raport

December 7, 2022

[ ]:
```
%matplotlib widget
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from matplotlib import cm
import seaborn as sns

import numpy as np
import pandas as pd

import uncertainties
from uncertainties import ufloat
from uncertainties.umath import *
from IPython.display import display, Math, Latex
```

1 Sonda Kelvina

[ ]:
```
df_CPD_Au = pd.read_csv("Wyniki pomiarow CPD dla Au.dat", skipfooter=31,␣
 ↪usecols=range(10), engine='python')
df_CPD_X1 = pd.read_csv("Wyniki pomiarow CPD dla probki X1.dat", skipfooter=31,␣
 ↪usecols=range(10), engine='python')
df_CPD_X2 = pd.read_csv("Wyniki pomiarow CPD dla probki X2.dat", skipfooter=31,␣
 ↪usecols=range(10), engine='python')
df_CPD_X2
```

[ ]:

	Point	WF (mV)	WFRA (mV)	WFDel (mV)	Std WF	GD (au)	Std GD	\
0	0	-514.9	-514.9	0.0	0.0	299.6	0.0	
1	1	-517.6	-516.3	-2.7	0.0	299.8	0.0	
2	2	-518.9	-516.7	-3.9	0.0	300.0	0.0	
3	3	-510.3	-515.6	4.6	2.0	299.9	0.2	
4	4	-514.3	-514.5	0.6	3.8	299.6	0.2	
…	…	…	…	…	…	…	…	
1496	1496	-517.2	-517.1	-2.3	2.9	294.5	1.5	
1497	1497	-517.0	-517.1	-2.1	2.9	294.4	1.5	
1498	1498	-510.5	-514.9	4.5	2.9	294.6	1.5	
1499	1499	-515.1	-514.2	-0.2	2.9	294.3	1.5	
1500	1500	-510.8	-512.1	4.1	2.9	294.4	1.5	

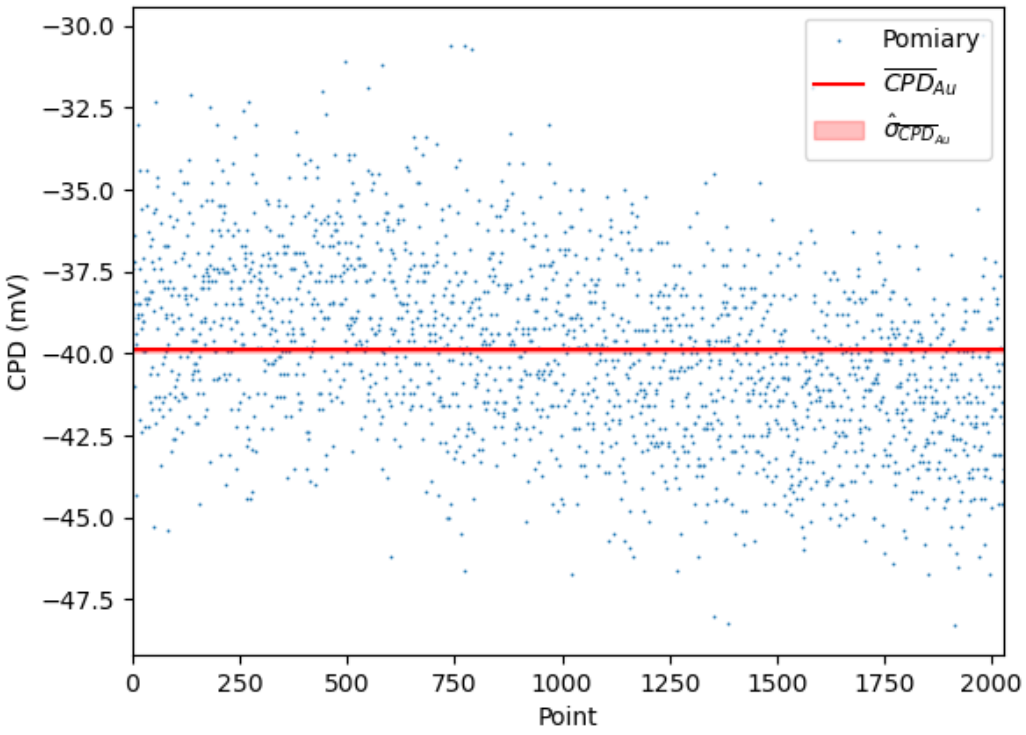
```
      Z Height (um)  User  Time(Secs)
0               0.0   1.6       0.000
1               0.0   1.4       0.561
2               0.0   1.4       1.139
3               0.0   0.9       1.685
4               0.0   1.2       2.246
…                 …   …           …
1496            0.0   0.5     863.803
1497            0.0   1.3     864.411
1498            0.0   1.4     865.004
1499            0.0   1.3     865.581
1500            0.0   0.3     866.190

[1501 rows x 10 columns]
```

