Optimization of UV Stabilization for Critical Dry Etch Applications

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Abstract

Stabilization of thin films of photoresist is a crucial upstream process directly related to the quality of features defined during dry etch. Traditional stabilization techniques involve thermal treatments by way of standard baking in a conventional box oven. This process has evolved to include incident UV light during the thermal treatment. In this study, we investigate the quality of stabilized films of resist by comparing newly developed UV stabilization processes to that of a traditional box oven hard bake. Quality metrics include sidewall profile, aspect ratio, and etch selectivity. Our results indicate that these metrics are highly related to process input parameters including stabilization temperature, time, and intensity of UV light. A review of our newly optimized UV stabilization recipes and how input parameters affect quality metrics will be presented. Lastly, we will report dry etch robustness of stabilized films where selectivity was found to be similar across all stabilization processes.

Background

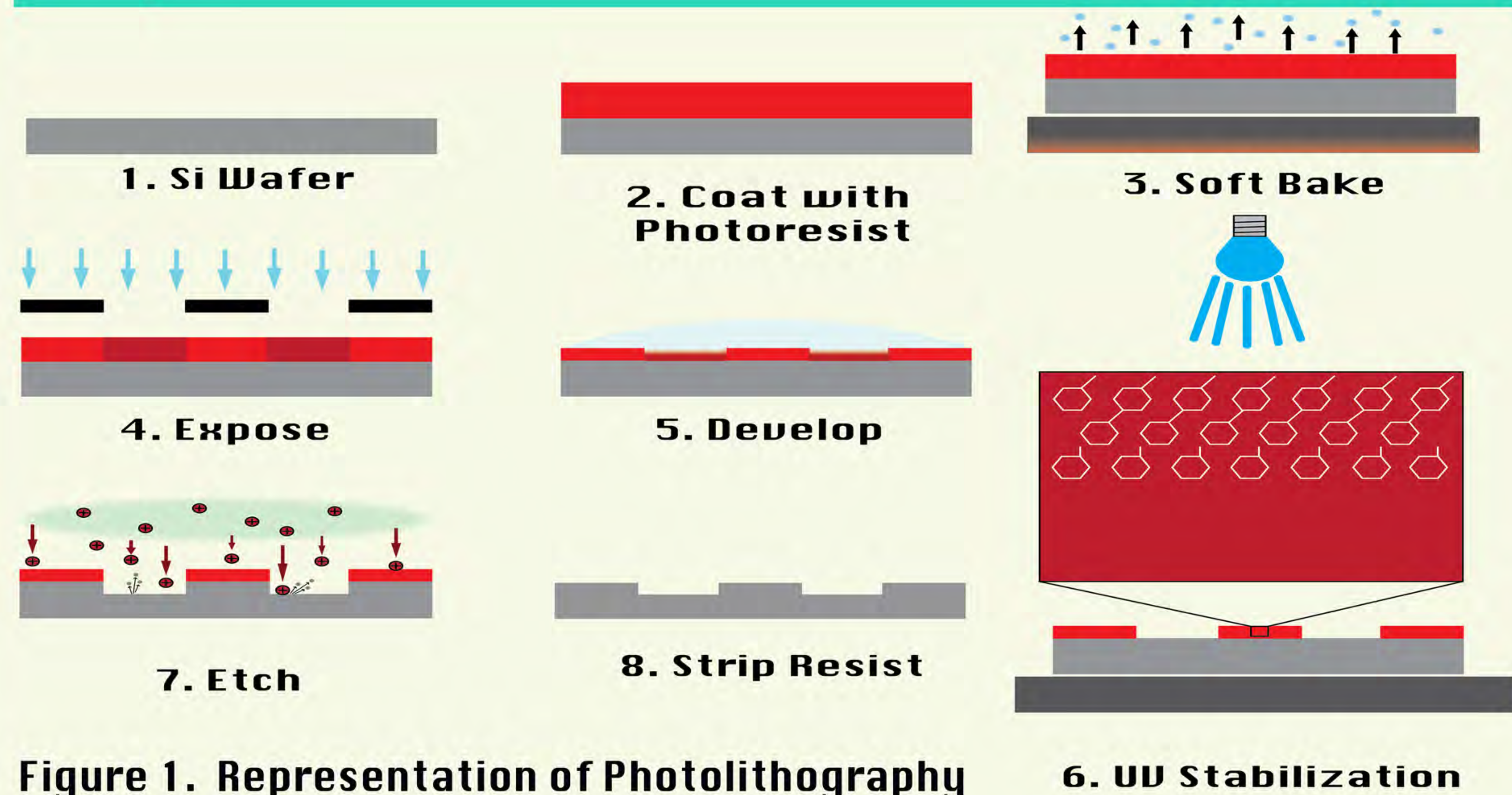


Figure 1. Representation of Photolithography and Etching Processes.

UV stabilization occurs after development and is intended to cure photoresist so it will be able to efficiently handle etching environments, thus yielding high selectivity while retaining sidewall profile and aspect ratio.

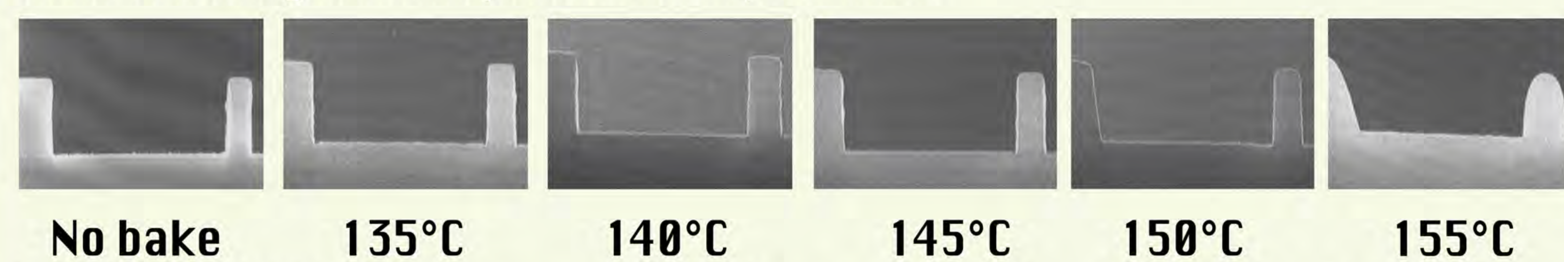


Figure 2. DUV 210 Thermal Flow Characteristics. Increasing temperature during conventional hard bake (oven) causes resist to reach T_g at 155°C.

"DOW (Rohm & Haas Electronic Materials)," in MicroChem, 2016. [Online]. Available: http://www.microchem.com/PDFs_Dow/UV210GS.pdf. Accessed: Aug. 2, 2016.

