Amorphous Carbon Hard Mask for Multiple Patterning Lithography

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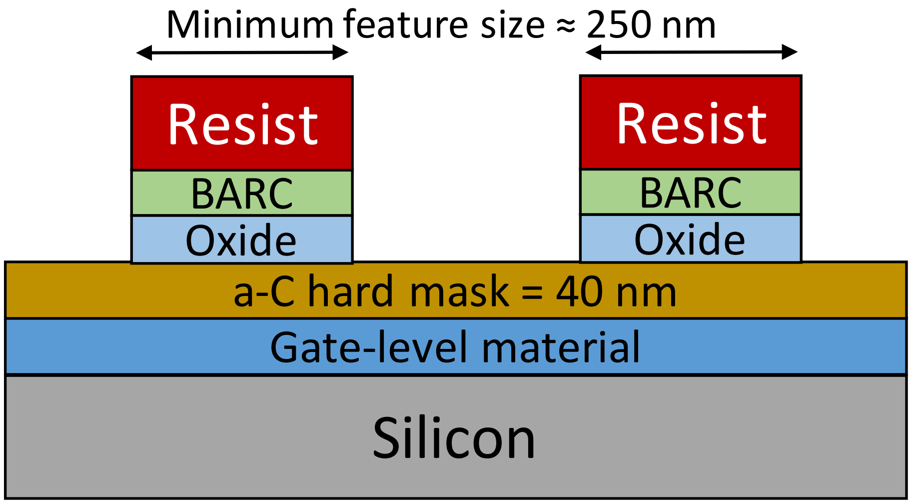
Outline

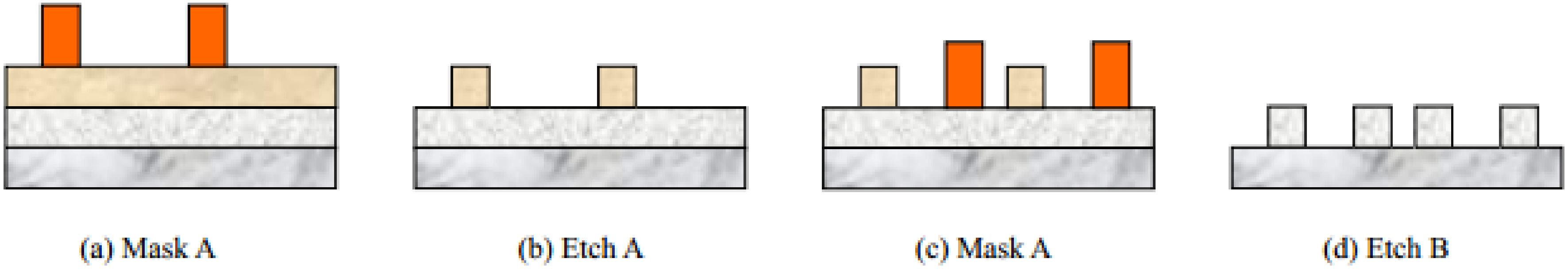
Amorphous Carbon Used as an Advanced Patterning Film (APF)

- Has been proven to be effective at eliminating stack reflectivity almost completely.
- Allows for “trimming” of exposed features.
- This has been highly researched for 193nm and 248nm wavelengths.



Double Patterning Lithography

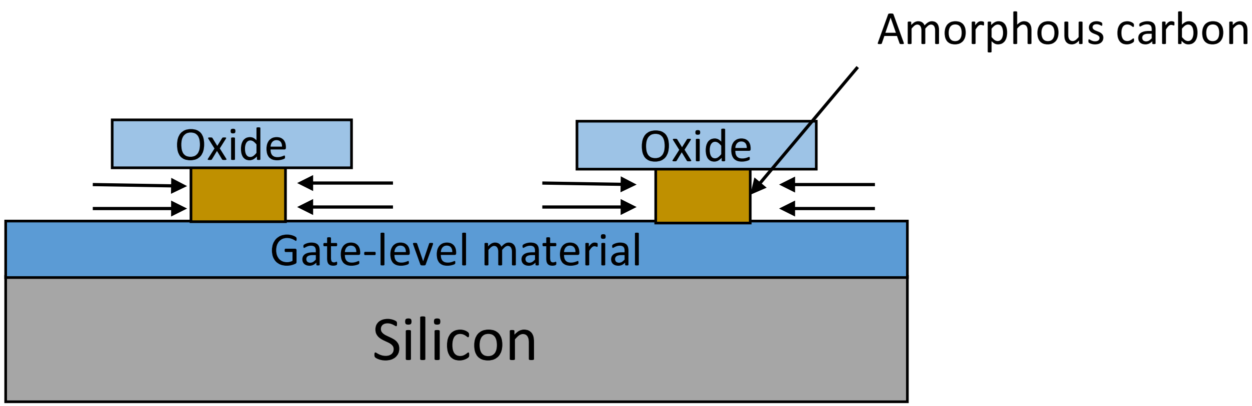
- Enables patterning of features below the lithographic limit.
- Can be performed multiple times to increase line density. (Multiple patterning lithography)