[ ]:
```
CPD_Au = ufloat(df_CPD_Au['CPD (mV)'].mean(), df_CPD_Au['CPD (mV)'].sem()) # mV
CPD_X1 = ufloat(df_CPD_X1['WF (mV)'].mean(), df_CPD_X1['WF (mV)'].sem()) # mV
CPD_X2 = ufloat(df_CPD_X2['WF (mV)'].mean(), df_CPD_X2['WF (mV)'].sem()) # mV

graph = sns.scatterplot(x="Point", y="CPD (mV)", data=df_CPD_Au, s=2,␣
 ↪label="Pomiary")
graph.axhline(CPD_Au.n, color='r', linestyle='-',␣
 ↪label='$\overline{CPD}_{Au}$')
graph.fill_between(df_CPD_Au["Point"], CPD_Au.n-CPD_Au.s, CPD_Au.n+CPD_Au.s,␣
 ↪color='r', alpha=0.25, label='$\hat{\sigma}_{\overline{CPD}_{Au}}$')
graph.set_xlim(df_CPD_Au["Point"].min(), df_CPD_Au["Point"].max())
graph.legend()

display(Latex(f"$\overline{{CPD}}_{{Au}} =$ {CPD_Au:.2uP} mV"))
display(Latex(f"$\overline{{CPD}}_{{X1}} =$ {CPD_X1:.2uP} mV"))
display(Latex(f"$\overline{{CPD}}_{{X2}} =$ {CPD_X2:.2uP} mV"))
```

$\overline{CPD}_{Au}$ = -39.886±0.060 mV

$\overline{CPD}_{X1}$ = -284.412±0.071 mV

$\overline{CPD}_{X2}$ = -515.152±0.075 mV



[ ]:
```
WF_Au = ufloat(4800, 3) # meV
# e = 1.602176634e-19 # C
e = 1 # e
WF_tip = WF_Au + 1*e * CPD_Au
WF_X1 = WF_tip + 1*e * CPD_X1
WF_X2 = WF_tip + 1*e * CPD_X2


display(Latex(f"$WF_{{{tip}}} =$ {WF_tip:.2uP} meV"))
display(Latex(f"$WF_{{{X1}}} =$ {WF_X1:.2uP} meV"))
display(Latex(f"$WF_{{{X2}}} =$ {WF_X2:.2uP} meV"))
```

$WF_{tip} = 4760.1 \pm 3.0$ meV

$WF_{X1} = 4475.7 \pm 3.0$ meV

$WF_{X2} = 4245.0 \pm 3.0$ meV

Zaokrąglanie liczb i niepewności zgodnie z wytycznymi Particle Data Group https://pdg.lbl.gov/2010/reviews/rpp2010-rev-rpp-intro.pdf

