Modified R2R patterning technology for continuous production of bio-inspired functional surfaces

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ABSTRACT

Bio-inspired surfaces, such as dry adhesives, super-hydrophobic surfaces, anti-reflection surfaces, etc., exhibit their functionality due to their unique design of micro/nanostructures and intrinsic properties of specific materials. Recently, as these bio-inspired functional surfaces developed by many researchers have been introduced, the demand for actual commercialization is increasing. In this study, the development of roll-to-roll production technology for mass production of bio-inspired surfaces expressing special functionality was carried out.

Keywords: Continuous production, R2R fabrication, Biomimetics, Gecko, Dry adhesive

1. INTRODUCTION

With the development of micro/nano structure fabrication technology, production of various artificial functional surfaces existing in nature has become possible. For example, dry-adhesive soles of geckos, water-repellent surfaces of lotus petals, and non-reflective surfaces of moths' eyes. For these artificial functional surfaces, the design of the micro/nano structure is important, but the original characteristics of the material constituting the structure are also very important. The various functional surfaces developed in this way have very useful performance and thus have the potential to be utilized in various industries. As a result, the demand for application to real industry has increased, and the need for mass production has naturally emerged. However, the complexity of the structure and limitations in material use are slowing the evolution of this mass production, especially R2R patterning. This paper deals with the serial production of artificial dry adhesives made of polydimethylsiloxane (PDMS) with a mushroom-shaped microstructure. This structure is a reverse tapered type, and since the tip has a larger diameter than the support pillar, it is difficult to form a designed microstructure with a typical molding process. In addition, since the used PDMS needs to be heated at 70 degrees Celsius for about 1 hour for curing, there is a limitation in increasing production efficiency by applying a continuous process. To solve this problem, we introduce a new type continuous production technique, which called thermal roller lithography(TRL) of dry-adhesive through modification of an appropriate R2R patterning equipment.

2. EXPERIMENTAL AND RESULTS

A belt-type soft mold was manufactured instead of a roll so that the high-viscosity PDMS pre-polymer could enter the hole of the mold. In addition, since PDMS needs to be heated for a certain period of time to be cured, this belt-type production device has an advantage in terms of production of target samples. The process temperature was set to 130 degrees Celsius by utilizing the characteristic that the curing of PDMS becomes faster in proportion to the temperature, and Polyurethaneacrylate (PUA) and Kapton film that can withstand this temperature were used to manufacture a belt-type soft mold.

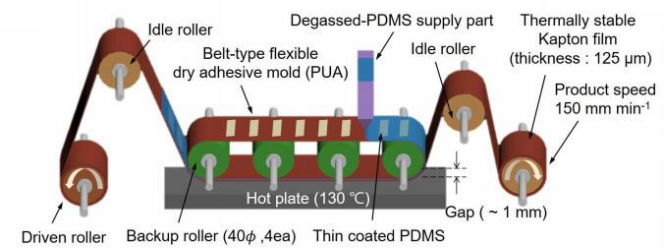

Figure **1**: Schematic description of the modified fabrication system for continuous fabrication with PDMS resin.

As a result, dry adhesive could be produced at a speed of 150 mm/min, and the produced adhesive expressed a pull-off strength of 10 N/cm^2. This is a level of adhesive performance that can be fully utilized in actual industry or daily life.

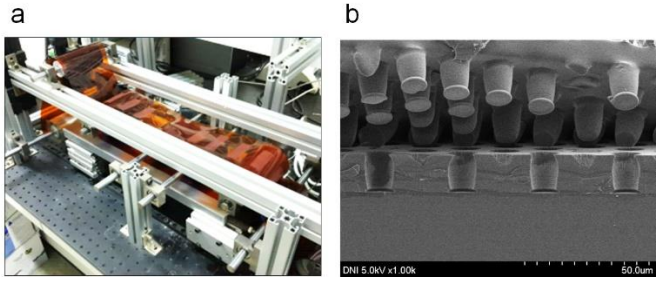

Figure **2**: (a) Photograph of TRL system (b) SEM image of gecko inspired dry adhesive

To prove this, in this study, a 3 kg glass substrate was transferred by attaching a dry adhesive manufactured as an end effector of the robot arm, and successful results were obtained.

3. CONCLUSION

Although PDMS has many advantages from various points of view, it has not been considered as a resin for a roll-type continuous-fabrication system because of its long curing time. In the study, we investigated the continuous-production method of thermosetting polymer. We developed the TRL system for continuous fabrication of PDMS using custom-built roll-type equipment. We also demonstrated the possibility of applying PDMS via gecko-foot-inspired dry adhesive fabrication. PDMS was cured at 130 ℃ in 3 minutes, and developing equipment that realizes continuous patterning of PDMS at a production speed of 150 mm /min is possible. To demonstrate its application, dry adhesive with hierarchical structures was fabricated continuously and rapidly with the TRL system. Furthermore, to check the feasibility of fabricated dry adhesives with the TRL system in real industries, a glass transportation system was successfully implemented with the dry adhesives applied on a robot arm. Its high productivity and product performance show that the TRL system is a promising production technique in the continuous production of thermosetting polymers and is expected to be used in various industries.

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