Fabrication of Micron-scale Electrodes for Periodic Poling in Nonlinear Optical Crystals

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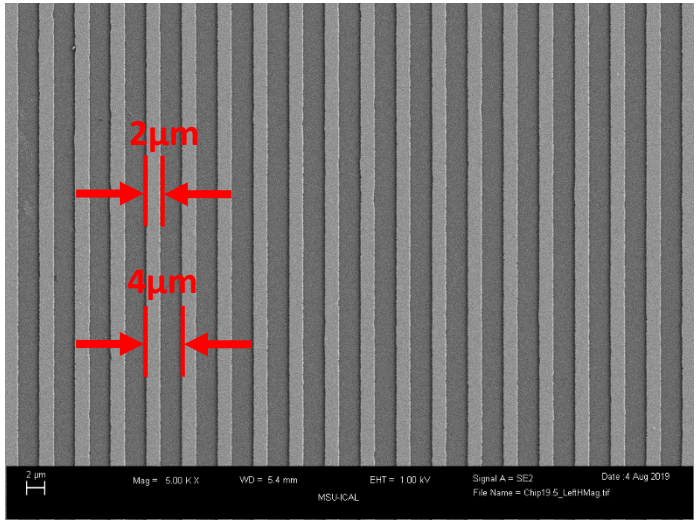
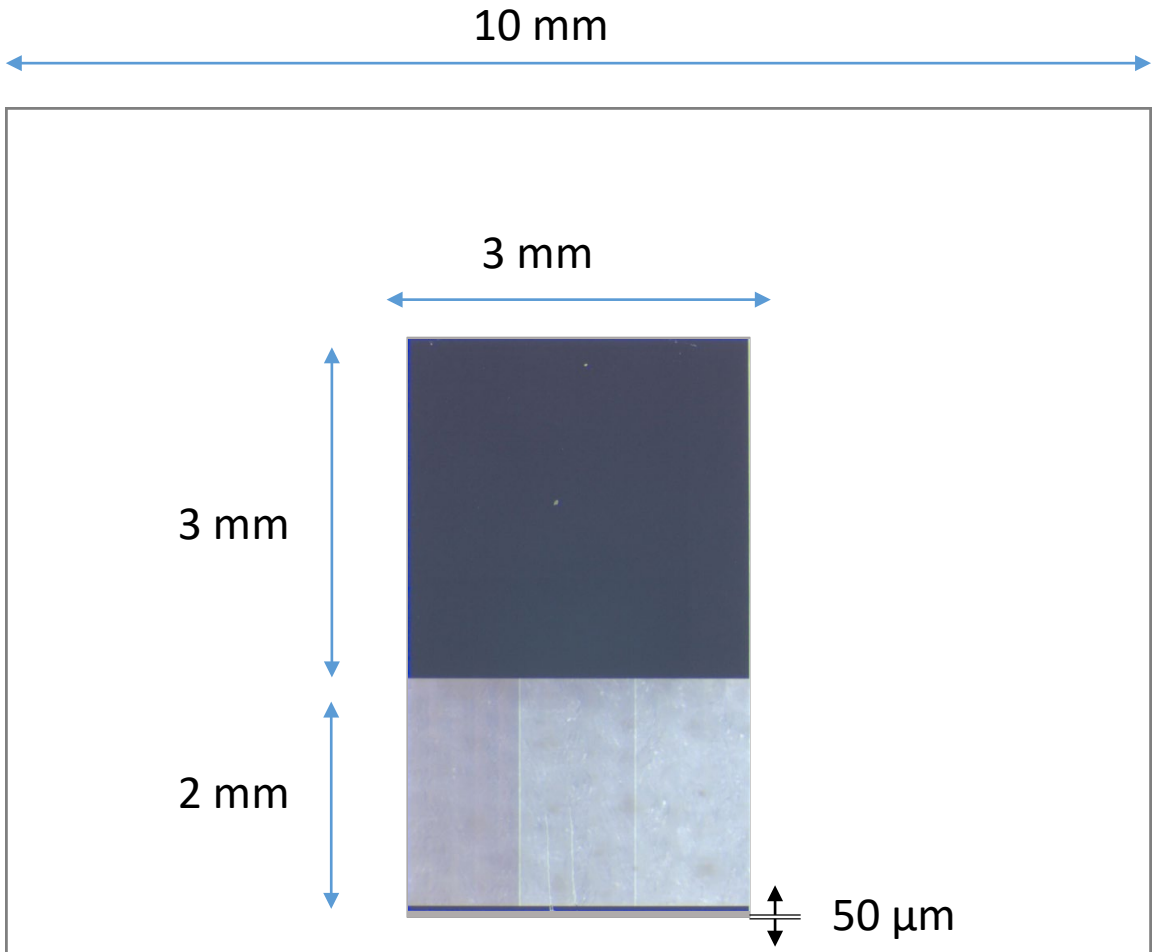
Introduction