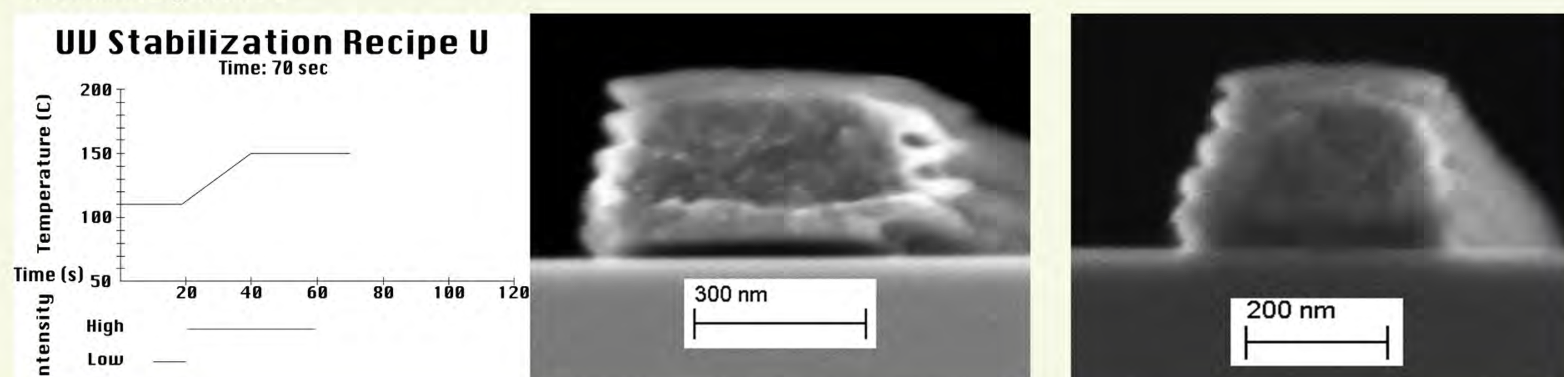


Figure 3. UV Stabilization recipe U, no BARC; Temperature and Intensity vs Time; stabilized single line of resist, cross-sectional image.

Figure 4. Box Oven hard baked resist, no BARC, cross-sectional image.

Current stabilization processes in use at the Marvell Nanofabrication Laboratory include UV stabilization and conventional hard bake with box oven at 120°C for 30 min.

Optimization Process

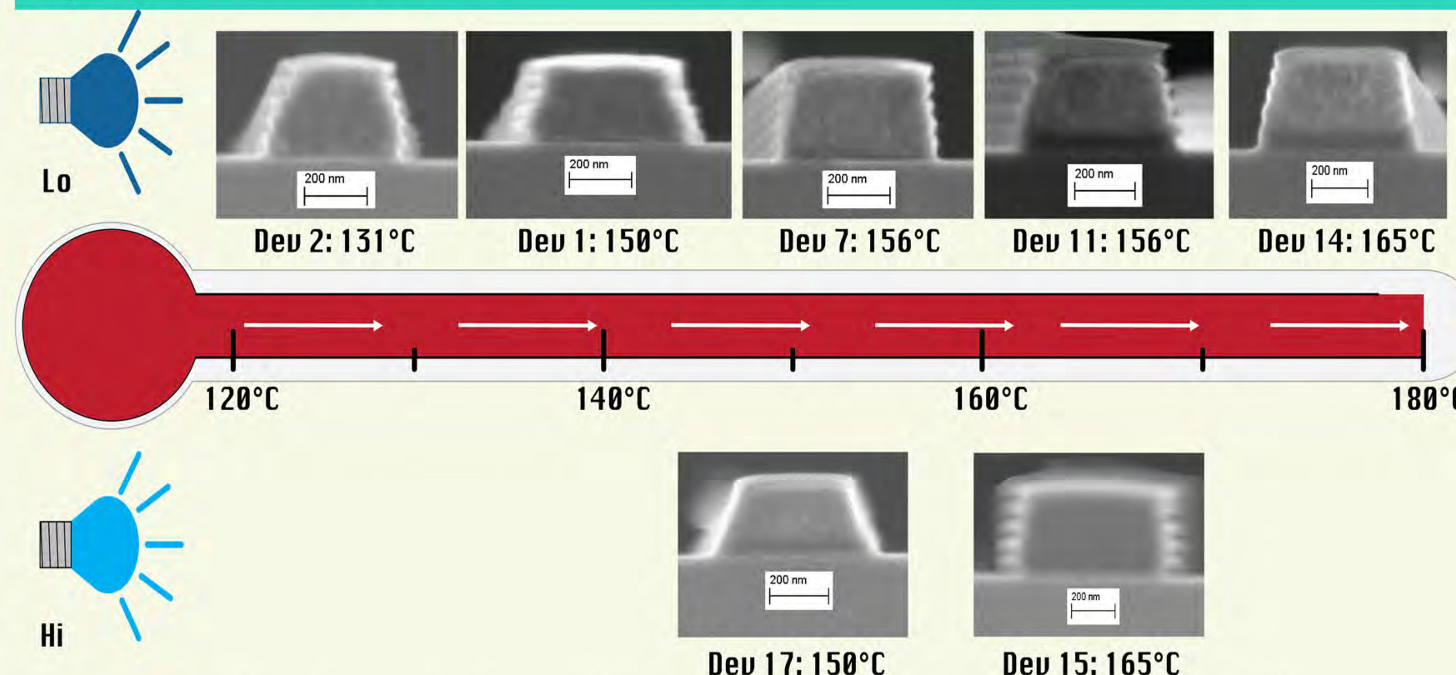


Figure 4. Photoresist profile images of top performing UV stabilization recipes.

