SAND2018-12015C

Sandia National Laboratories

Optimal Contact Photolithography Techniques for HEMT Substrates Using I-Line Photoresist

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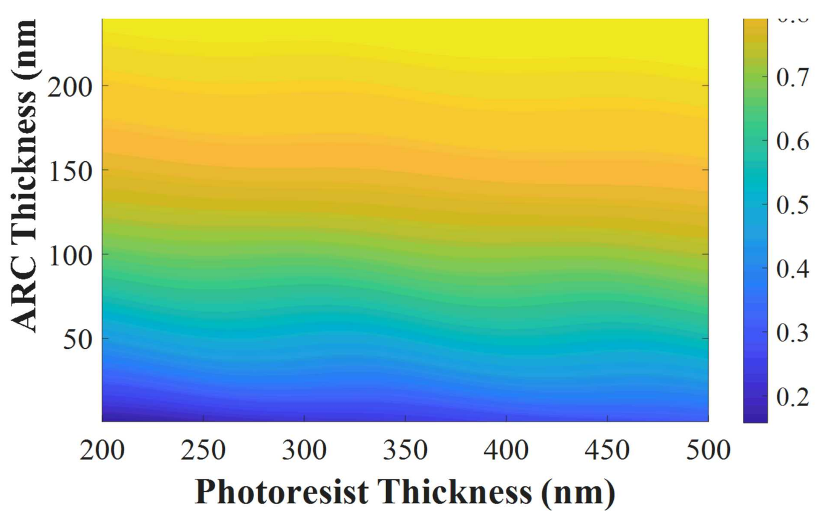
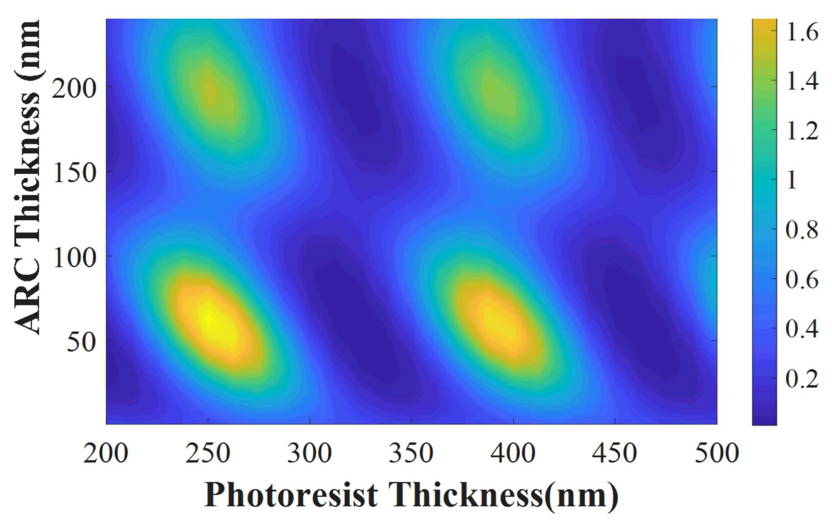
Background

- For HEMT substrates, sapphire substrates are less expensive material and available in larger wafer sizes, compared silicon carbide
- Common resolution capabilities within are 1 to 1.5 µm for contact aligners
- Optical influence of the photoresist and bottom antireflective coating (BARC) films should be considered when patterning near photolithography resolution limits on transparent substrates.