- Periodically poled crystals are created by applying high voltages to patterned electrodes pressed into contact with the crystal
- The electrode patterns are made using photolithography and wet etching



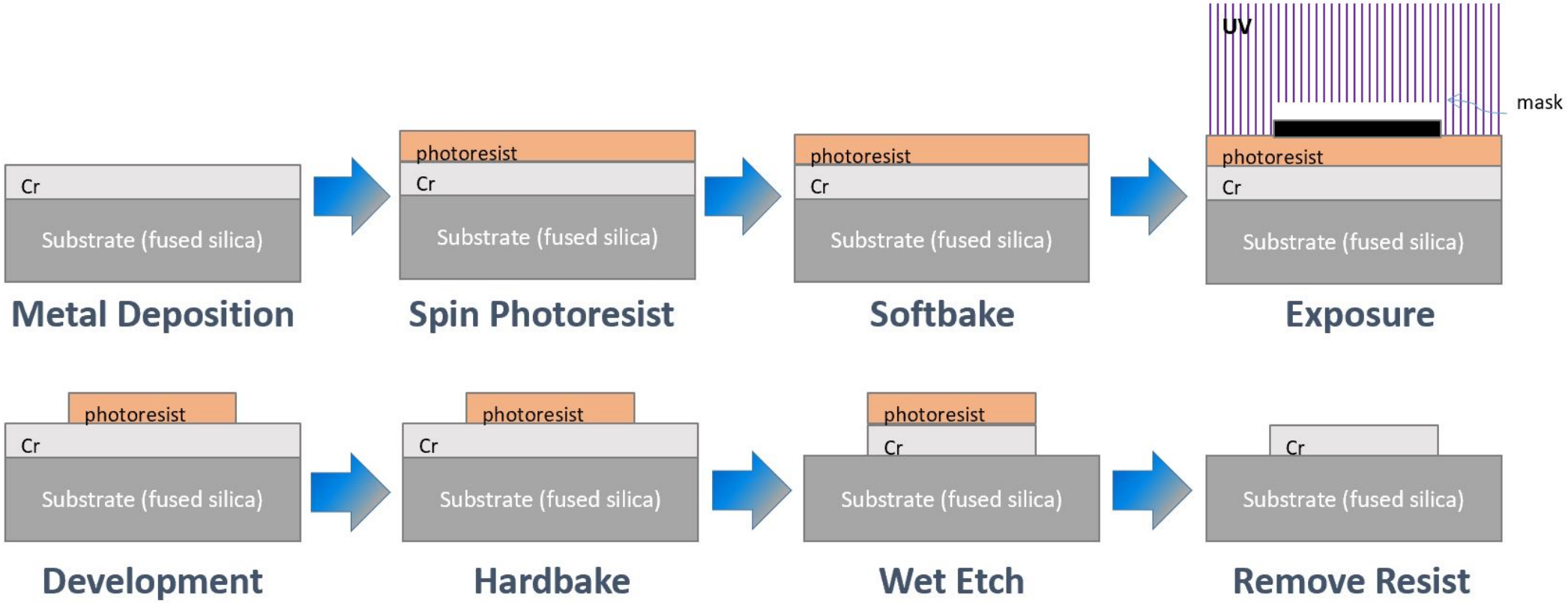
FE-SEM image of 2µm linewidth and 4µm period with 33.2 mJ/cm^2 exposure dose and 120 second development time.



Device pattern showing metal contact pad (top) and 2µm linewidth electrodes with 4µm (left), 6µm (middle), and 8µm (right) periods.

Note: variable line spacing is used in this device to aid in fabrication process optimization.

