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Ultra-low birefringence silica glass synthesized by VAD method for photonic components for UV photolithography

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Abstract – Ultra-low birefringence silica glass employed as photonic component in photolithography tools can be synthesized by controlling the processing parameters of VAD method with reduced fabrication time and cost besides simple processing stages.

Advances in the photolithography technology employed in the high integration microchips print have encouraged research activities of photonic materials. Exposure light sources of shorter wavelength to enhance microchips resolution have created a need for higher precision of photonic components (e.g. lenses) used in photolithography tools. Silica glass is the main material used as photonic components [1] but achieving an ultra-low birefringence has proven to be a challenge using conventional fabrication processes, which require a post-consolidation homogenization step (annealing). This birefringence is usually caused by optical anisotropy which originates from residual stress as result of its thermal history [2].

This research reports the effect of the boule deposition surface (bottom) shape synthesized by H_2-O_2 flame aerosol VAD (Vapor-phase Axial Deposition) method in correlation with consolidation time on the birefringence magnitude of silica aiming the development of a high performance material for photonic components used in photolithography. Silica soot boules with different bottom shapes were deposited by VAD method changing the burner-target distances (D), H_2 and O_2 gases fluxes in the range of 34 to 57 mm, 3000 to 6000 cm³/min, and 2000 to 4000 cm³/min, respectively. Boule bottom shape is automatically parameterized in real-time by *h* parameter [3]. This parameter is the axial distance from the deposition surface tip to a fixed height (reference diameter) (Figure 1). By virtue of this, *h* defines the radial homogeneity of material structure, where for lower *h*, higher homogeneity is obtained. Afterwards, the silica boules were consolidated in He gas atmosphere at 1450 ºC for 120, 240, and 360 minutes. Consolidated samples were characterized by polarization spectrophotometry to measure the birefringence. It was observed that for lower distances D and gas fluxes, boules tend to have $h > 2.0$ mm and high birefringence (Figure 1), while $D > 45$ mm and H_2 and O_2 gas fluxes higher than 4500 and 3000 cm³/min, respectively, tend to produce boules with $h \leq 2.0$ mm and low birefringence (Figure 1). This birefringence can be reduced in the consolidation stage by setting the consolidation time according to *h* parameter value (Figure 2). For instance, birefringence of 2 nm/cm was obtained without performing annealing, with processing conditions of $h \leq 2.0$ mm and consolidation time 120 minutes; $h \geq 3.5$ mm and time ≥ 360 minutes. The effect of consolidation time on birefringence has a direct relationship with the radial homogeneity of material structure, which is higher in boules produced with $h \leq 2.0$ mm. In this case, a lower consolidation time is required to obtain structure relaxation and, therefore, minimize the stress embodied in the material during its synthesis.

In conclusion, low birefringence silica glass (≤ 2 nm/cm) can be synthesized by the VAD method without annealing by controlling the silica boule bottom shape in correlation with the consolidation time.

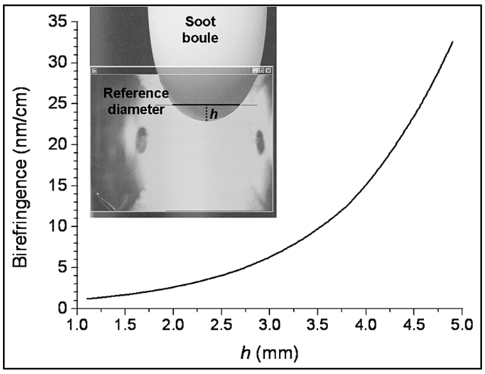

Figure 1: Influence of *h* parameter on the birefringence.

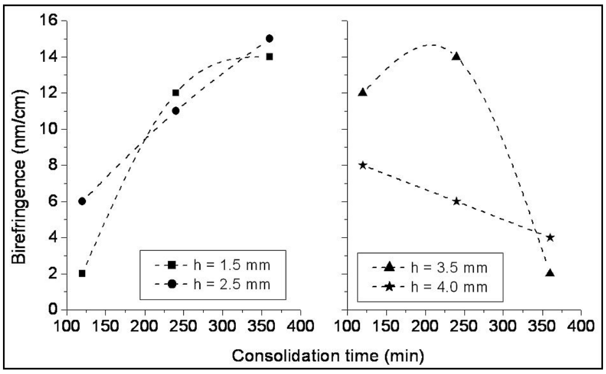

Figure 2: Effect of consolidation time on the birefringence of silica boules synthesized with different *h* parameters.

References

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