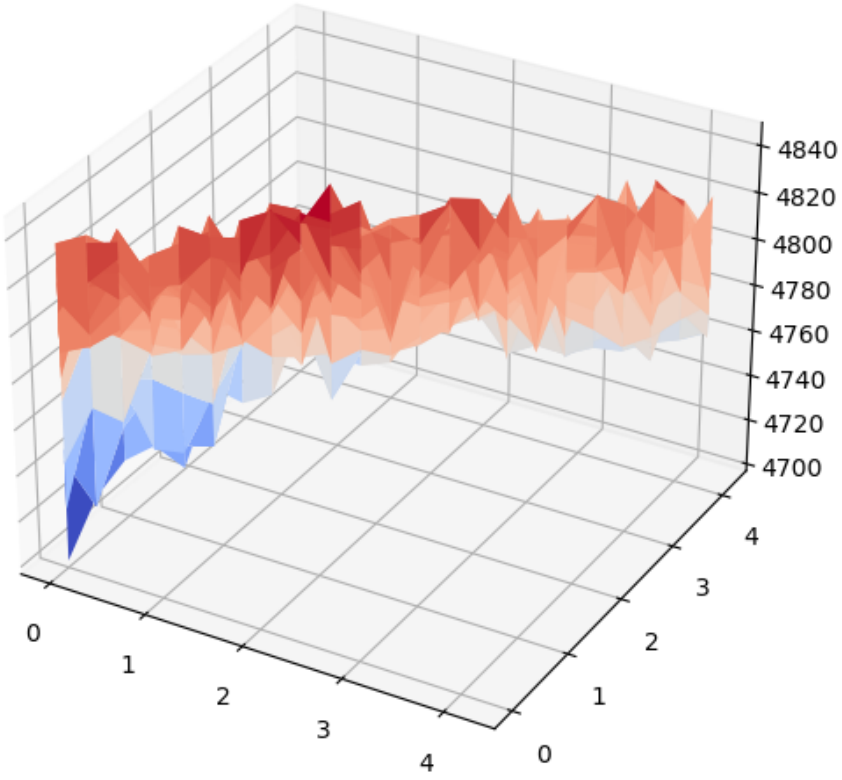
1.1 Topografie

[ ]:
```
X = np.linspace(0, 4.19, 23)
Y = np.linspace(0, 4.19, 23)

fname = "Topografia CPD dla Au.dat"
topo_Au = dict()
topo_Au["work"] = np.genfromtxt(fname, skip_header=1, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
topo_Au["tracking"] = np.genfromtxt(fname, skip_header=25, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
topo_Au["grad"] = np.genfromtxt(fname, skip_header=49, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
topo_Au["time"] = np.genfromtxt(fname, skip_header=73, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))

topo_Au["WF"] = WF_tip.n + 1*e * topo_Au["work"]
print(topo_Au["WF"].mean())

# fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
fig = plt.figure()
ax = Axes3D(fig)
ax.plot_surface(X, Y, topo_Au["WF"], cmap=cm.coolwarm)
# surf = ax.plot_surface(X, Y, topo_Au["WF"], cmap=cm.coolwarm)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# plt.show()

# axes3d.Axes3D(X, Y, topo_Au["WF"])
```

```
4798.304668786527
```

```
/tmp/ipykernel_2183/1280536295.py:16: MatplotlibDeprecationWarning: Axes3D(fig)
adding itself to the figure is deprecated since 3.4. Pass the keyword argument
auto_add_to_figure=False and use fig.add_axes(ax) to suppress this warning. The
default value of auto_add_to_figure will change to False in mpl3.5 and True
values will no longer work in 3.6.  This is consistent with other Axes classes.
  ax = Axes3D(fig)
```

