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (2.10.1)

Requirement already satisfied: nbconvert in /opt/conda/lib/python3.7/site-packages (from notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (5.4.0)

Requirement already satisfied: attrs>=17.4.0 in /opt/conda/lib/python3.7/site-packages (from jsonschema!=2.5.0,>=2.4->nbformat>=4.2.0->ipywidgets) (19.1.0)

Requirement already satisfied: pyparsing>=2.0.2 in /opt/conda/lib/python3.7/site-packages (from jsonschema!=2.5.0,>=2.4->nbformat>=4.2.0->ipywidgets) (2.4.6)

Requirement already satisfied: parso>=0.3.0 in /opt/conda/lib/python3.7/site-packages (from jedi>=0.10->ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.5.1)

Requirement already satisfied: wcwidth in /opt/conda/lib/python3.7/site-packages (from prompt_toolkit<2.1.0,>=2.0.0->ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.2.1)

Requirement already satisfied: ptyprocess>=0.5 in /opt/conda/lib/python3.7/site-packages (from pexpect->ipython>=4.0.0; python_version >= "3.3"->ipywidgets) (0.6.0)

Requirement already satisfied: python-dateutil>=2.1 in /opt/conda/lib/python3.7/site-packages (from jupyter-client->ipykernel>=4.5.1->ipywidgets) (2.6.0)

Requirement already satisfied: MarkupSafe>=0.23 in /opt/conda/lib/python3.7/site-packages (from jinja2->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (1.1.1)

Requirement already satisfied: mistune>=0.8.1 in /opt/conda/lib/python3.7/site-packages (from nbconvert->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (0.8.4)

Requirement already satisfied: entrypoints>=0.2.2 in /opt/conda/lib/python3.7/site-packages (from nbconvert->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (0.3)

Requirement already satisfied: bleach in /opt/conda/lib/python3.7/site-packages (from nbconvert->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (2.1.0)

Requirement already satisfied: pandocfilters>=1.4.1 in /opt/conda/lib/python3.7/site-packages (from nbconvert->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (1.4.1)

Requirement already satisfied: testpath in /opt/conda/lib/python3.7/site-packages (from nbconvert->notebook>=4.4.1->widgetsnbextension~=3.4.0->ipywidgets) (0.4.2)

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Requirement already satisfied: pandas in /opt/conda/lib/python3.7/site-packages (0.24.2)
Requirement already satisfied: python-dateutil>=2.5.0 in /opt/conda/lib/python3.7/site-packages (from pandas) (2.8.0)
Requirement already satisfied: pytz>=2011k in /opt/conda/lib/python3.7/site-packages (from pandas) (2019.1)
Requirement already satisfied: numpy>=1.12.0 in /opt/conda/lib/python3.7/site-packages (from pandas) (1.16.4)
Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.7/site-packages (from python-dateutil>=2.5.0->pandas) (1.12.0)
Requirement already satisfied: matplotlib in /opt/conda/lib/python3.7/site-packages (3.1.0)
Requirement already satisfied: pyparsing!=2.0.4,!<2.1.2,!<2.1.6,>=2.0.1 in /opt/conda/lib/python3.7/site-packages (from matplotlib)
Requirement already satisfied: python-dateutil>=2.1 in /opt/conda/lib/python3.7/site-packages (from matplotlib) (2.8.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /opt/conda/lib/python3.7/site-packages (from matplotlib) (1.1.0)
Requirement already satisfied: numpy>=1.11 in /opt/conda/lib/python3.7/site-packages (from matplotlib) (1.16.4)
Requirement already satisfied: cyclor>=0.10 in /opt/conda/lib/python3.7/site-packages (from matplotlib) (0.10.0)
Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.7/site-packages (from python-dateutil>=2.1->matplotlib) (1.12.0)
Requirement already satisfied: setuptools in /opt/conda/lib/python3.7/site-packages (from kiwisolver>=1.0.1->matplotlib) (40.8.0)
Enabling notebook extension jupyter-js-widgets/extension...
  - Validating: OK
Requirement already up-to-date: py4ceedlib in /opt/conda/lib/python3.7/site-packages (0.4.29)
```

Import Py4Ceed Library and Data plotting Library¶

In [2]:

```
from py4ceedlib import py4ceed
from matplotlib import pyplot as plt
```

Enter 4Ceed Key¶

For this demonstration, please enter the provided key:

011c066d-a1e5-423b-a84e-a6a476926a3c

In [3]:

```
py4ceed.enter_key()
```

Successfully validated credentials

Select Metadata to Read from 4Ceed¶

Make sure to select all 14 of BCB Etch Test datasets in "MSE 598-DM: Jupyter Demo Data".
After hitting "Submit", wait until the table prints.

In [7]:

