Polycarbonate 필름의 롤투롤 패터닝 시뮬레이션
Roll to Roll Patterning Simulation of Polycarbonate Film

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1. Introduction

In recent 20 years, various lithography technologies for fabricaion of micro- to nano-scale patterns have been developed. Among them, imprint lithography is considered as one of the most cost effective processes with its high throughput and high resolution. However, conventional imprint lithography methods are still inappropriate for mass production of micro and nano patterns. Roll-to-roll imprint lithography, meanwhile, has been introduced as a solution for this problem, since it can produce patterns continuously with relatively small pressing force. Most of the R2R imprint lithography processes are developed for thermoset resist materials with UV curing method. For example, Guo's research group has made much progress in developing R2R based nanoimprint lithography on flexible plastic substrates with thermoset resist materials[1]. On the other hand, thermoset materials are not commonly used as a resist material for R2R imprint process because they usually require relatively high pressure and long process time. In this work, feasibility of using thermoplastic polycarbonate(PC) as a resist material for R2R imprint is investigated by numerical simulation. The influence of process temperature and imprinting speed are investigated with various micro-scale line patterns.

2. Equipment and Process

Fig. 1 depicts conceptual diagram of R2R imprint process for a thermoplastic resist. The diameter of the imprint and back up rollers is 152mm(6in) and the total pressing force of the imprint roller is 400kg$_f$, which is generated by two hydraulic cylinders. In this work, imprint temperature of PC is set as 100℃ and 150℃. For the PC, the Tg (glass transition temperature) is 145℃, and it shows good deformability at 100℃ eventhough it is under Tg. Meanwhile, if the temperature of the PC reach 150℃, which is just above the Tg, the deformability is expected to increase drastically. The angular velocity of the two rollers is set as 0.76rpm for 100℃ and 3.60rpm for 150℃.

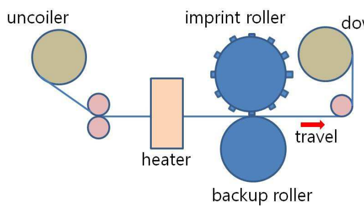

Fig. 1 Conceptual diagram of thermoplastic R2R imprint process

3. Material Properties of PC

The PC film used in this study is 'CCL+' provided by i-components corp. The thickness of the PC film is 120㎛ and mechanical properties required for this research is obtained by high temperature tensile test. The result of the tensile test is illustrated in Fig. 2. and the elastic modulus and yield strength at each temperature are given in the table 1. From the result, It can be noticed that yield strength of PC shows greater value as the strain rate given gets higher. Therefore, strain rate dependent plasticity should be considered and more yield strength data at different strain rates is required. In this study, the yield strenghth of PC is assumed to be linearly dependent on log($\dot{\varepsilon}$), where $\dot{\varepsilon}$ is the strain rate, and the other yield strength data is calculated based on the result in table 1.

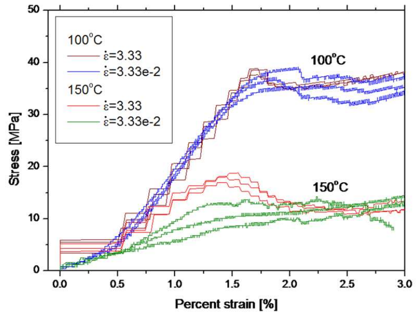

Fig. 2 Tensile test result of PC film at 100℃ and 150℃

Table 1 Elastic modulus and yield strength of PC

	Elastic modulus (MPa)	Yield strength (MPa)	
		$\dot{\varepsilon}=3.33\times10^{-2}\ s^{-1}$	$\dot{\varepsilon}=3.33\ s^{-1}$
100℃	2.9×10^{3}	36.9	38.4
150℃	5.1×10^{2}	10.7	17.9

4. Simulation

Using the material properties, finite element analysis has been conducted to simulate R2R patterning on the PC film. Micro-scale rectangular line patterns are investigated and the shape of patterns engraved on the stamp is illustrated in Fig. 3. The interval between adjacent channels 'a' is fixed as 100㎛ and the width of the channel 'b' is given as 5㎛, 10㎛, 20㎛, 40㎛ and 80㎛, respectively.

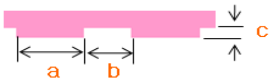

Fig. 3 Shape of patterns engraved on the stamp

For the strain rate dependent plastic deformation analysis, commercial finite element analysis code Abaqus 6.10 is used and an example of the simulation for 20㎛ pattern at 150℃ is shown in figure 4. All other results are summarized in Fig. 5 and it can be seen that , for the same pattern size, the height of the resultant pattern at 150℃ is much higher than the height at 100℃. In addition, as the width of the pattern gets wider, the resultant pattern height also becomes higher.

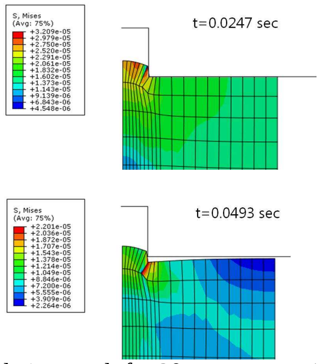

Fig. 4 Simulation result for 20㎛ pattern at 150℃

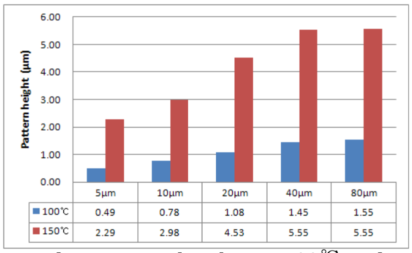

Fig. 5 Resultant pattern heights at 100℃ and 150℃

5. Conclusion

Micro scale roll-to-roll line patterning on polycarbonate film is investigated by finite element simulation. The result shows that, as the process temperature increases above Tg, the deformability of the PC becomes higher, and it is difficult to make high patterns with narrow channel width.

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