- A total of 20 UV stabilization processes varying in idle temperature, ramp rate, UV intensity exposure, and time were developed
- Only those recipes that yielded a selectivity close to or higher than the UV stabilization recipe U and conventional hard bake with box oven were imaged using a scanning electron microscope (SEM)

Development Recipes

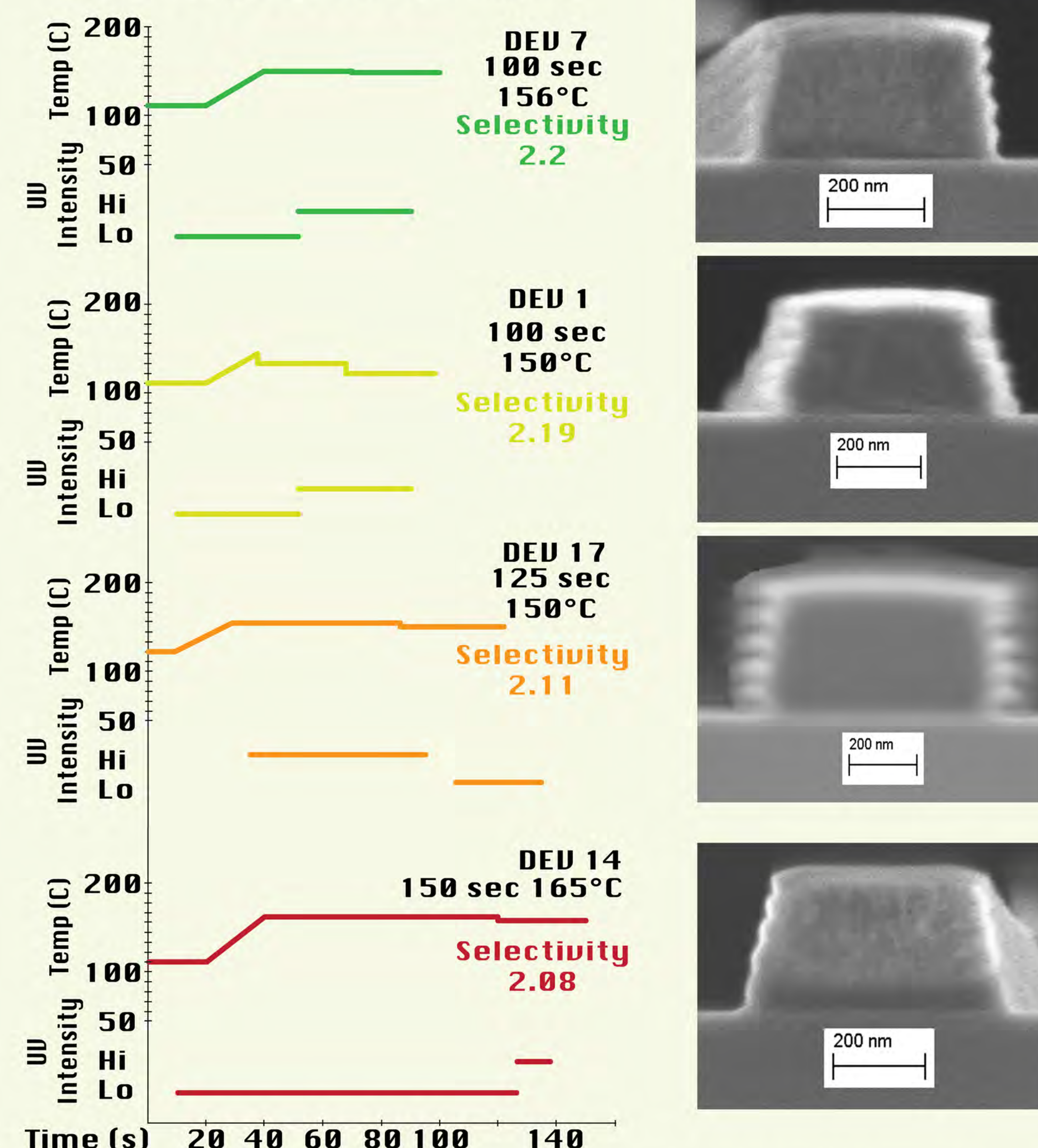


Figure 5. Profile images of single lines of resist with lowest roughness.

- Sidewall roughness is maintained when high intensity exposure is applied from the beginning regardless of temperature
- High temperatures causes reflow of resist where it contacts the substrate