Double patterning lithography realized with positive acting resist. [1]

Double Patterning with Line Width Trimming

- Line-width trimming
  - Amorphous carbon, when combined with a capping layer, may be undercut in unexposed regions.
  - This allows for "trimming" of exposed features, enabling a smaller line-width than the photoresist defines.



Justification – Small Feature Sizes at RIT

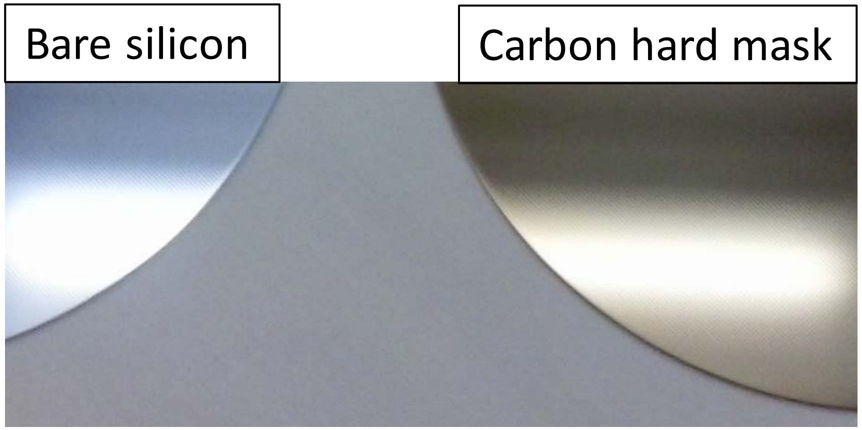
- Using the multiple patterning concept in conjunction with the carbon line-width trimming step allows for the following:
  - Narrow lines with high density.
  - Line widths approaching 100nm using the i-line (365nm) stepper.

Amorphous Carbon Film Deposition

- Drytek Quad Plasma (Etching?) tool
  - Capable of striking a plasma
  - Already plumbed with methane (carbon source)

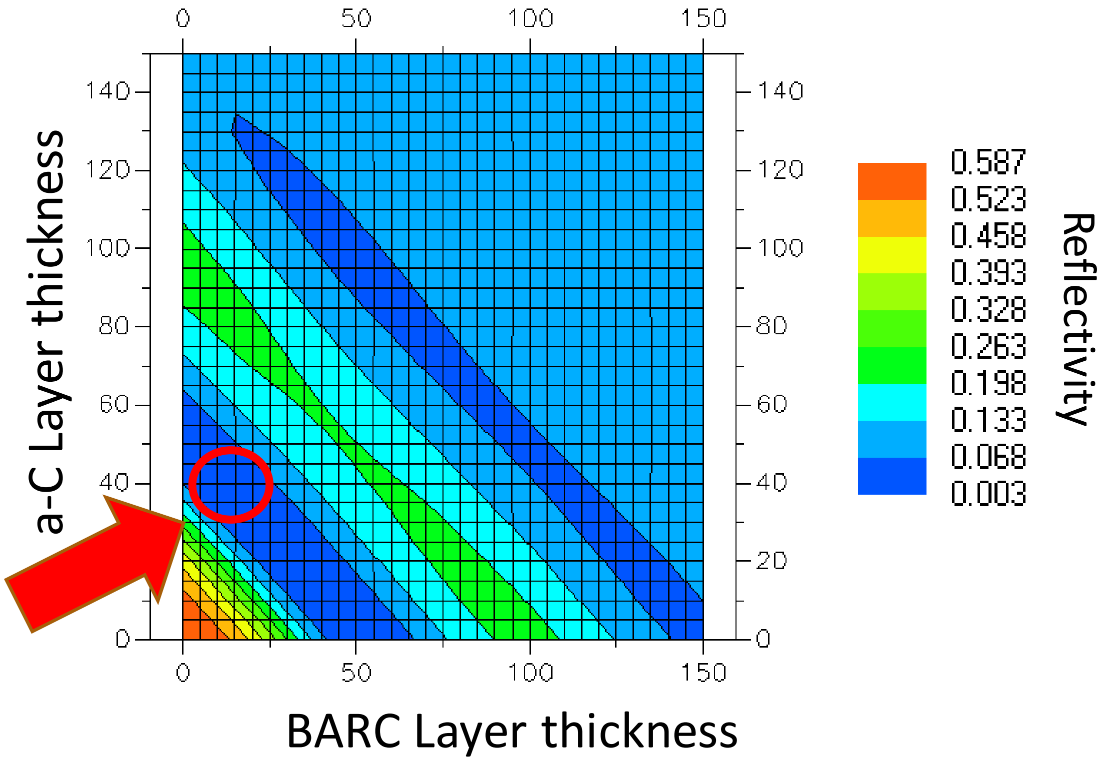
Basic Tool Configuration and Screening Experiment

