Method #2: Calibration file creation

Video: Method #2 (Calibration file creation)

In Method #1 a design folder was created and used to generate an exposure stream file for the FEBID of a simple pillar and segment. A calibration curve can be created by repeating this process in order to create a set of design folders that span the full range of segment angles (ζ = 0º–90º). Table 1 shows a list of design folders (column 1) along with the segment angles defined (column 2) for the segment element in each file (ζ_{CAD}).

FEBID CAD folder name *[string]*	ζ_{CAD} *[degrees]*	$\tau_{d,CAD}$ *[ms]*	**Exposure file name** *[string]*	ζ_{exp} *[degrees]*
FEBiD_CAD_Design_1934	15.0	4.573	*Segment_15p0.str*	23.7
FEBiD_CAD_Design_1935	17.5	4.827	*Segment_17p5.str*	25.1
FEBiD_CAD_Design_1936	20.0	5.085	*Segment_20p0.str*	30.4
FEBiD_CAD_Design_1937	22.5	5.338	*Segment_22p5.str*	35.8
FEBiD_CAD_Design_1938	27.5	5.885	*Segment_27p5.str*	39.1
FEBiD_CAD_Design_1939	32.5	6.981	*Segment_32p5.str*	39.6
FEBiD_CAD_Design_1940	37.5	8.315	*Segment_37p5.str*	47.4
FEBiD_CAD_Design_1941	50.0	11.18	*Segment_50p0.str*	51.8
FEBiD_CAD_Design_1942	60.0	16.76	*Segment_60p0.str*	64.2
FEBiD_CAD_Design_1943	70.0	30.147	*Segment_70p0.str*	73.5
FEBiD_CAD_Design_1944	80.0	77.014	*Segment_80p0.str*	80.7

Table1

The dwell times listed (column 3) were interpolated from the selected calibration curve during design except for the last point which was extrapolated [S7: Calibration data interpolation and extrapolation]. The calibration data used during design for this example was;

Pt_FEINovaNowIIb - Notepad

File Edit Format View Help

```
3.86    4.1
4.20    10.3
4.56    14.8
5.3     22.1
6.10    29.2
6.54    30.8
8.60    38.5
11.47   51.1
12.65   54.2
18.39   62.3
30.19   70.0
66.1    77.0
```

This method shows how to update the calibration curve in the case that it is no longer valid due to, e.g., changing experimental conditions.

The interpolated dwell times shown in Table 1 ($\tau_{D,CAD}$) are saved in the location \EBiD 3D (CAD)\FEBiD_CAD_Design_*number* as the comma delimited file FEBiD_3D_ExpFile.txt when an exposure file is created. Opening the file in Microsoft Excel gives;

	A	B	C	D	E	F	G	H	I	J	K	L
1	1	1	1	-200	0	0	-200	0	400	4.5	90	4.5
2	2	2	1	-200	0	400	146.4	0	599.99	7.7585	30	3.8792

Table 2

Each row in Table 2 describes the characteristics of an exposure element. Next, an exposure element is classified either as a pillar or a segment. The characteristics of each exposure element are organized in columns;

(A) Element index
(B) Exposure level of the element
(C) Element index within the exposure level
(D) x–coordinate for the vertex of index “i” [nm]
(E) y–coordinate for the vertex of index “i” [nm]
(F) z–coordinate for the vertex of index “i” [nm]
(G) x–coordinate for the vertex of index “f” [nm]
(H) y–coordinates for the vertex of index “f’ [nm]
(I) z–coordinate for the vertex of index “f” [nm]
(J) The specified dwell time for the exposure element [ms]
(K) Element angle with respect to the focal plane [deg]
(L) The actual dwell time used in the exposure file after applying the limit of a maximum dwell time. In this case, two exposures will be executed at the same pixel to accumulate the requested dwell time, i.e., 2 x 3.879 = 7.758 [ms].