Optical Simulation

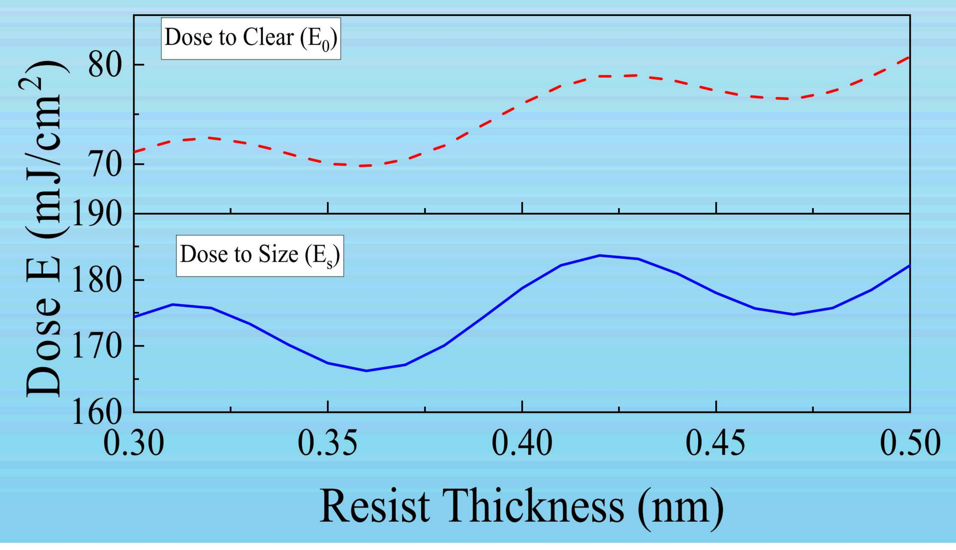




- Film stack consists of a sapphire substrate, I-Con® (BARC), and Ultra-I resist (photoresist)
- Above about 200 nm ARC , >90% of light is absorbed.
- Reflected light attenuates with thicker ARC.

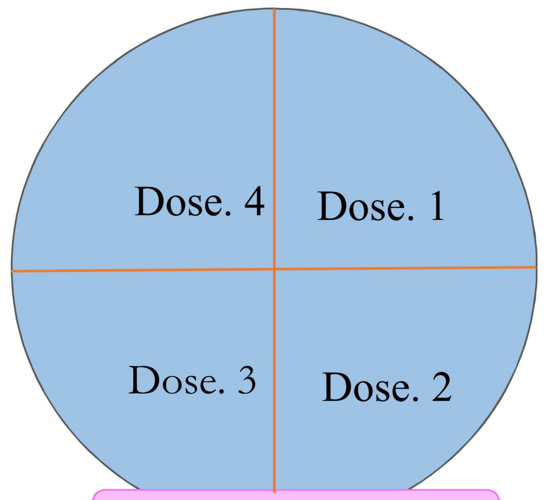
Dose Simulation

- Dose to clear is the minimum resist dose to size calculations were performed on a mask with 500 μm line and 1.0 μm pitch.
- Dose to size is the minimum energy needed to clear the resist



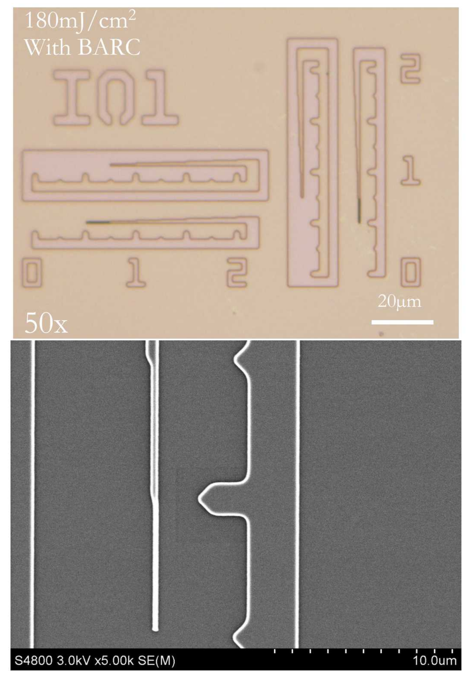
Experiment Methods

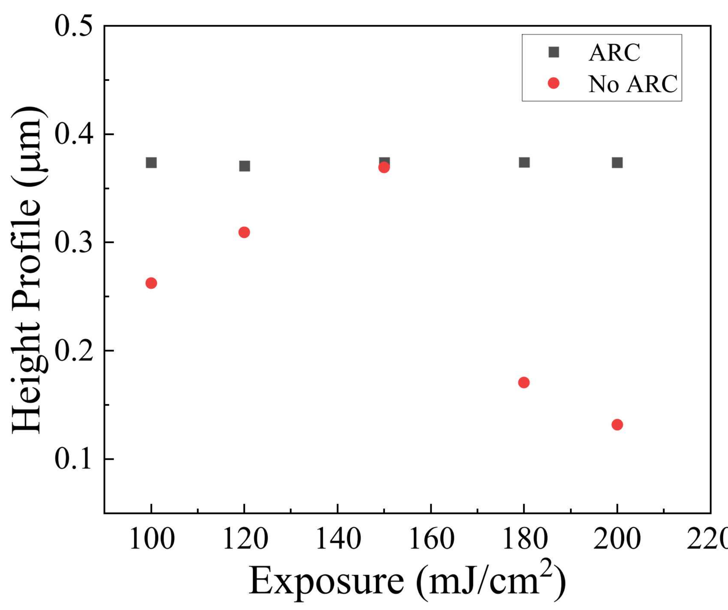
- ARC thickness: 0.230 µm
- Ultra-I Thickness: 0.380 µm
- I-Line Exposure: 80 - 250 mJ/cm^2
- 2” Sapphire wafers partially exposed
- MF-321 Spin Development: 36s with BARC and 10s no BARC



