접착력이 강화된 생체친화적 의료용 패치
Skin-affinitive medical patch with reinforced adhesion

*김두곤 [1], 배원규 [1], #서갑양 [1]
*D. Kim[1], W. G. Bae[1], K. Y. Suh
[1] 서울대학교 기계항공공학부

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1. Introduction

Unlike flat contact surfaces such as a glass sheet or a Si wafer, the human skin possesses hierarchically organized topography. To obtain an optimal skin adhesive structure, variables such as subjects' skin type, and age, and material's biocompatibility and toxicity should be considered; otherwise unwanted side-effects may be resulted in. Also, current dry adhesive-based medical skin patch still needs to be enhanced in terms of adhesion force. In our previous study, 7.5 wt% of curing agent (Sylgard B, Dow Corning) was added into base (Sylgard 184 A, Dow Corning) to fabricate a dry adhesive medical patch. It is predictable to produce further enhanced dry adhesive medical patch by mixing PDMS(polydimethylsiloxane) elastomer and reduced the weight percent of curing agent. However, substrate's diminutive elastic modulus can causes difficulty in demolding process; during demolding process, structures can be torn off or stuck in the master mold. In addition, fabricating skin adhesive with low-modulus PDMS may cause collapse or mating of micropillars, which requires cleaning procedure to restore its adhesion property.

In this paper, we present a simple yet robust method of fabricating a hierarchically-modulus-tunable dry adhesive in order to better mimic gecko's hierarchical structure on their foot by exploiting the two-step fabrication procedure; replica molding and inking method. Briefly, micropillars were fabricated using high modulus PDMS to take advantages of structural stability and prevent defects when demolding the cured structure, and low modulus PDMS was inked on the end of the high modulus PDMS micropillars, which is called as "inking method" in this study to enhance the adhesion force on human skin. Using this approach, modulus-tunable dry adhesive is demonstrated, which is capable of increasing the adhesion force up to ~50% compared to our preceding result.

2. Materials and method

A silicon master mold was made by conventional photolithography. In brief, holes were made by deep reactive ion etching (DRIE) on a silicon wafer in which a layer of silicon oxide was embedded (Silicon-on-insulator). This oxide layer not only acted as an etch-stop layer, but also provided an additional layer which was to be over-etched after the initial etching process, rendering a mushroom-shaped feature at the bottom of each hole. High modulus PDMS containing curing agent of 15 wt% was casted onto the prepared master mold and thermally cured in 70 ℃ to have a replica having a number of mushroom-shaped micropillars. Demolded replica was ready to be further processed via inking method as shown in figure 1 to enhance the adhesion property. To proceed to the inking method, a thin PDMS layer was prepared by spin-coating PDMS with curing agent of 5 wt% on glass substrate. The PDMS replica was slightly laid on the substrate and detached in a moment, leading to the PDMS with low curing agent on the tips of micropillars. Post-curing was performed on Teflon substrate to flatten the end of each tip. After post-curing, we can obtain a modulus-tunable dry adhesive with reinforced adhesion.

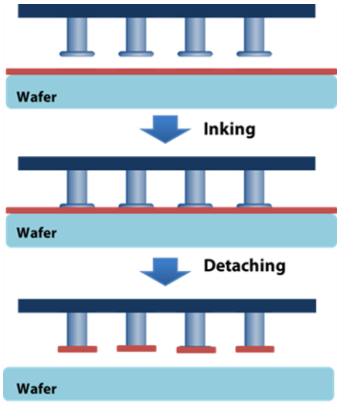

Fig. 1 Schematic illustration of fabricating a modulus-tunable dry adhesive. Micropillars were made by high modulus PDMS (15 wt% curing agent), whereas each tip were inked with low modulus PDMS (5 wt% curing agent).

3. Results

We used PDMS whose mechanical strength can be tune in a facile manner by varying the amount of curing agent for inking material, which is the same as the material used for the micropillar structure. We varied the amount of curing agent from 2.5 wt% to 15 wt% to perform the inking method. As can be seen in figure 2, adhesion force increases in overall as the amount of used curing agent decreases except the case of 2.5 wt%. The maximum adhesion force was about 1.8 N/cm^2 when inking 5 wt% of PDMS curing agent, which is superior to the previous result (~ 1.2 N/cm^2).

It is worth noting that there is a significant increase of adhesion force at 5 wt%, followed by a decrease of adhesion force at 2.5 wt%. We presumed that too low modulus rather leads to the incapability of remaining intact. One of the most important point to secure a enough adhesion in dry adhesive is to prevent initial crack propagation at the adhesion interface. Taking this fact into consideration, the initial crack propagation may easily occur in case of 2.5 wt%, due to a very low modulus and this can eventually give rise to the decline in adhesion force.

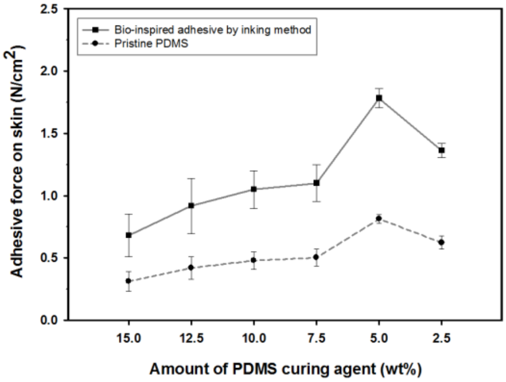

Fig. 2 Normal adhesion force of inked dry adhesive and flat PDMS sheet on human skin with various ratio of curing agent from 15 wt% to 2.5 wt%.

4. Conclusion

We have presented enhanced skin adhesives with increased adhesion that was realized by inking method. Our suggestion in this study will be expected to broaden the possibility for dry adhesive to replace with conventional adhesives, thereby minimizing any unwanted side-effects when applying medical devices mediated by adhesives on skin.

참고문헌

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