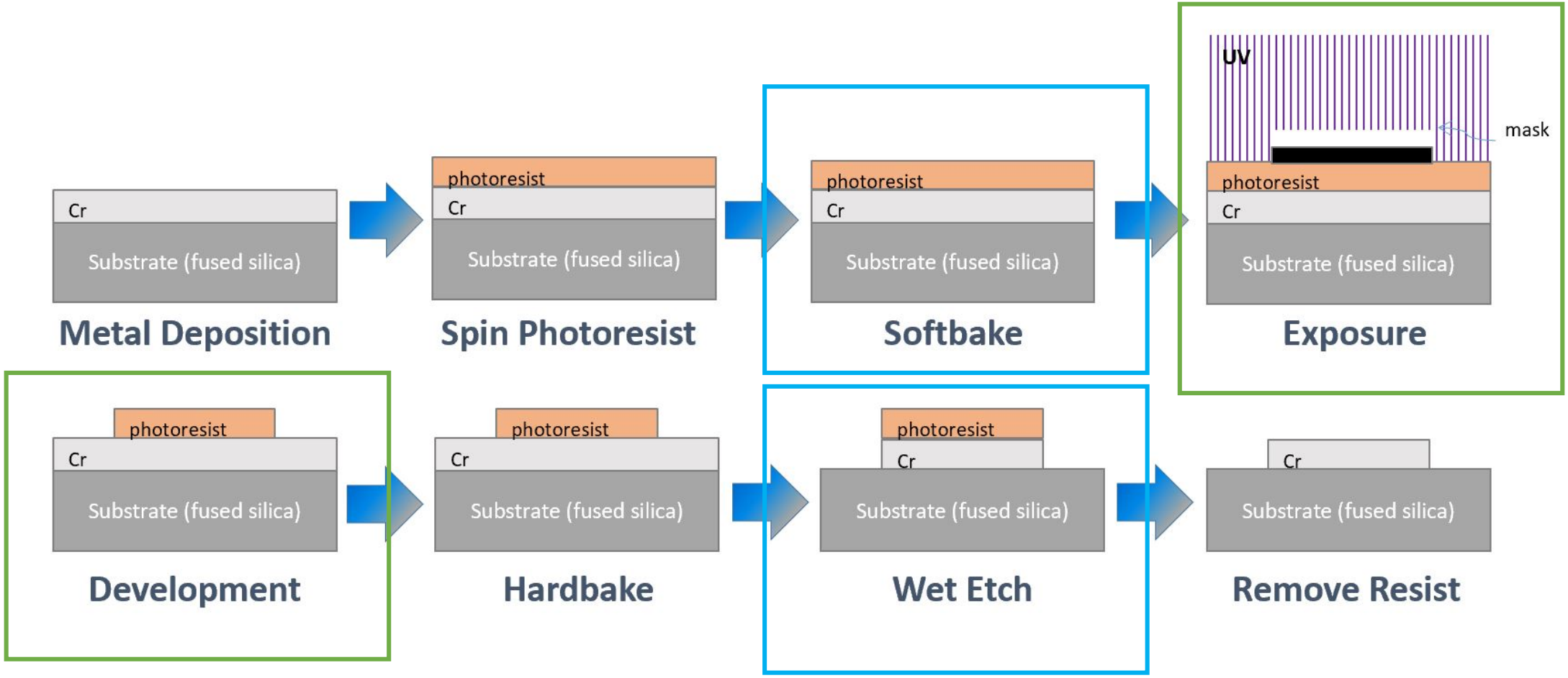
Microfabrication Process



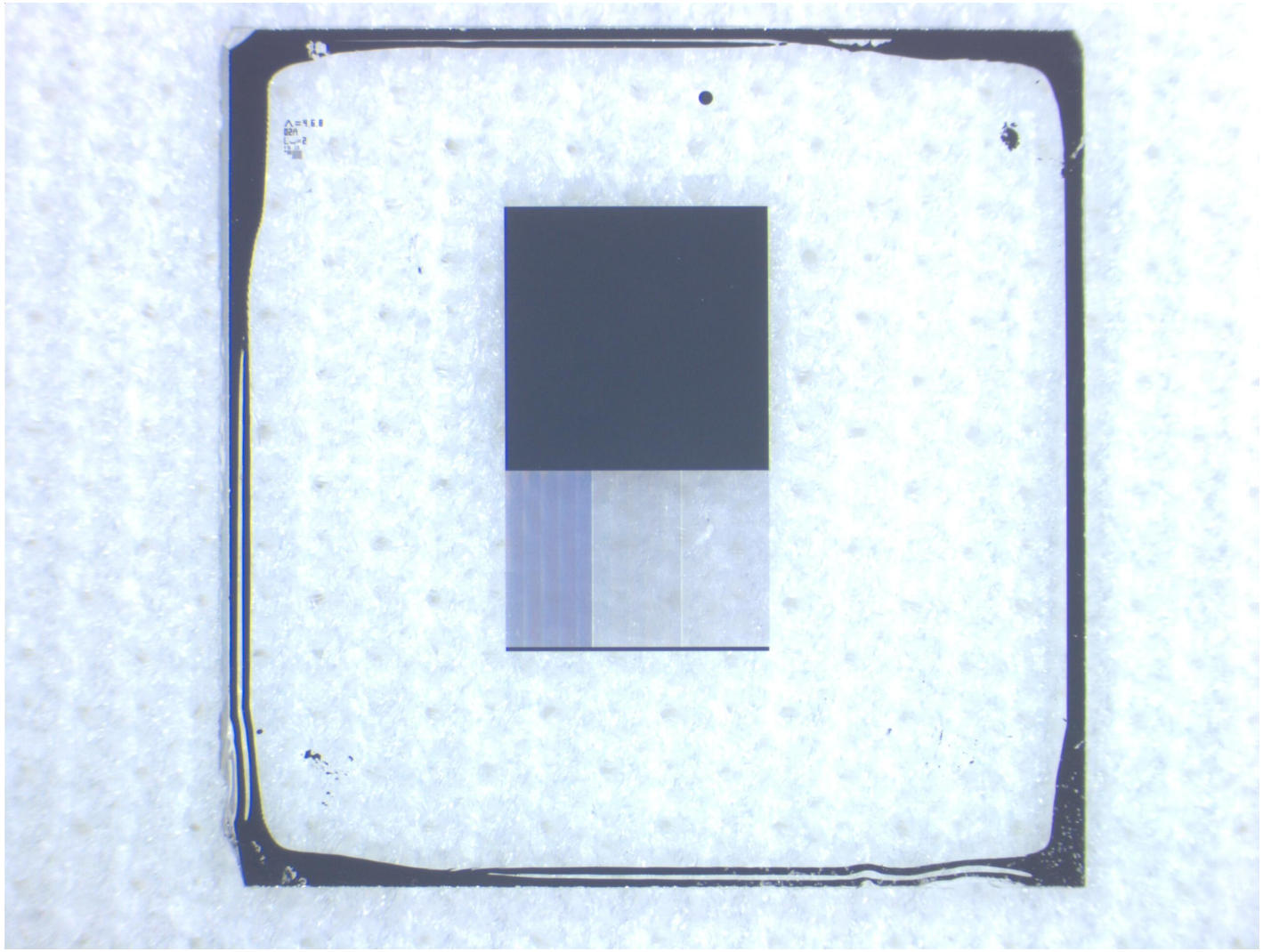
Goals for the REU

- Learn and understand the electrode fabrication process (photolithography)
- Train on equipment necessary to make fabrication possible
- Optimize the microfabrication process recipe in order to improve the electrode gratings
- Produce usable electrodes