Wafer diagram

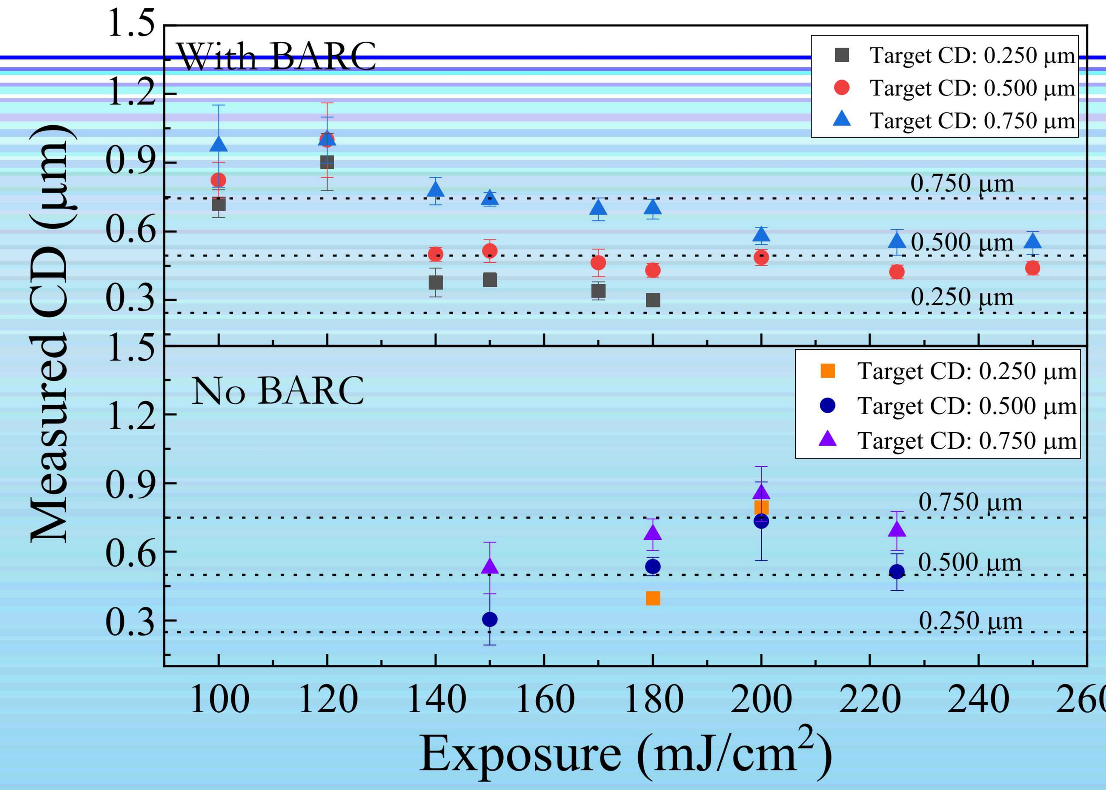
Pattern Profile and Measurement





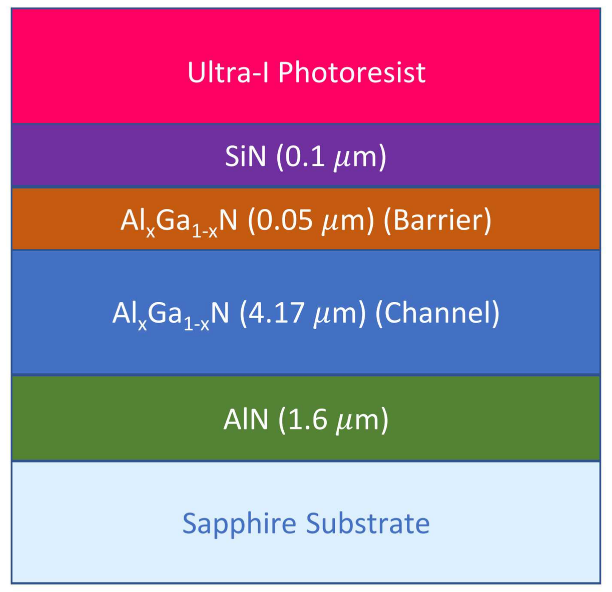
- Evaluation and post-development resist profile shows non-BARC coatings shows signs of dark erosion.