- Setting up the tool for the experimental runs required checking the following parameters:
  - Power
  - Pressure
  - Flow Rates
  - Time (remains constant at 105 s)
- Comparison of bare silicon and amorphous carbon coated wafers
- Preliminary screening experiment shows ability to deposit carbon using the Drytek quad.
- Measured film with the VASE



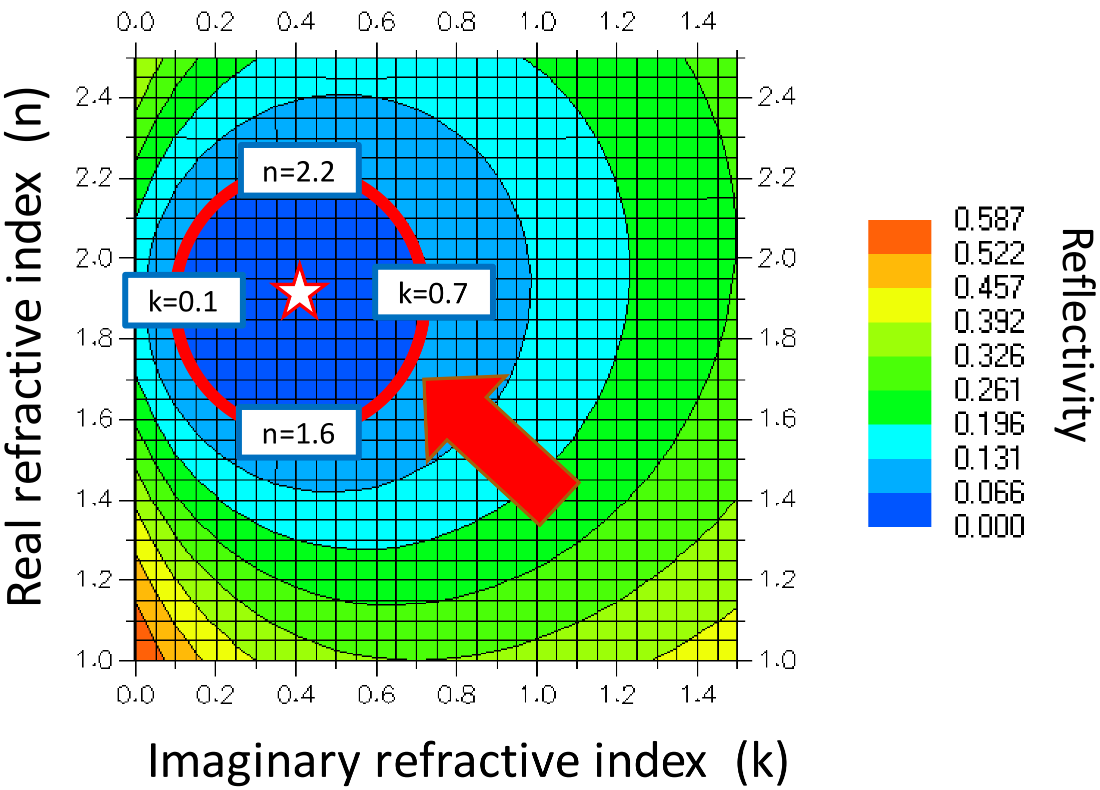
PROLITH Reflectivity Simulation

- Target thicknesses for amorphous carbon and BARC are shown by the red circle demonstrating the area of interest.
- This area of interest is chosen based on the lowest reflectivity (shown by the **dark blue** areas) which also allows for the most process latitude.



