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DIFFUSION, VISCOSITY, AND CYCLE TIMES FOR HIGH ASPECT RATIO GLASS NANOIMPRINTING

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ABSTRACT

Antireflective (AR) surfaces are critical developments for electronic displays, solar panels, LED/OLED lighting, and lenses. Biomimetic moth-eye nanostructures offer significant reductions in glass reflection across the visible and near-IR spectrum and are self-cleaning due to their hydrophobic nature. However, current AR glass surfaces rely on clean-room-based manufacturing processes, which are costly, have limited throughput, and restrict the patternable surface area.

Thermal nanoimprinting has emerged as a promising alternative for large-scale, cost-effective AR patterning on glass. However, the literature pertaining to high transition temperature glass nanoimprinting is limited to shallow aspect ratios due mainly to interdiffusion between the mould and substrate. Furthermore, the fundamental relationship between temperature, pressure, and feature-scale on glass flow remains insufficiently explored.

To study high aspect ratio glass nanoimprinting, high-temperature glass nanoimprinting equipment and moulds were developed. Experiments were conducted on borosilicate and soda-lime glass using various moulds with large aspect ratios and were compared to numerical models to elucidate the effect of the process parameters on the cycle time, repeatability and interdiffusion between mould and substrate.

Findings indicate that as the mould feature scale decreases, higher temperatures are required to ensure adequate material flow and pattern replication. However, at elevated temperatures, diffusion rates increase, leading to higher fracture risks and interfacial degradation. Comparative analysis between borosilicate and soda-lime glass highlights key material-dependent factors that influence the process.

By integrating experimental data with numerical modeling, this study offers insights into the underlying physics governing glass nanoimprinting. The findings contribute to the development of process optimization strategies that can facilitate industrial-scale production. Future work will focus on extending the model to various glasses, ensuring scalable high throughput glass nanoimprinting for diverse glass compositions.