Experimental Results



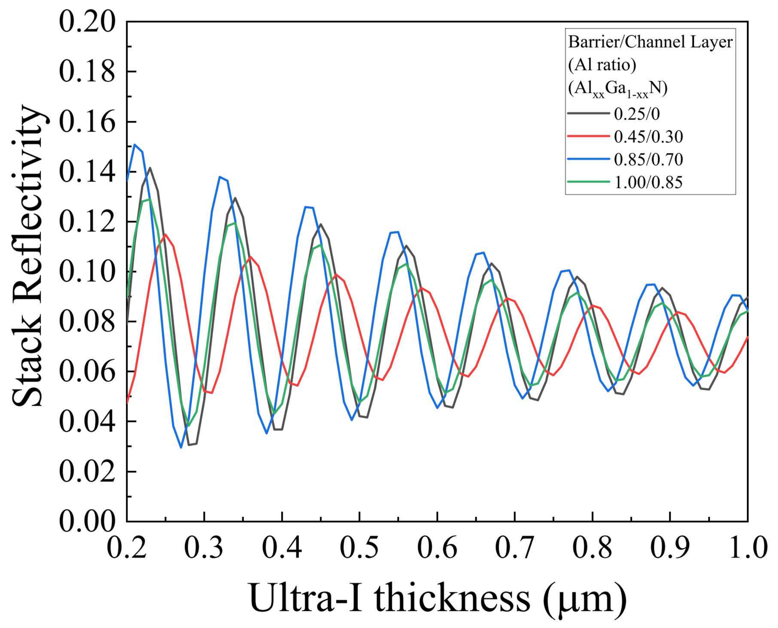
- Substrates with ARC cleared after 100 mJ/cm^2 after 150mJ/cm^2 without ARC.
- Deviation in CD linewidth is significantly lower with BARC

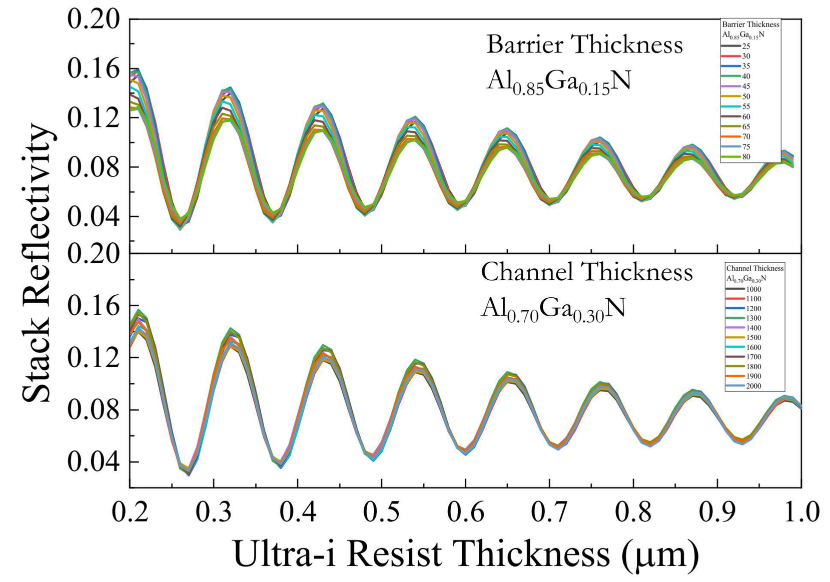
HEMT Stack Simulations



- Basic HEMT stack consists of barrier
  - Barrier(% Al): 25, 45, 85, and 100
  - Channel (% Al): 0, 30, 70, 85
- Prolith Simulation Parameters:
  - 365nm wavelength
  - NA: 0.7
  - Partial Coherence: 0.6

HEMT Simulations Results





- HEMT Stack reflectivity evaluated for barrier and channel AlGaN compositions versus resist thickness.
- Reflectivity due to composition variation must be considered in film stack.
- HEMT stack barrier and channel thickness variation also shows swing curve in reflectivity caused by light interference from the film stack.

Conclusion

- The optical simulations were used to determine resist and ARC thickness .
- Exposure within the resist can be minimized by exposing wafers close to the dose to size.
- Sufficiently thick ARC can minimize optically influenced defects such as dark erosion and CD width variation.

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SAND No. 2018-4965 C