```
py4ceed.read_datasets_metadata()
```

Retrieving datasets ...

Done Retrieving ...

	BCB_Etch_Depth	PR_Etch_Depth	Etch_Time	SF6_Flow	O2_Flow	Pressure	ICP_Power
BCB Etch Test 14	4.83	6.440	3.0	15.0	35.0	3.0	1000.0
BCB Etch Test 13	4.92	6.390	3.0	15.0	35.0	3.0	750.0
BCB Etch Test 12	3.78	4.667	3.0	15.0	35.0	3.0	500.0
BCB Etch Test 11	1.80	1.714	3.0	15.0	35.0	3.0	0.0
BCB Etch Test 10	2.40	3.750	3.0	37.5	12.5	7.5	300.0
BCB Etch Test 9	1.92	3.840	3.0	25.0	25.0	7.5	300.0
BCB Etch Test 8	2.22	3.581	3.0	15.0	35.0	7.5	300.0
BCB Etch Test 7	2.55	3.750	3.0	5.0	45.0	7.5	300.0
BCB Etch Test 6	1.80	1.525	3.0	50.0	0.0	3.0	300.0
BCB Etch Test 5	2.40	2.162	3.0	37.5	12.5	3.0	300.0
BCB Etch Test 4	1.95	2.786	3.0	25.0	25.0	3.0	300.0
BCB Etch Test 3	2.22	2.775	3.0	15.0	35.0	3.0	300.0
BCB Etch Test 2	2.55	3.542	3.0	5.0	45.0	3.0	300.0
BCB Etch Test 1	0.42	3.231	3.0	0.0	50.0	3.0	300.0

Analyzing Our Data: Etch Rate¶

Now that we have the BCB metadata loaded, we can retrieve it in the form of a pandas DataFrame:

In [8]:

```
metadata = py4ceed.get_metadeta() #Store's the loaded metadata into a variable 'metadata' as a pandas DataFrame
metadata #Prints out the full metadata table
```

Out[8]:

	BCB_Etch_Depth	PR_Etch_Depth	Etch_Time	SF6_Flow	O2_Flow	Pressure	ICP_Power
BCB Etch Test 14	4.83	6.440	3.0	15.0	35.0	3.0	1000.0
BCB Etch Test 13	4.92	6.390	3.0	15.0	35.0	3.0	750.0
BCB Etch Test 12	3.78	4.667	3.0	15.0	35.0	3.0	500.0
BCB Etch Test 11	1.80	1.714	3.0	15.0	35.0	3.0	0.0
BCB Etch Test 10	2.40	3.750	3.0	37.5	12.5	7.5	300.0
BCB Etch Test 9	1.92	3.840	3.0	25.0	25.0	7.5	300.0
BCB Etch Test 8	2.22	3.581	3.0	15.0	35.0	7.5	300.0
BCB Etch Test 7	2.55	3.750	3.0	5.0	45.0	7.5	300.0
BCB Etch Test 6	1.80	1.525	3.0	50.0	0.0	3.0	300.0
BCB Etch Test 5	2.40	2.162	3.0	37.5	12.5	3.0	300.0
BCB Etch Test 4	1.95	2.786	3.0	25.0	25.0	3.0	300.0
BCB Etch Test 3	2.22	2.775	3.0	15.0	35.0	3.0	300.0
BCB Etch Test 2	2.55	3.542	3.0	5.0	45.0	3.0	300.0
BCB Etch Test 1	0.42	3.231	3.0	0.0	50.0	3.0	300.0

Adding new columns by function and basic filtering¶

While seeing all of this data in a table is helpful to understand it, defining some key calculations can be even more beneficial.

Etch rate is a critical variable when designing an etching process and is defined simply as the amount of material etched in some unit of time. Here, we'll define it in terms of $\mu\text{m}/\text{min}$ (which are the units our etch depth and time are kept as)

Creating and adding this new value to the metadata table is simple, as done below. In addition, to reduce the clutter of the table, we filter the metadata to only print relevant parameters:

In [9]:

```
metadata['Etch_Rate']=metadata['BCB_Etch_Depth']/metadata['Etch_Time'] #Creates a new column as a function of other columns
metadata[['SF6_Flow','O2_Flow','Pressure','ICP_Power','Etch_Rate']] #Prints out only the selected parameters
```

Out[9]:

	SF6_Flow	O2_Flow	Pressure	ICP_Power	Etch_Rate
BCB Etch Test 14	15.0	35.0	3.0	1000.0	1.61

	SF6_Flow	O2_Flow	Pressure	ICP_Power	Etch_Rate
BCB Etch Test 13	15.0	35.0	3.0	750.0	1.64
BCB Etch Test 12	15.0	35.0	3.0	500.0	1.26
BCB Etch Test 11	15.0	35.0	3.0	0.0	0.60
BCB Etch Test 10	37.5	12.5	7.5	300.0	0.80
BCB Etch Test 9	25.0	25.0	7.5	300.0	0.64
BCB Etch Test 8	15.0	35.0	7.5	300.0	0.74
BCB Etch Test 7	5.0	45.0	7.5	300.0	0.85
BCB Etch Test 6	50.0	0.0	3.0	300.0	0.60
BCB Etch Test 5	37.5	12.5	3.0	300.0	0.80
BCB Etch Test 4	25.0	25.0	3.0	300.0	0.65
BCB Etch Test 3	15.0	35.0	3.0	300.0	0.74
BCB Etch Test 2	5.0	45.0	3.0	300.0	0.85
BCB Etch Test 1	0.0	50.0	3.0	300.0	0.14

Conditional filtering and sorting¶

When trying to determine the effect some parameter, such as SF₆ Flow, has on the etch rate, we want to isolate it as the only variable. This is where conditional filtering comes in; we can extract each dataset with an ICP Power of 300 W and Pressure of 3 mT to ensure only the gas flow is changing.

After that, to find the recipe with the highest etch rate, we can sort the values and display them.

In [10]:

```
metadata_300ICP_3mT = metadata[(metadata['ICP_Power']==300) & (metadata['Pressure']==3)] #Filters and returns data meeting the crit
metadata_300ICP_3mT.sort_values(by=['Etch_Rate'], ascending=False) #Sorts and prints the data by the given parameters
```

Out[10]:

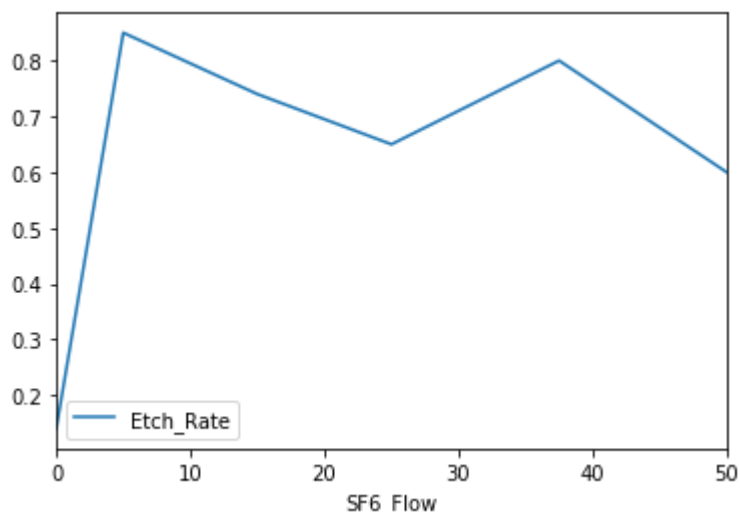
	BCB_Etch_Depth	PR_Etch_Depth	Etch_Time	SF6_Flow	O2_Flow	Pressure	ICP_Power	Etch_Rate
BCB Etch Test 2	2.55	3.542	3.0	5.0	45.0	3.0	300.0	0.85
BCB Etch Test 5	2.40	2.162	3.0	37.5	12.5	3.0	300.0	0.80
BCB Etch Test 3	2.22	2.775	3.0	15.0	35.0	3.0	300.0	0.74
BCB Etch Test 4	1.95	2.786	3.0	25.0	25.0	3.0	300.0	0.65
BCB Etch Test 6	1.80	1.525	3.0	50.0	0.0	3.0	300.0	0.60
BCB Etch Test 1	0.42	3.231	3.0	0.0	50.0	3.0	300.0	0.14

Visualizing the data¶

Lastly, let's create a plot of our etch rate vs. SF₆ Flow to try and visualize any trends:

In [11]:

```
metadata_300ICP_3mT.plot(x='SF6_Flow', y='Etch_Rate')    #Plot the metadata according to the provided x and y
plt.show()
```



This is just a short example of how Jupyter 4CeeD integration, using pandas DataFrames, can allow rapid and consistent analysis of measured experiment data. For further functionality:

See pandas DataFrame Reference (<https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.html>) for other built in functions available for the metadata¶

Analyzing Our Data: Your Turn¶

Think of some other important quantity that can be calculated from the provided data to give further insight. Using the examples above and the DataFrame reference:

- **Create this quantity and add it to the metadata.**
- **Create a visualization of this quantity versus some relevant parameter.**

Remember to filter your data to avoid capturing effects of other parameter changes.

In [12]:

```
#Add new quantity here:
```

In [13]:

```
#Create visualization here:
```

Saving Our Analysis:¶

Finally, after gathering valuable information from our experiment, we need to save this data. Thankfully 4CeeD has a built in function that can capture this entire document:

(Note: Make sure to include the current file name and to save before saving)

In [14]:

```
py4ceed.save_notebook('MSE598JupyterDemo', save_as='MSE598sp21-Demo')    #Saves a snapshot of this notebook to your 4CeeD
```

```
<Response [200]>  
Done submitting Notebook
```