The interpolated dwell times were gathered from position (J2) for each FEBiD_3D_ExpFile.txt file generated to populate the ($\tau_{D,CAD}$) column in Table 1. A new calibration file was prepared in anticipation of conducting the experiments as shown below.

NewCalibration - Notepad

File Edit Format View Help

```
4.57    0.0
4.83    0.0
5.08    0.0
5.34    0.0
5.88    0.0
6.98    0.0
8.31    0.0
11.18   0.0
16.76   0.0
30.15   0.0
77.01   0.0
```

Exposure stream files were created from each design folder. The names of the stream files are provided in Table 1 (column 4). The stream files were exposed using FEBID. The segment angles (in units of degrees) were then measured for each segment using secondary electron imaging and the new calibration file was populated with the results.

CalibFile2017 - Notepad

File Edit Format View Help

```
4.57    23.7
4.83    25.1
5.08    30.4
5.34    35.8
5.88    39.1
6.98    39.6
8.31    47.4
11.18   51.8
16.76   64.2
30.15   73.5
77.01   80.7
```

The measured values from experiments are also provided in the last column of Table 1 as (ζ_{exp}). Next, the parameters file must be generated;

CalibFile2017_Parameters - Notepad

File Edit Format View Help

```
Patterning format (FEI or NVPE)
FEI
Primary electron beam energy [keV]
30
Primary electron beam current [pA]
21
Primary electron beam size {FWHM} [nm]
4.1
Precursor gas type
Pt
Precursor temperature [C]
45
Precursor gas nozzle position {x} [um]
222
Precursor gas nozzle position {y} [um]
222
Precursor gas nozzle positions {z} [um]
50
Precursor gas nozzle angle [deg]
52
Substrate
5nmSiO2/Si
(Magnification)*(Horizontal field width [um])
128000
Patterning bit depth (12 or 16)
12
```

In preparation for uploading the calibration files into the FEBID CAD program I renamed the files;

(1) CalibFile2017.txt
(2) CalibFile2017_Parameters.txt

The calibration files were then moved to the directory \EBiD 3D (CAD)\FEBiD 3D CAD (Supporting Files).

Action #1: The program FEBiD_CAD_v9p0.m is executed from the Matlab Command Window. Select a Custom or Default design folder name. The main GUI will launch

Action #2: Select "new" from the "Calibration file" dropdown menu (figure 1a)