Microfabrication Process

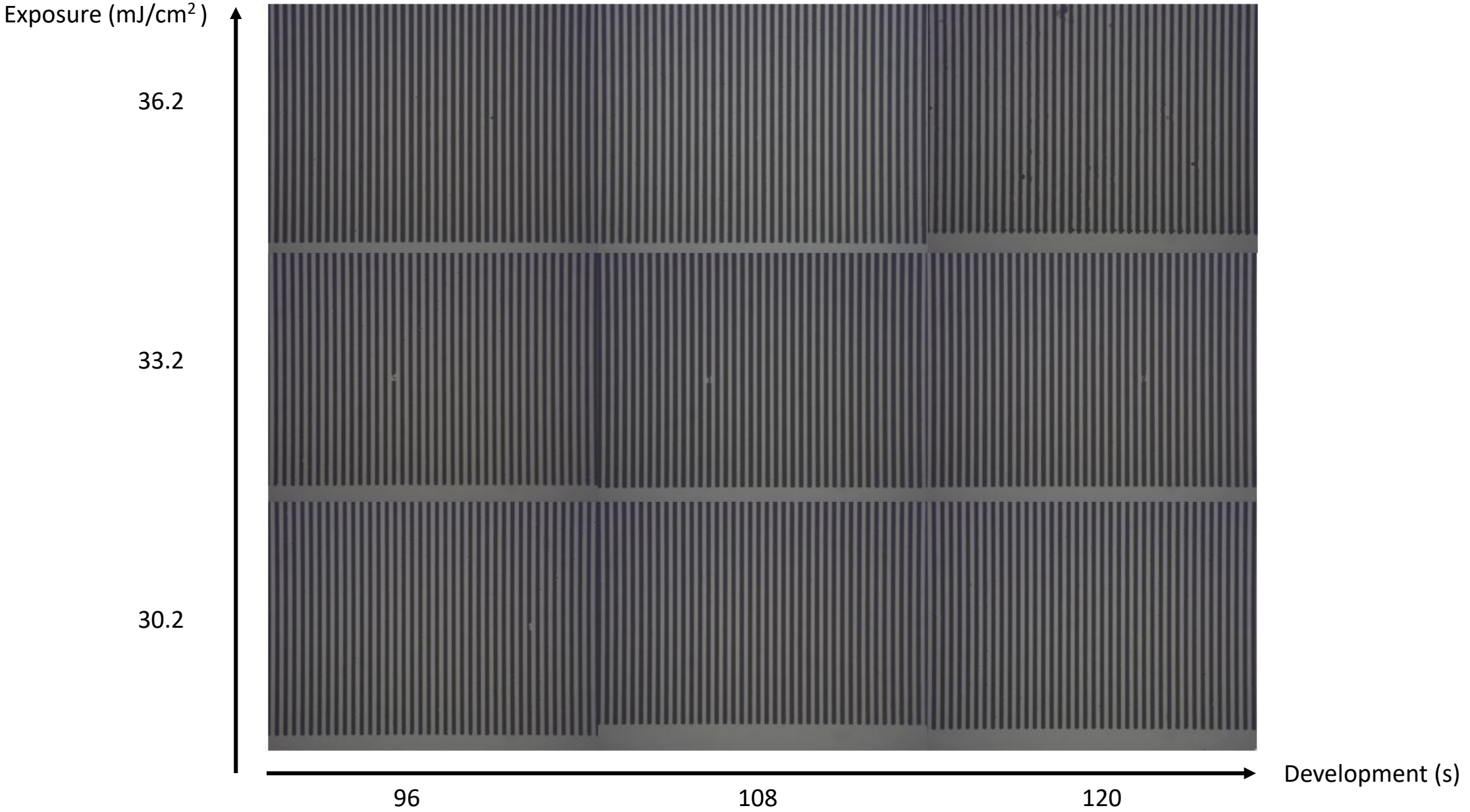


Micron-scale electrode



30.2 mJ/cm^2 exposure dose and 120 second development

Electrodes array with 4µm linewidths and 8µm period



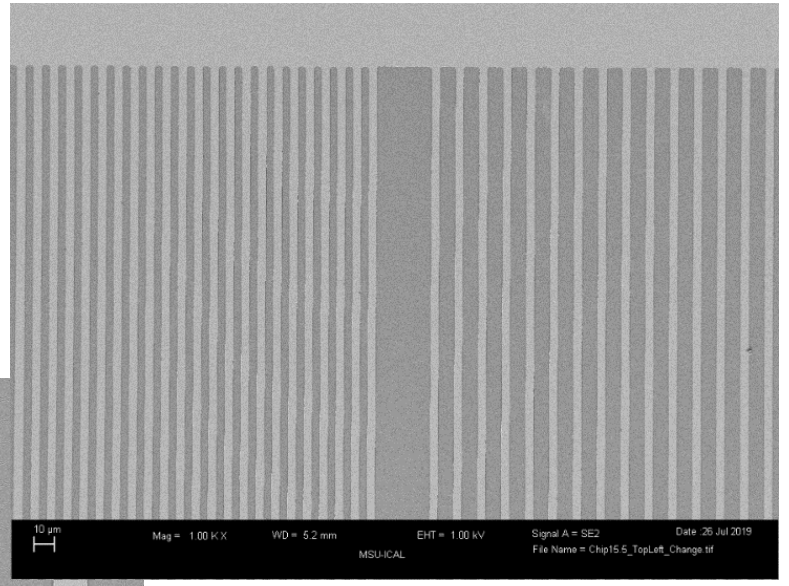
Results of 4 µm linewidth electrodes

- Fairly consistent 4µm linewidth reproducibility
- Fill factor varied by approximately 2.4% but is not clearly correlated to exposure dose and development time
- Feature sizes and quality are relatively stable when exposure dose and development time are varied by approximately ±10% from the central value (exposure dose: 33.2 mJ/cm^2 and development time: 108 seconds)