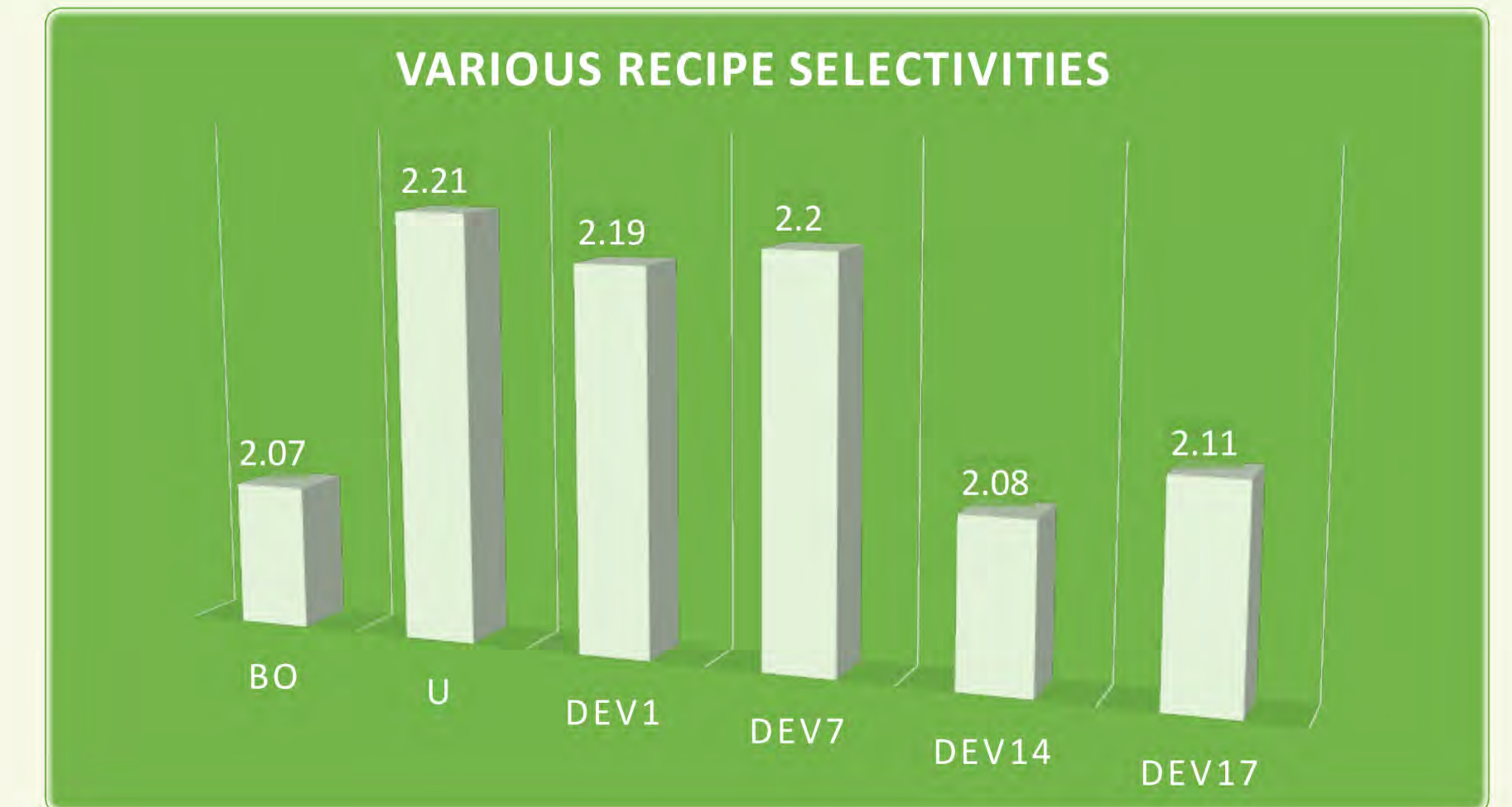
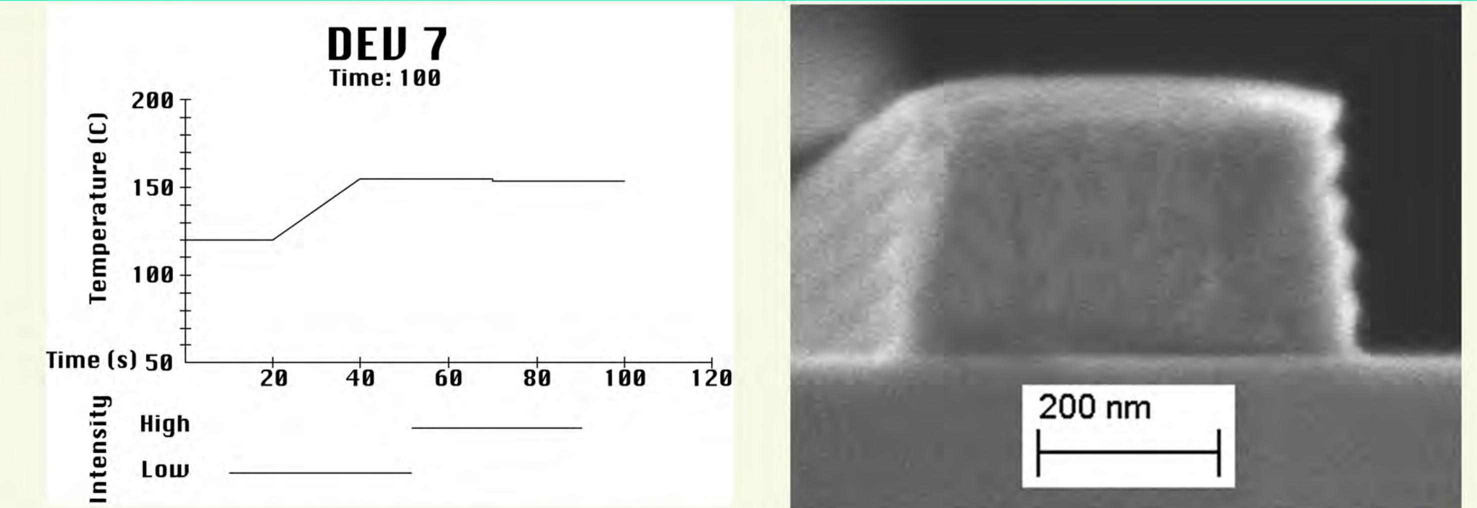


Figure 6. Selectivity for top performing UV Stabilization Recipes including Standard Recipe U and Box Oven Hard Bake.

- Selectivity obtained for top perfomring UV stabilization recipes is similar to that of standard recipe U and conventional box oven hard bake
- UV stabilization recipes DEV 1 and 7 exhibited the highest selectivity

Conclusion



- Exposing resist to high intensity UV light causes premature crosslinking that results in greater sidewall roughness
- Increasing idle temperature at low intensity exposure decreases sidewall roughnes
- UV stabilization recipe DEV 7 had high intensity UV light introduced 50 sec into the recipe and exhibited a comparatively low sidewall roughness
- UV stabilization recipe DEV 7 is the optimal stabilization process based on selectivity values, sidewall angle, and sidewall roughness

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