[ ]:
```
<mpl_toolkits.mplot3d.art3d.Poly3DCollection at 0x7fe07354ed90>
```



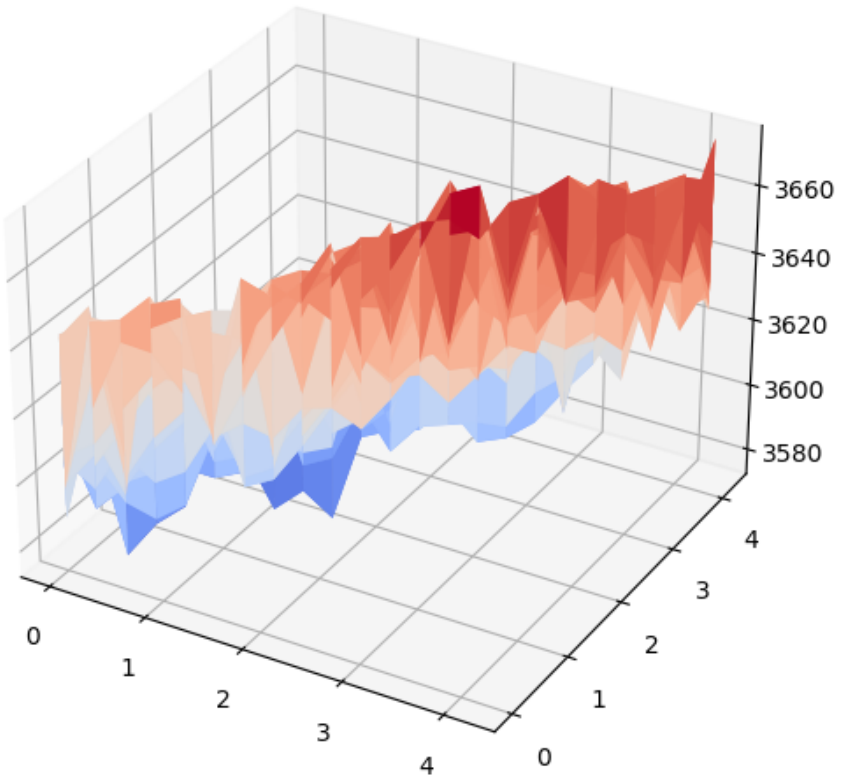
[ ]:
```
X = np.linspace(0, 4.19, 23)
Y = np.linspace(0, 4.19, 23)

topo_Al = dict()
fname = "Topografia CPD dla Al.dat"
topo_Al["work"] = np.genfromtxt(fname, skip_header=1, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
# topo_Al["tracking"] = np.genfromtxt(fname, skip_header=25, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
# topo_Al["grad"] = np.genfromtxt(fname, skip_header=49, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))
# topo_Al["time"] = np.genfromtxt(fname, skip_header=73, max_rows=23,␣
 ↪delimiter=',', usecols=range(23))

topo_Al["WF"] = WF_tip.n + 1*e * topo_Al["work"]
print(topo_Al["WF"].mean())

# fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
fig = plt.figure()
ax = Axes3D(fig)
```

```
ax.plot_surface(X, Y, topo_Al["WF"], cmap=cm.coolwarm)
# surf = ax.plot_surface(X, Y, topo_Au["WF"], cmap=cm.coolwarm)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# plt.show()

# axes3d.Axes3D(X, Y, topo_Au["WF"])
```

```
3629.4600563101567
```

```
/tmp/ipykernel_2183/96360438.py:16: MatplotlibDeprecationWarning: Axes3D(fig)
adding itself to the figure is deprecated since 3.4. Pass the keyword argument
auto_add_to_figure=False and use fig.add_axes(ax) to suppress this warning. The
default value of auto_add_to_figure will change to False in mpl3.5 and True
values will no longer work in 3.6.  This is consistent with other Axes classes.
  ax = Axes3D(fig)
```

[ ]:
```
<mpl_toolkits.mplot3d.art3d.Poly3DCollection at 0x7fe073612eb0>
```



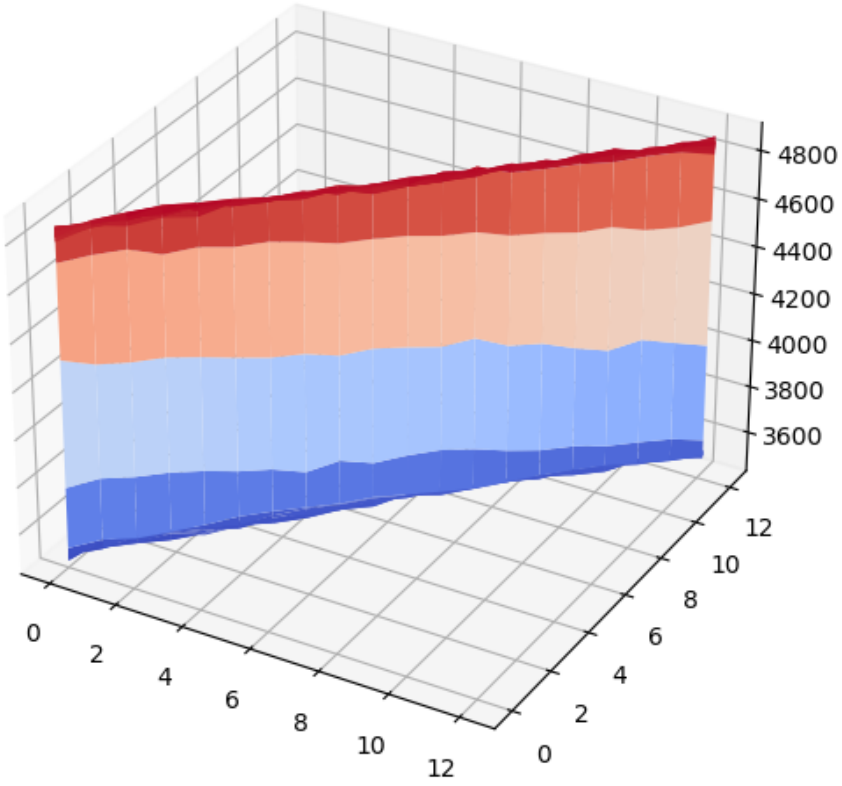
[ ]:
```
X = np.linspace(0, 12.1, 20) # mm
Y = np.linspace(0, 12.1, 20)
```

```
topo_Au_Al = dict()
fname = "Topografia CPD dla probki Au-Al.dat"
topo_Au_Al["work"] = np.genfromtxt(fname, skip_header=1, max_rows=20,␣
 ↪delimiter=',', usecols=range(20))


topo_Au_Al["WF"] = WF_tip.n + 1*e * topo_Au_Al["work"]
print(topo_Au_Al["WF"].mean())

# fig, ax = plt.subplots(subplot_kw={"projection": "3d"})
fig = plt.figure()
ax = Axes3D(fig)
ax.plot_surface(X, Y, topo_Au_Al["WF"], cmap=cm.coolwarm)
# surf = ax.plot_surface(X, Y, topo_Au["WF"], cmap=cm.coolwarm)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# fig.colorbar(surf, shrink=0.5, aspect=5)
# plt.show()

# axes3d.Axes3D(X, Y, topo_Au["WF"])
```

```
4218.622053474618
```

```
/tmp/ipykernel_2183/3668958641.py:14: MatplotlibDeprecationWarning: Axes3D(fig)
adding itself to the figure is deprecated since 3.4. Pass the keyword argument
auto_add_to_figure=False and use fig.add_axes(ax) to suppress this warning. The
default value of auto_add_to_figure will change to False in mpl3.5 and True
values will no longer work in 3.6.  This is consistent with other Axes classes.
  ax = Axes3D(fig)
```