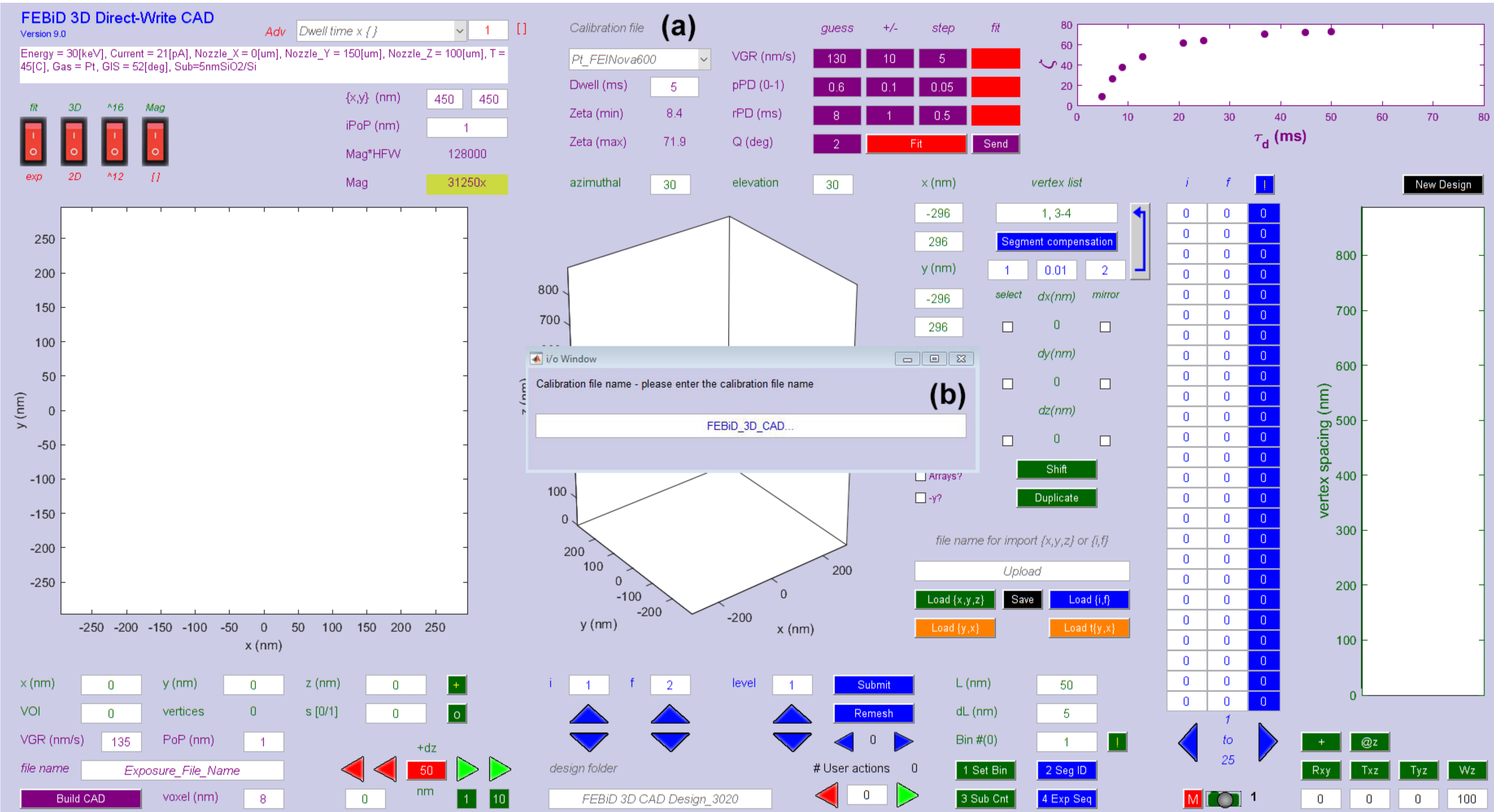
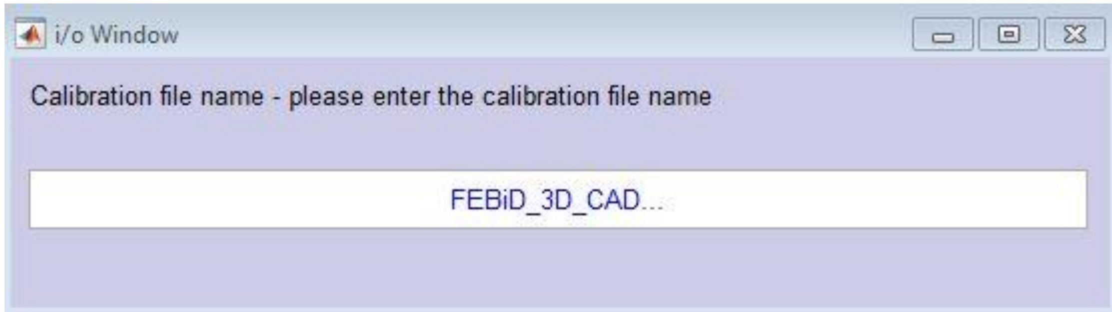


Figure 1

Selecting “new” launches a separate window which allows the User to type in the name of the new calibration file. This window is shown below.



Action #3: Type the calibration filename. In the video example “CalibFile2017” was entered (figure 1b).

The calibration data will appear in the dwell versus segment angle plot and the calibration file name will be indicated in the “Calibration file” drop down menu.