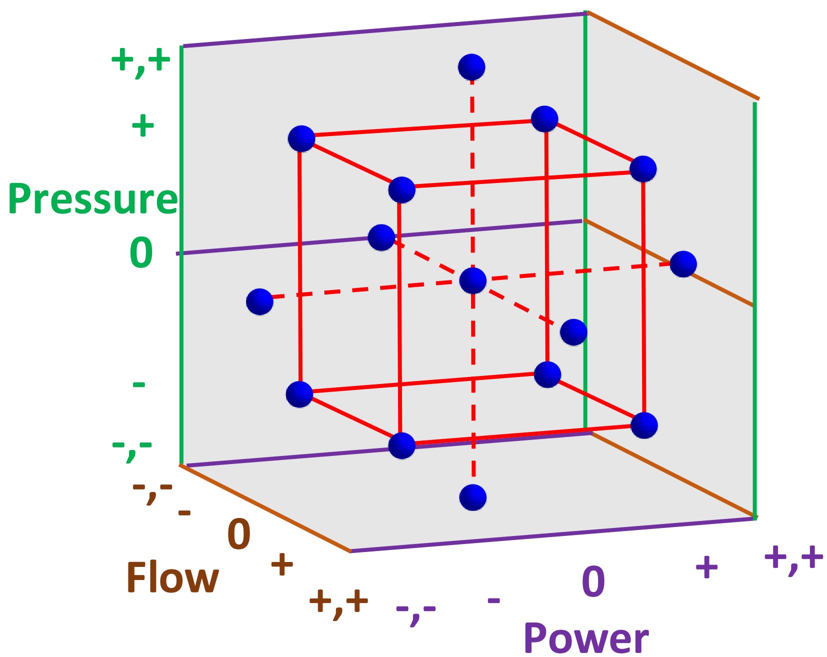
PROLITH n, k Simulations

- The target refractive index for the film is indicated by the large red circle.
- Chosen due to the lowest reflectivity, shown by the **dark blue** areas on the plot.



Experimental Setup

- Central composite design
  - Inputs centered around chamber pressure, power, and gas flow rates.
  - Responses are n, k, and thickness.
  - Set constant time for all samples (105 s).



Inputs

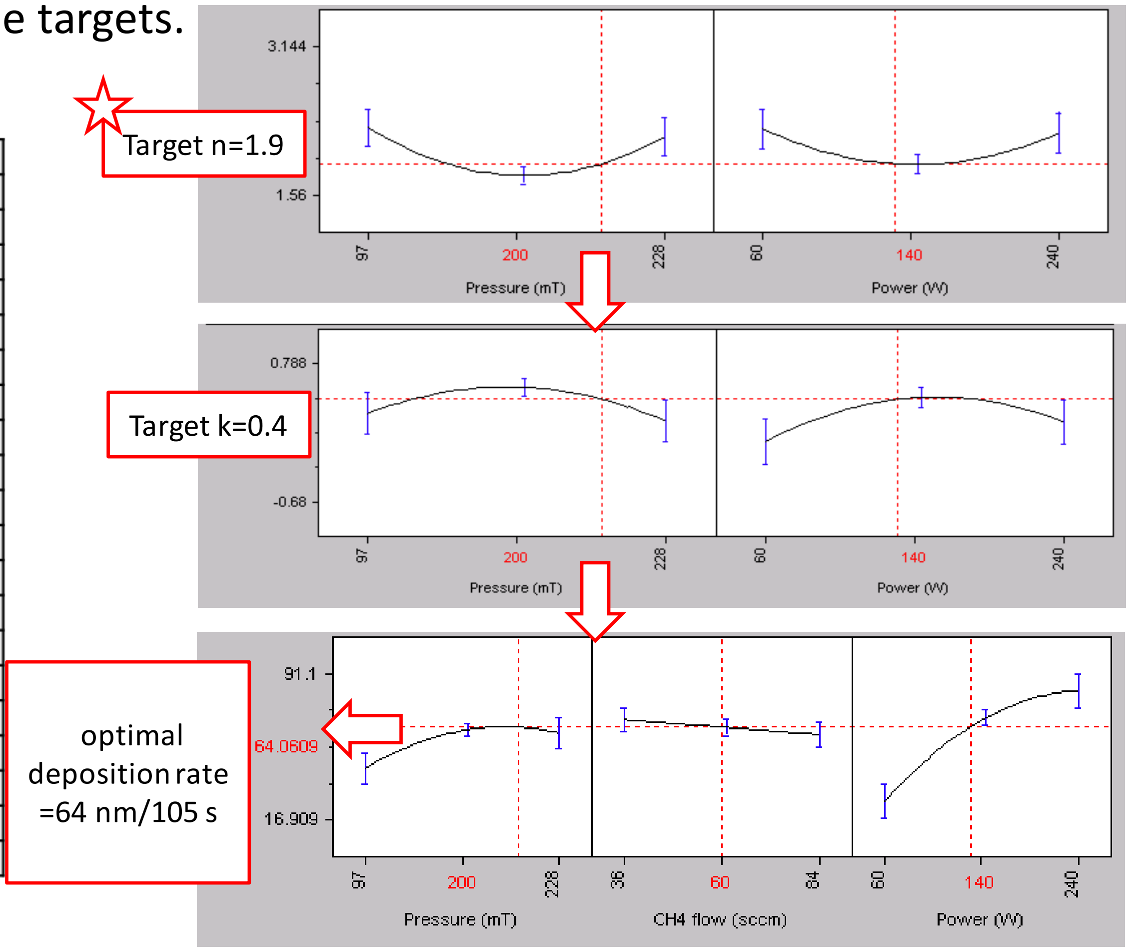
Pressure (mT)	CH4 flow (sccm)	Power (W)
125	45	100
200	75	100
125	75	200
200	45	200
163	60	150
163	60	150
125	75	100
200	45	100
125	45	200
200	75	200
163	60	150
163	60	150
163	36	150
163	84	150
97	60	150
228	60	150
163	60	60
163	60	240
163	60	150
163	60	150

