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Morphology of Metal-Coated Silicone Films

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INTRODUCTION: Electrically activated polymer (EAP) thin film structures are promising alternatives to the currently used, mechanically driven artificial urinary sphincters. In order to reach clinically relevant voltages (below 42 V) the thickness of the EAP has to be reduced to around 1 µm or even below. The thickness homogeneity of the films should be better than 2% to guarantee a constant electrical field in the polymer. State-of-the-art spin coating of biocompatible silicone can provide such precision over 2-inch wafers.

METHODS: The first contact layer of the EAP structure, i.e. Au, Au/Cr or Ti each 50 nm thin, was deposited onto a 30 µm-thick part of 4"-Si(100) by sputtering or thermal vapour deposition (Nordiko Ltd. NS 2550 and Pfeiffer ONF 010, respectively). Subsequently, the micrometer-thick silicone film was fabricated using spin coating (Laurell WS-400A 6NPP). The EAP structure, which is asymmetrically positioned on one side of the wafer piece, was finalized forming the second contact like the first one. The morphology of the EAP structures was characterized by means of optical and atomic force microscopy (Leica DMRM and Nanosurf Mobile S, respectively).

RESULTS: The physical vapour deposition onto the silicone film, i.e. sputtering or thermal techniques, did not result in homogeneous and flat EAP structures but in more or less regular ripple morphologies. Although the orientation was arbitrary and only directed at defects such as cracks (see Fig. 1), the periodicity of the corrugation was constant for each sample. The wavelength of the pattern formed only depends on the choice of metal coating and thickness. Based on Fourier transforms it has been found that 50 nm Au leads to 2.5 µm periodicity, 50 nm Ti to 4.0 µm and 50 nm Cr to 6.0 µm. The ripples align perpendicular to frequently detected defects in the silicone film, such as cracks, dust particles and sample edges. In defect-free regions no preferential orientation occurs. For the specimens sputtered with Ti, however, a remarkable amount of cracks in the silicone film was observed. Parallel cracks with distances varying between 0.2 and 10 mm run across the whole specimen. While the height variation of the ripples corresponds up to 10% of the silicone film thickness, the cracks were more than 30% of the film thickness deep as shown by the AFM image in the inset of Fig. 1. The ripple and crack structures were not present before the metal deposition.

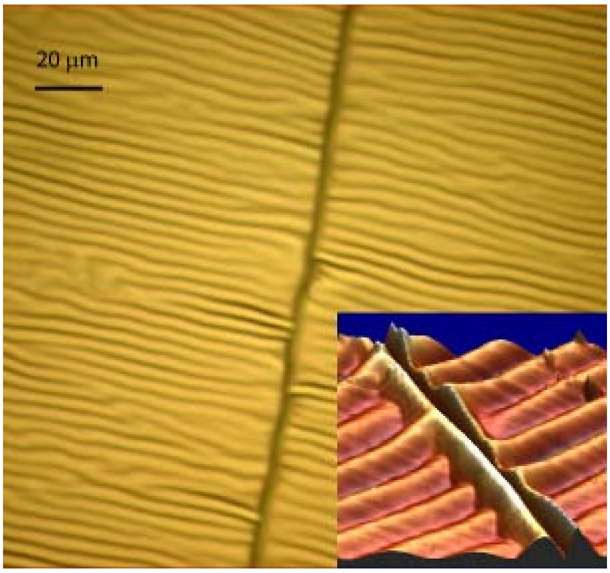

Fig. 1: The optical micrograph shows the regular corrugation of the Ti-coated silicone film oriented perpendicular to the crack. A related AFM image is given in the inset.

DISCUSSION & CONCLUSIONS: The ripples originate from the different thermal expansions of the silicone and the deposited metals.[1] The periodicity of the corrugation depends on the thickness and the Young's modulus of the deposited metal. Higher Young's moduli and thicker films result in larger periodicities. Regular pattern of desired periodicity can be manufactured selecting the suitable metal and film thickness.[2] The crack formation is associated with local charges that are generated during the sputtering process but not by thermal deposition.

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