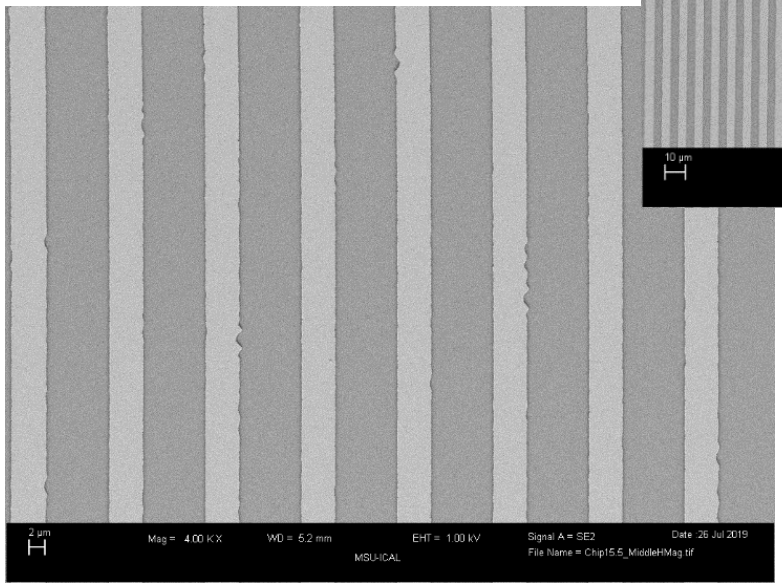
FE-SEM images of 4 µm linewidth electrodes

- Clear grooves
- Good connection to contact pad
- Some visible defects such as ‘mouse-bites’ are seen

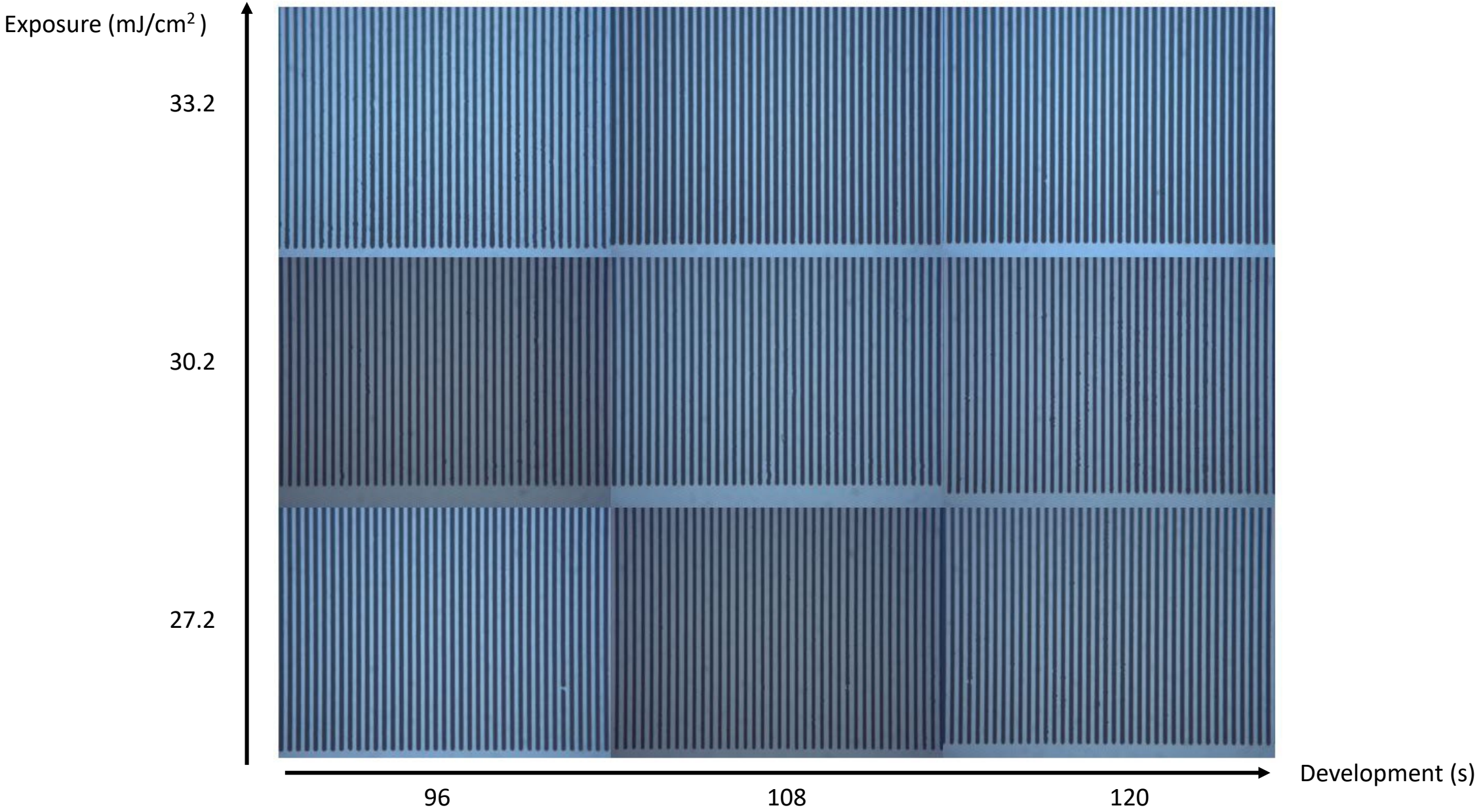
Electrodes with 4µm linewidths and periods of 8µm (left) and 12µm (right)



