Development of a fiber-optic based metrology for nano/microscale mold filling

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Injection over-molding of polymeric material is a recent method in serial manufacturing of optic components in micro and nanoscale [1]. The advantages of injection molding processing are: High throughput, ease of control of process parameters, low fabrication cost and the wide flexibility of shapes that can be formed. Quality control during of a replication process plays a key role in any micro-fabrication technology, and is the focus of this research. The impact of the technology developed at Adama, in fundamentally enabling a rapid prototype mold fabrication, is intended to drive disruptive innovation in several application fields ranging from medical device microfluidics to optics. Micromachining, combined with DLC coating and subsequent nanostructuring (technology patented by Adama LLC) allows creation of steel inserts which can be used for replication of thousands to hundreds of thousands of polymer parts with functional nanofeatures. Adama has developed a two-step patterning technology as a simple and efficient method to create micro and nanoscale features. It is a resist-free, direct-write patterning technique for materials including diamond and DLC, for non-planar surfaces.

In-mold quality control as a key factor in serial replication process was targeted using fiber delivered reflectance measurement. Our aim is to monitor the progress of filling process using the fiber based measurement of scattering or reflection optical signals. While Time Resolved Diffraction Scatterometry is a proven metrology for nanoimprint lithography, here we propose Fiber-based interferometry as a nanoscopic mold-filling sensor for compatibility with injection molding machinery. Fiber-Optic Interferometry is often used in high resolution Atomic Force Microscopes (AFMs) to measure the deflection of cantilever. This system has outstanding sensitivity and allows measurement of displacements to sub-Angstrom levels. Beams reflected from the fiber end-face and surface of target form an interference signal that is monitored using signal photodiode. The change in power of interference signal can be accurately converted to displacement in a calibrated system [2].

We have achieved preliminary results showing that the technique can measure the relative motion of a polymeric sheet with nanometric precision. However, some challenges still remain, the laboratory test results demonstrate the capability of this system to be used as mold filling sensor.

Reference:

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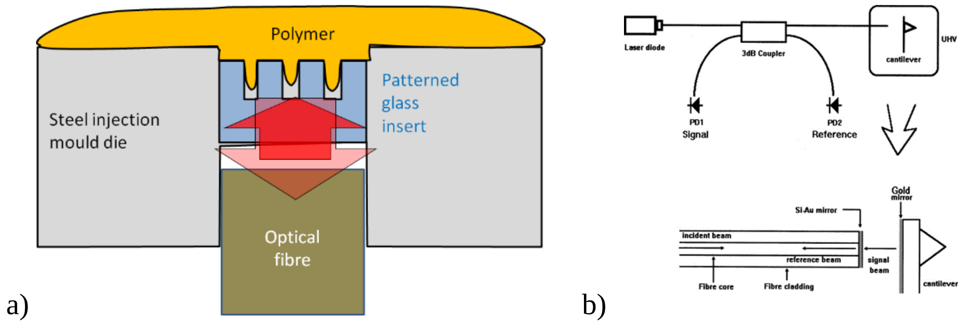

Figure 1. Schematics of a) fiber delivered reflectance measurement for mold filling monitoring and b) fiber-optic interferometer used for cantilever deflection detection in AFM [2].