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Gecko-like Skin Adhesion

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Background

Considerable attention is being paid to wearable medical systems owing to their seamless integration with the human body and prolonged recording of physiological activities.Continuous monitoring of important vital signs, such as respiratory rate, heart rate, body temperature, and blood pressure level, can greatly assist early diagnosis of diseases and subsequent therapy. To this end various wearable payloads comprising physical sensors, electrochemical transducers, and transdermal drug delivery systems have been developed by the incorporation of functional nanomaterials into flexible supporting materials. However, their conformal attachment to the rough, curvilinear, soft, and textured surface of the skin remains a challenge.

Nature can offer alternative strategies for strong and reliable adhesion to complex surfaces. For instance, geckos can adhere to rough surfaces with their adhesive pads consisting of dense arrays of fine hairs or starfishes stick to complex under water surfaces through chemical glue secretion. Both approaches can be combined to provide a carrier that can be removably attached to human or animal skin and that adheres conformably and reliably to the skin through a facile, cost-effective, and mass-producible method.

Technology

The proposed soft and stretchable skin-adhesive micropatterns are composed of polydimethylsiloxane (PDMS) microfibers decorated with conformal and mushroom-shaped vinylsiloxane (VS) tips. The PDMS microfibers provide a structure that has a good strength and can allow the skin beneath the carrier to breathe and sweat. The flexible compliant material can readily adapt its shape, i.e. be deformed, in order to adapt to and/or conform to the shape of the surface it is attached to.

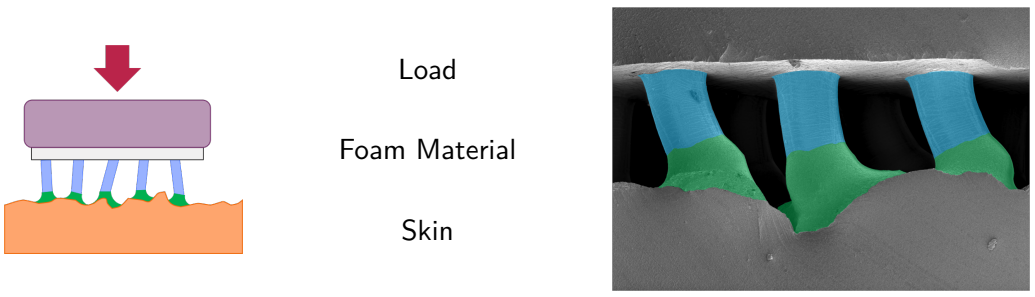

Figure 1: left: Sketch of the conformal attachment to the skin; right: cross-sectional SEM image of an adhesive film attached to an artificial skin; blue: PDMS microfiber, green: VS tip.

On use of the carrier, the tips of the microfibers are coated with VS, which is acting as an adhesive layer, on the one hand, and as a layer that enhances the conformity and/or adaptation of the carrier to the skin, on the other hand. Crosslinking of the viscous VS directly on the skin surface greatly enhances the skin adhesion through excellent shape conformation to the multi-scale roughness of the skin. Furthermore, this process enables reusability of the carrier: Each time the carrier is to be re-used the tips of the fibres simply have to be re-dipped in VS to reactivate a capability of being cross-linked.

VS tips provide a strong adhesion to the skin. As shown in Figure 1, mushroom-shaped microfibers with optimal tip shapes form when the viscous VS is directly crosslinked on the skin. Additionally, the viscous VS completely fills the space of the skin microgrooves prior to its crosslinking. Therefore, the micropatterned adhesive films are capable of establishing intimate contact with both micro- and nanoscale roughness of the skin.

The reusability of our adhesive films was tested by multiple times inking and printing of a microfibrillar adhesive film. The adhesion strength of the sample was 14, 10, and 8 kPa for first, second, and third time inking, respectively (see Fig. 2). The microfibrillar skin-adhesive film exhibited a robust skin adhesion under more than 300 loading cycles, while unstructured sample started to partially detached from the skin after 100 cycles.

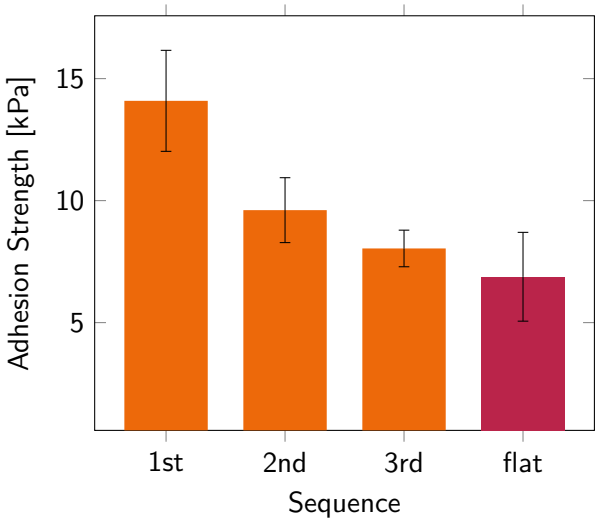

Figure 2: Adhesion strength of skin adhesive films after multiple inking and attachment processes compared to flat surface.

In addition to skin, the proposed composite microfibrillar adhesive films could attach to other surfaces with complex topographies and a wide range of surface roughness length scales under various dry and wet environmental conditions.

Summary

- good skin conformity, high adhesion
- soft and flexible material
- tip structure leaves free skin to breath and sweat
- re-useable by reactivating tips by dipping into ink
- materials approved for medical applications

Patent Information

EP priority application filed April 2017. PCT application filed April 2018.