**ASML Optics Tackles Calcium Fluoride Fabrication with State-of-the-Art Processes**

Whereas many optical shops avoid Calcium Fluoride, ASML Optics has developed robust fabrication solutions for both large and medium-sized substrates. Developmentally, we support the advanced requirements of lithography optics. As a result, we’ve extended its capability to CoF polishing of substrates for other applications. Due to its high transmittance at both UV and IR, CaF₂ can be used exceptionally well, where conventional glass materials absorb too much. We have developed our CoF polishing processes to support fabrication of blanks from ~25 mm up to 300 mm diameter, with surface roughness of <1 nm and figure accuracy to better than 1/1000 wave.

Shown in Figures 1a and 1b are surface figure results of our CoF process for an approximately 100 mm diameter optic, before and after the critical ion beam figuring (IBF) process. These results show how we are able to polish the surface figure results to better than 1/1000 wave.

**Power Spectral Density (PSD)**

The physical structure of Calcium Fluoride can make it particularly challenging for polishing with conventional glass structures. It exhibits softness and crystalline solid-state structure that makes CaF₂ sensitive to process variables like surface roughness and polish tools. These relative extreme material specifications challenge the polishing process for the glass manufacturer and can drive up the cost for single crystal material when compared with more conventional glass materials such as fused silica.

The inherent transmission properties of CaF₂ make it a desirable material for visible and infrared applications. Although CaF₂ is not a single crystal, and has more relaxed index homogeneity and stress tolerances, this multi-crystal material can be especially challenging for manufacturing, because different orientations of the multiple crystals will produce different wavefront results. Shown in Figures 2a and 2b are surface roughness results of much larger approximately 300 mm diameter CaF₂ optics. Before our advanced polishing processes, the surface roughness results were approximately 300 nm peak to valley and 5.957 nm root mean square. However, with the new optical surface micro-roughness of <1 nm RMS as shown in Figure 3.

**Optical Surface Micro-Roughness**

Surface micro-roughness is an important characteristic for precision optics applications. The surface micro-roughness characteristics are largely dependent on the final polishing processes and for the most extreme precision lithography lens elements we are able to achieve surface micro-roughness of <1 nm RMS as shown in Figure 3. This represents a 10x improvement in figure accuracy across the surface of this 100 mm diameter CaF₂ optic. However, as shown in Figure 3, upon Ion Beam Figuring (IBF) the surface roughness parameters have improved to 9.935 nm peak to valley and 0.335 nm root mean square. Shown in Figure 1a the rms surface figure is 2.93 nm. After Ion Beam Figuring (IBF) the rms surface figure is 0.24 nm. This represents a 10x improvement in figure accuracy across the surface of this 100 mm diameter CaF₂ optic. Whereas many optical shops avoid Calcium Fluoride, combined with extreme precision figuring and surface smoothness characteristics, consider ASML Optics. Based on our experience and established processes, we look forward to tackling your next generation challenges.