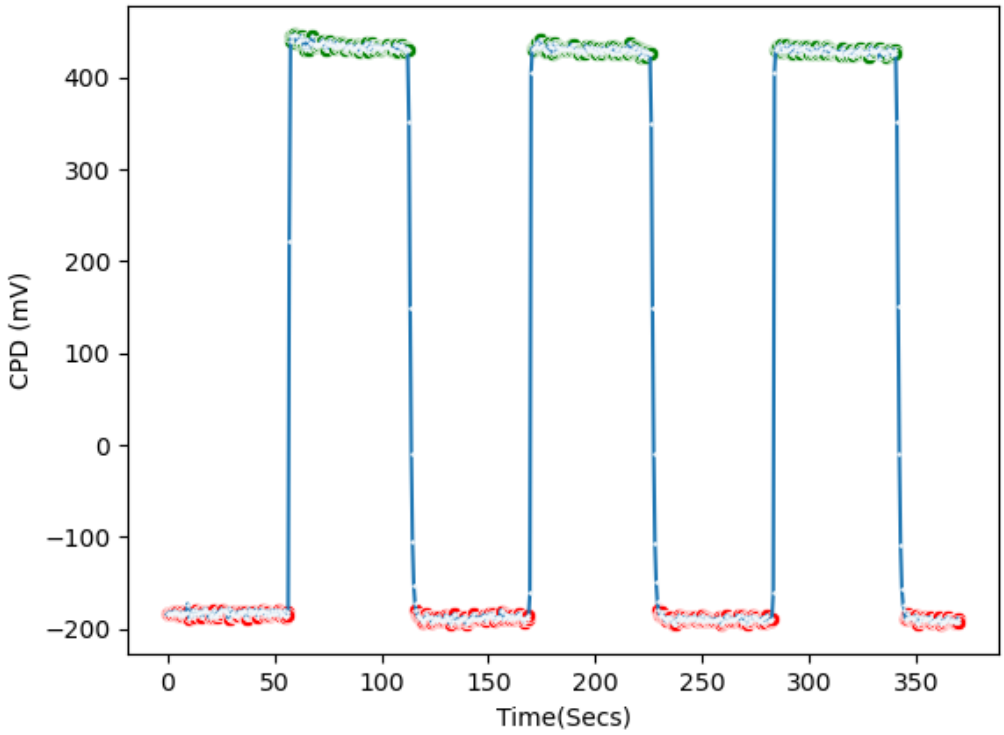
[ ]:
```
<mpl_toolkits.mplot3d.art3d.Poly3DCollection at 0x7fe0733e9790>
```