Samples were exposed at 33.2mJ/cm^2 and developed for 96 seconds



Electrodes array with 2µm linewidths and 4µm period



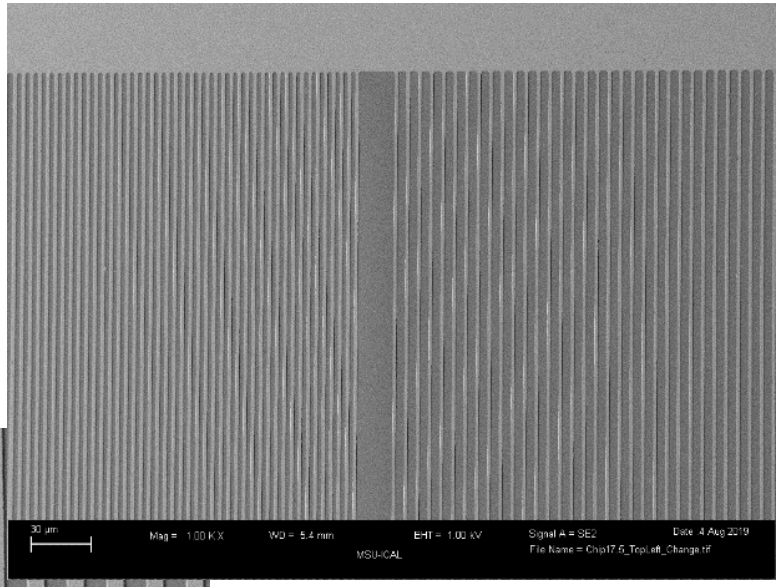
Results for 2 µm linewidth electrodes

- Optimized process parameters for 4µm linewidths transfer well to 2µm linewidth fabrication
- Fill factor varies by approximately 6.1%
  - not clearly correlated to exposure dose and development time
  - greater variability than 4µm linewidth chips

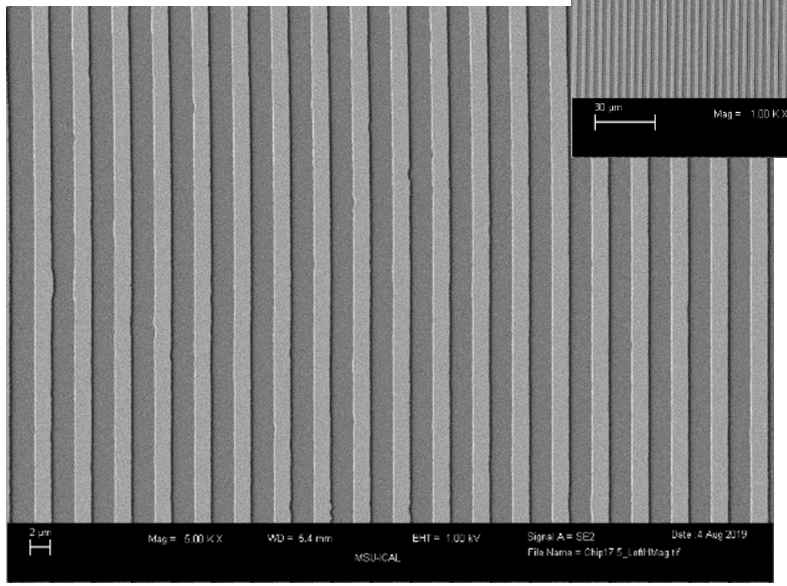
FE-SEM images of 2 µm linewidth electrodes

