Fabrication of Microstructures on Curved Hydrogel Substrates

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Wearable devices with various functionalities have been wildly applied in the healthcare field for measuring and monitoring biomarker-associated signals, such as glucose level, heart rate, and sweat compositions. [1,2] Among all the wearable device substrates, hydrogel substrates, such as contact lenses, have attracted huge attention because of their superior bio-compatibility and mechanical properties. Current smart contact lenses with embedded metal structures are fabricated by sandwiching metal layers inside the contact lenses during manufacturing processes. However, such integrated metal microstructures inside curved and flexible hydrogel substrates induce unwanted mechanical stress that could break the contact lenses and irritate users' eyes. [3] Further, such a fabrication method cannot be used for producing customized functional microstructures.

Here, we present a shadow-mask-assisted deposition method capable of directly generating microscale metal patterns (e.g., titanium, gold, and aluminum) on contact lenses. The process integrates a silicon shadow mask with pre-defined patterns and regular physical vapor deposition method, capable of generating arbitrary patterns on curved and flexible hydrogel substrate. Taking advantage of the flexibility of the hydrogel substrates, we can flatten a cone-shaped contact lens on the planar shadow mask for high resolution feature deposition. After the recovery of the lens, a patterned metal layer has been deposited on the curved substrate. During this process, the pattern deformation and distortion caused by the flattening process are quantitatively simulated, and the corresponding compensation features are introduced to the initial patterns on the shadow masks, therefore minimizing such flattening-induced distortion.

The presented method includes three main steps: (i) etching through a silicon wafer to fabricate a shadow mask, which defines the patterns of the to-be-deposited metal features; (ii) Aligning the target contact lens and the shadow mask on a 3D-printed supporting mold to precisely determine the location of the patterns; (iii) Evaporating metal with the suitable deposition rate to achieve stable metal structures on the hydrogel substrates. **Fig.1(a)** shows the schematic illustration of a shadow mask, and **Fig. 1 (b)** illustrates the metal deposition on a contact lens with the shadow mask. **Fig. 2** shows the photograph of a representative contact lens coated with densely arranged Ti lines of 100μm width and spacing.

This work could be further developed as a reliable manufacturing method for generating functional devices, such as strain and biomedical sensors, on curved flexible substrates. Additional details of the presented fabrication method as well as device demonstrations will be presented in the formal presentation.

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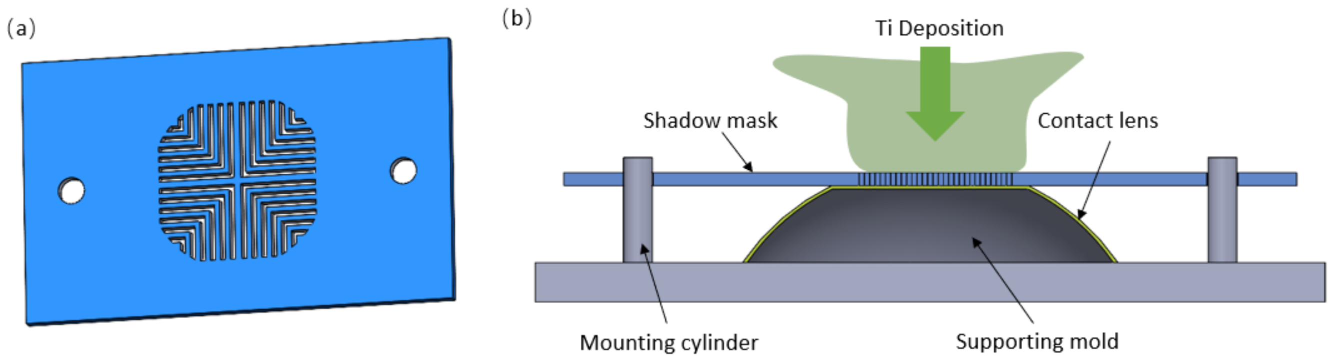

Fig.1 Schematic illustration of a shadow mask and the metal deposition on a contact lens with the shadow mask.

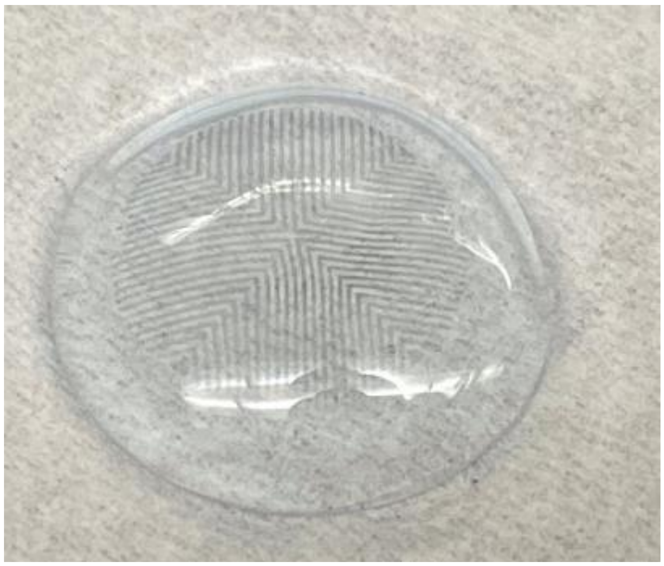

Fig.2 Photograph of a representative contact lens coated with densely arranged Ti lines of 100µm width and spacing

[1] Keum, Do Hee, et al. "Wireless smart contact lens for diabetic diagnosis and therapy." Science Advances 6.17 (2020): eaba3252.
[2] Izmailova, Elena S., et al. "Continuous monitoring using a wearable device detects activity-induced heart rate changes after administration of amphetamine." Clinical and translational science 12.6 (2019): 677-686.
[3] Park, Jihun, et al. "Soft, smart contact lenses with integrations of wireless circuits, glucose sensors, and displays." Science advances 4.1 (2018): eaap9841.

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