Micro/Nano Glass & Metal Forming using Vitreous Carbon mold

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Polymer micro/nano replication processes are popular for commercializing micro/nano-structured systems due to their cost-effectiveness. However, polymeric micro/nano structures face limitations in applications requiring high thermal stability, chemical resistance, optical properties, and mechanical stability. To address these challenges, glass or metallic micro/nano structures offer promising solutions. Micro and nano glass or metal forming is an effective method for mass-producing these structures. This technique involves pressing glass or metallic material at high temperatures against a mold with the inverse shape of the desired structure. A critical aspect of this process is developing molds with sufficient thermal, chemical, and mechanical resistance. In this study, we present a method for creating vitreous carbon (VC) molds by carbonizing replicated Furan precursor from the initial master pattern. Since the VC molds shows high hot hardness, high chemical resistance and low surface energy, it can be a promising mold for high temperature glass or metal forming process. Any master patterns fabricated by photolithography or precision machining can be transferred to the VC mold surface, allowing for easy creation of VC molds with nano, micro, and macro-scale cavity structures. We optimized the Furan curable polymer composition and adjusted processing parameters to achieve high-quality VC molds. Additionally, we developed a method to predict shape changes during the fabrication process. To demonstrate the practical applications of our techniques, we designed, fabricated, and evaluated various devices, including glass microfluidic chips, microlens arrays, micro Fresnel lenses, macro single aspherical lenses, wafer-level lens arrays, and glass nanophotonic devices. Additionally, we successfully fabricated micro metal formed functional surfaces and applied them to enhance boiling heat transfer and anti-icing applications.