Preparation and characterization of nanometer-thin silicone films for dielectric elastomer transducers

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Nanometer-thin silicone films are essential components of low-voltage dielectric elastomer transducers and will, for example, play a vital role in future artificial muscles [1]. Organic molecular beam deposition (MBD) is a versatile technique to prepare silicone films under well-defined conditions [2,3], but the achievable growth rates of about 1 µm per hour are too low for the fabrication of multi-layer devices. Therefore, we have developed electro-spraying as an alternative deposition method with one or two orders of magnitude faster rates [4,5]. For the two approaches, spectroscopic ellipsometry (SE) has been employed for *in situ* monitoring the film's optical properties, the film thickness and the surface morphology during deposition and ultra-violet (UV) light irradiation. The derived quantities were verified by means of atomic force microscopy (AFM).

Subsequent to the silicone deposition and the cross-linking by UV light curing, Au has been deposited using MBD and sputtering. This deposition process was also quantitatively characterized using SE and controlled by means of the plasmonic fingerprints of the metal nanostructures [6]. The *ex situ* AFM measurements revealed well-known modulations characteristic for strained surface layers [7]. Recent nano-indentation tests have demonstrated that the Au-layers on the silicone near the critical stress regime hardly contribute to the overall elastic modulus and are, therefore, a sound basis for smart electrodes [8]. The nano-mechanical probing of the powered thin-film dielectric elastomer transducers evidenced the importance of the thickness homogeneity for such devices [9]. The function of planar thin-film dielectric elastomer transducers can be precisely determined taking advantage of the cantilever bending approach [10].

In conclusion, spectroscopic ellipsometry and advanced atomic force microscopy with nano-indentation capability enables us to thoroughly characterize the film morphology as well as the optical and local mechanical parameters of silicone and Au/silicone nanostructures.

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Supplementary Page

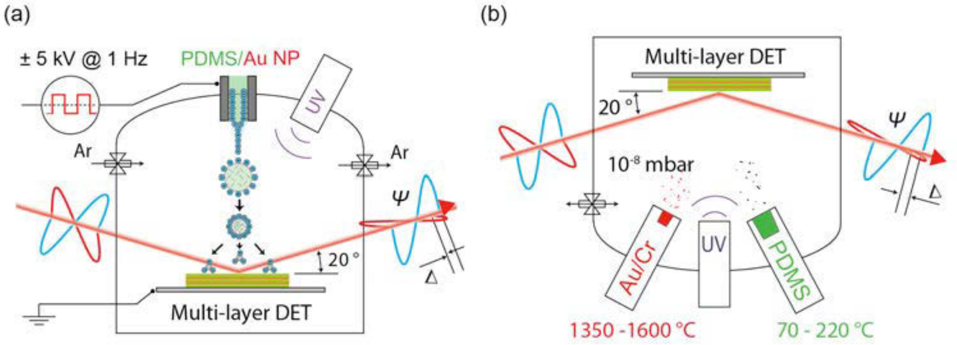

Figure 1. Schematics of experimental setup for the fabrication of DETs using (a) electrospray deposition (ESD) and (b) organic molecular beam deposition (MBD) system. Spectroscopic ellipsometry serves for the *on line* monitoring of the film growth.

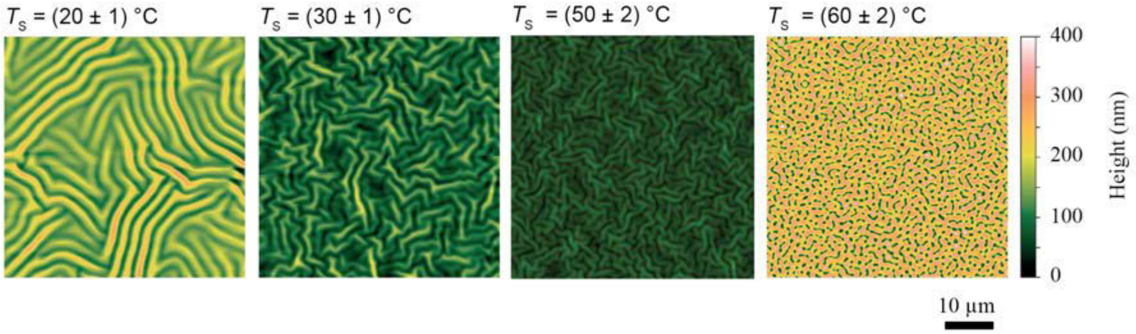

Figure 2. The morphology of (350 ± 50) nm-thick silicone films, oxygen plasma treated at selected substrate temperatures T_s. The substrate temperature determines the formation of nanostructures: wrinkles at T_s = 20 °C and sub-micrometer knops at T_s = 60 °C.

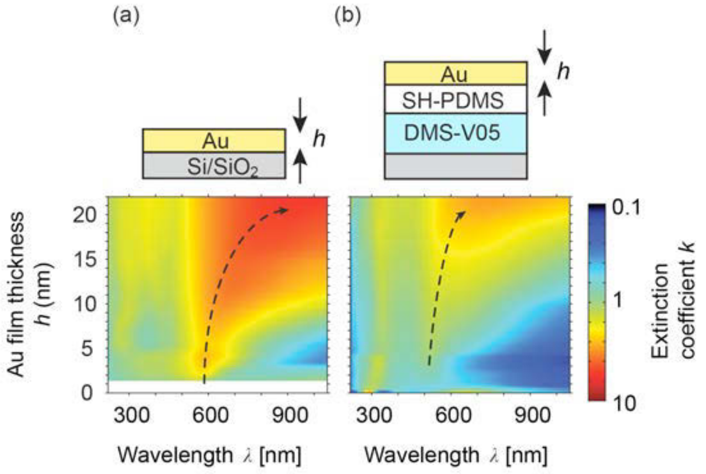

Figure 3. Plasmonics of growing Au. The film-thickness-dependent spectroscopy results of the extinction coefficient k are shown for thermally evaporated Au (a) on SiO_2/Si and (b) on thiol-functionalized silicone thermally deposited on a UV-cured commercially available elastomer film.