Experimental Results

Using JMP IN, an analytical tool for statistical analysis, the measured responses were optimized to reach the targets.

Responses

Sample ID	n	k	thickness
17	2.01	0.15177	26.4
18	2.08	0.359	81.1
19	1.96	0.316	68.1
20	1.896	0.31292	71.4
21	2.02	0.2758	69.566
22	2.28	0.332	43
23	1.75	0.554	60
24	1.56	0.78761	78
25	2.05	0.33	79.4
26	2.04	0.354	68.8
27	2.14	0.18	44
28	2.02	0.301	41
29	1.69	0.683	63.114
30	1.67	0.691	63.43
31	2.2	0.256	40.633
32	2.13	0.184	41.8
33	2.04	0.354	67.4
34	2.06	0.334	78
35	1.71	0.646	61.745
36	1.706	0.614	61.18



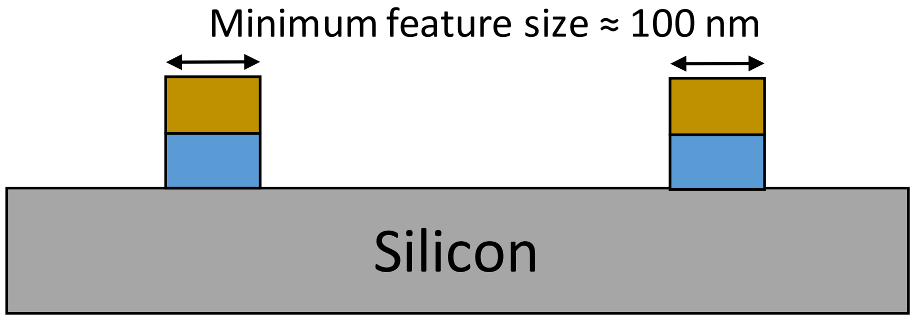
Conclusions and Future Work

I. Simulation of an optically optimized carbon hard mask has been done.

II. A designed experiment has verified a simulation model for an optically optimized carbon hard mask.

III. Collection of amorphous carbon etch rates (vertical and horizontal) in an oxygen plasma will be done by a graduate student.

IV. This process module will enable sub-lithographic resolution of approximately 100 nm line width.



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  - Help with process flow
- Matt Filmer
  - Assistance and advice

References

[1] W. Y. Jung*, et al.*, "Patterning with amorphous carbon spacer for expanding the resolution limit of current lithography tool - art. no. 65201C," in *Conference on Optical Microlithography XX*, San Jose, CA, 2007, pp. C5201-C5201.

[2] S. Pauliac-Vaujour, P. Brianceau, C. Comboroure, and O. Faynot, "Improvement of high resolution lithography by using amorphous carbon hard mask," *Microelectronic Engineering,* vol. 85, pp. 800-804, May-Jun 2008.