CO_2-Assisted Embossing Process for Replication at Lower-Than-Tg

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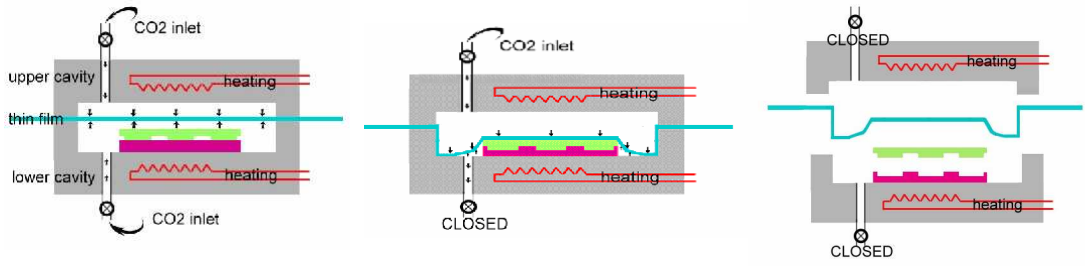
Abstract

Gas-assisted hot embossing has been proven to be effective in replication of submicron microstructures onto substrates. Since the distribution of gas embossing pressure is uniform, the process is advantageous for large-area imprinting. This paper reports an attempt to develop CO_2–assisted embossing employing CO_2 as the pressuring media. Since CO_2 is also a good solvent for poly(methyl methacrylate)(PMMA), it can serve as a plasticizing agent as well ; the embossing temperature can be operated below T_g. Imprinting in low-temperature and with low-pressure can reduce residual stress and shrinkage; this is advantageous especially for large-area imprinting of optical elements.

Fig.1 shows the procedure of the CO_2–assisted embossing process. The mold/PMMA substrate stack is placed into the lower chamber. CO_2 is then blown into both upper and lower chambers. The pressure is remained for a period of time to allow CO_2 dissolved into the PMMA substrate until it is plasticized. Imprinting is also performed on the mold/substrate stack. Finally, after degassing, the mold and the imprinted substrate are fetched and detached.

Using CO_2–assisted embossing, fabrications of microstructures of an micro-actuator and optical diffuser films on an area of 50 mm x 50 mm PMMA substrates from Silicon and Nickel molds were performed. Left sides of Figs. 2 and 3 show the optical microscope (OM) photos of the microstructures on two molds. Right sides of Figs. 2 and 3 show the OM photos of the replicated microstructures by CO_2–assisted embossing on PMMA substrates. The patterns can be transferred to the surface of at 35^{o}C. The goal is to replicate large-area nano-scale micro-structures at room temperature.



(a) (b) (c)

Fig.1 Schematic diagram showing the procedure: (a) CO_2 blows in for dissolving; (b) embossing; and (c) degassing, releasing and demolding.

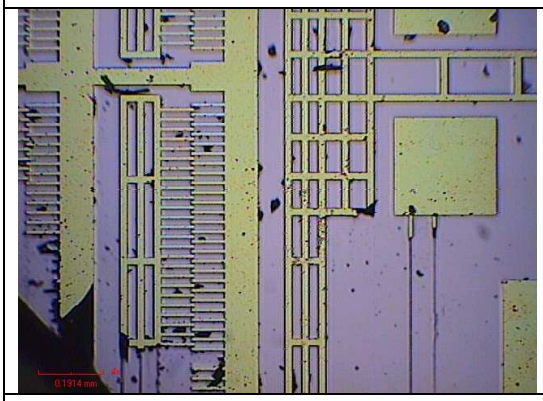
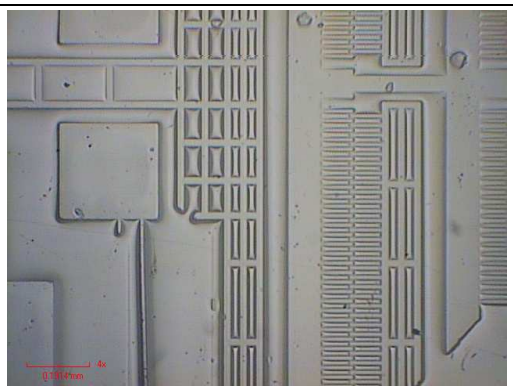
（a） On Silicon mold	（b）On PMMA substrate
	

Fig.2 (a) The microstructures on silicon mold (b) Replicated microstructures on PMMA substrate (CO_2 soaking pressure = 50 bar, Imprint pressure = 0.3 bar. Embossing temperature = 35℃).

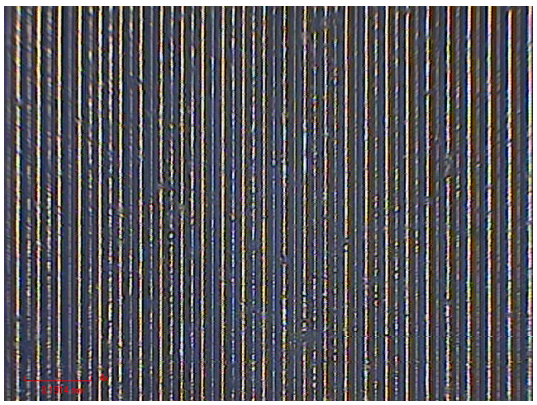
（a）On Ni mold	（b） On PMMA substrate
	

Fig.3 (a) The microstructures for optical diffuser films on Nickel mold.
(b) Replicated microstructures on PMMA substrate (CO_2 soaking pressure = 50 bar, Imprint pressure = 0.3 bar. Embossing temperature = 35℃).