- Generally good metal connectivity between electrodes and contact pad
- Less instances of ‘mouse-bite’ defects after mask cleaning

Electrodes with 2µm linewidths and periods of 4µm (left) and 6µm (right)



Sample was exposed at 33.2mJ/cm^2 and developed for 108 seconds



Optimized Process Recipe

Cleaning

3 solvent clean: acetone, methanol, isopropanol

Spinning

4000 rpm at 500 r/s for 35 seconds on the Brewer CEE 100CB Spinner with positive AZ1512 Photoresist (produces resist layer thickness of 1.4µm)

Soft Bake

100°C for 84 seconds

Exposure

33.2 mJ/cm^2 on AB-M Contact Aligner

Development

108 seconds using AZ 300 MIF Developer

Hard Bake

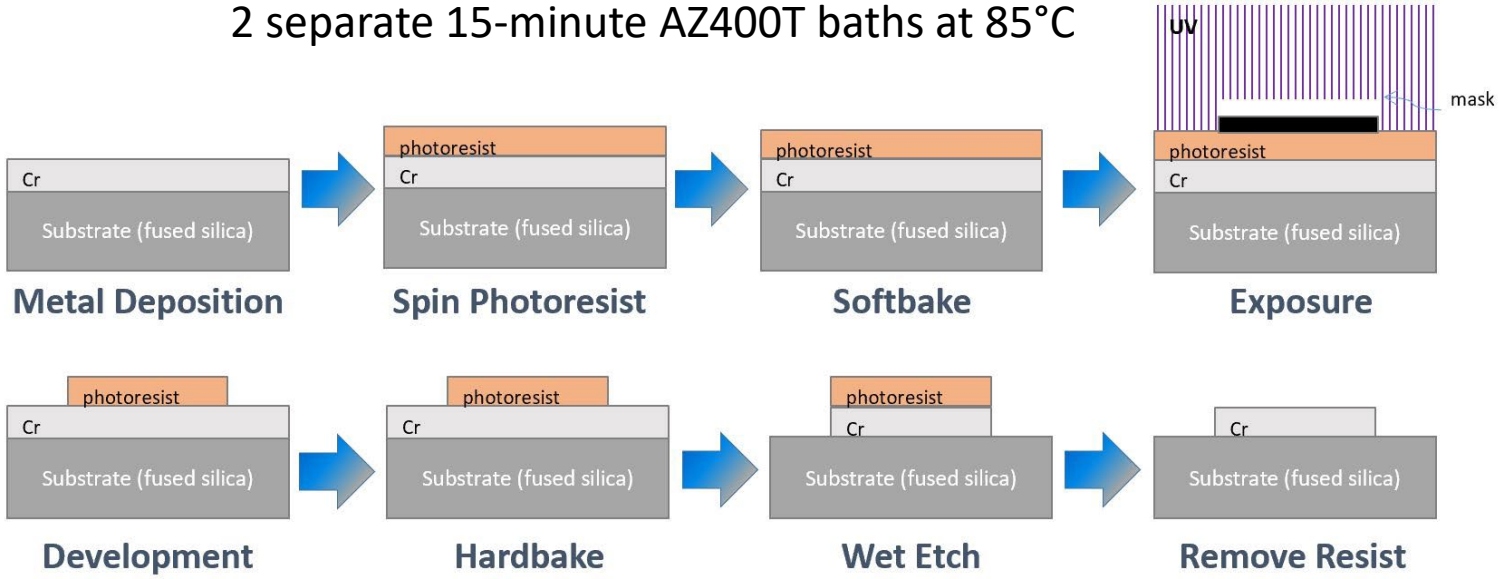
115°C for 5 minutes

Chromium Etch

1 minute 30 seconds with Chromium Etchant 1020

Resist Removal

2 separate 15-minute AZ400T baths at 85°C



Summary

- Optimized fabrication process recipe was developed for this family of electrodes
- Fabricated device characteristics were relatively unchanged with at least an approximate ±10% variation in exposure dose or development time
- FE-SEM pictures show fairly good quality electrodes, but some defects are observed
- Several test devices were fabricated for further characterization and testing

Future Work

- Investigate edge bead removal on chips to improve photomask contact
- Fabricate more chips with the same exposure dose and development time to check repeatability and uncontrolled variation in fill factor
- Standardize photomask cleaning procedure
- Make larger electrode patterns

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