1.2 Napięcie rozwarcia V_{OC} ogniwa Si

[ ]:
```
df_CPD_Si = pd.read_csv("CPD dla ogniwa mono Si - pomiar ze swiatlem i bez.
 ↪dat", skipfooter=31, usecols=range(10), engine='python')

fig = plt.figure()
sns.lineplot(x="Time(Secs)", y="WF (mV)", data=df_CPD_Si, marker='o',␣
 ↪markersize=1)
sns.scatterplot(x="Time(Secs)", y="WF (mV)", data=df_CPD_Si[df_CPD_Si["WF␣
 ↪(mV)"] < -180], marker='o', sizes=10, color='red')
sns.scatterplot(x="Time(Secs)", y="WF (mV)", data=df_CPD_Si[df_CPD_Si["WF␣
 ↪(mV)"] > 420], marker='o', sizes=10, color='green')
plt.ylabel("CPD (mV)")
plt.show()


V_CPD_d = df_CPD_Si[df_CPD_Si["WF (mV)"] < -180]["WF (mV)"]
V_CPD_il = df_CPD_Si[df_CPD_Si["WF (mV)"] > 420]["WF (mV)"]

V_d = ufloat(V_CPD_d.mean(), V_CPD_d.sem())
```

```
V_il = ufloat(V_CPD_il.mean(), V_CPD_il.sem())
V_OC = V_il - V_d
display(Latex(f"$V_{{OC}} =$ {V_OC:.2uP} meV"))
```

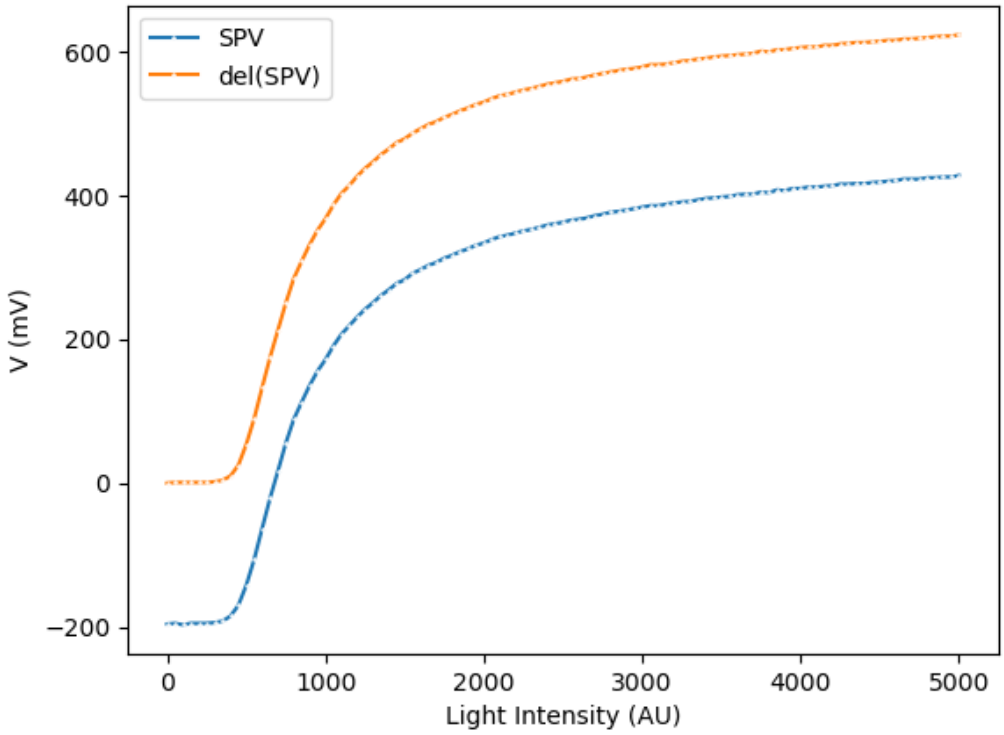


$V_{OC} = 618.98 \pm 0.32$ meV

1.3 SPV (surface photovoltage) ogniwa Si

[ ]:
```
df_SPV = pd.read_csv("SPV dla ogniwa mono-Si.dat.DAT", names=["Point", "INT␣
↪(AU)", "SPV (mV)", "del(SPV) mV"], engine='python', delimiter=",",␣
↪skiprows=1)
df_SPV
fig = plt.figure()
sns.lineplot(x="INT (AU)", y="SPV (mV)", data=df_SPV, marker='o', markersize=1,␣
↪label="SPV")
sns.lineplot(x="INT (AU)", y="del(SPV) mV", data=df_SPV, marker='o',␣
↪markersize=1, label="del(SPV)")
plt.xlabel("Light Intensity (AU)")
plt.ylabel("V (mV)")
```

```
plt.show()
```


SPV
del(SPV)
600
400
200
0
−200
V (mV)
0
1000
2000
3000
4000
5000
Light Intensity (AU)