A.7: Electrostatic comb-drive: a powerful tool for microsensing and microactuation fabricated using BL-07 of Indus-2

Deep X-ray lithography (DXRL) is a core process in X-ray LIGA technology for fabricating high aspect ratio microstructures and microsystems and currently being done at BL-07 of Indus-2. LIGA is a German acronym for lithography, electroplating and polymer replication and has emerged as a strong tool for developing high aspect ratio microstructures. The advantage of DXRL lies in its ability to fabricate high resolution and high aspect ratio microstructures with excellent surface finish, which is not possible by conventional micromachining techniques. For instance, to fabricate electrostatic comb-drives few of the important microfabrication techniques are surface micromachining, bulk micromaching and LIGA. Electrostatic comb-drives are at the heart of many of the present day's mechatronic system. The comb-drive can be used as microactuator, resonator, accelerometer, switch, energy harvester, voltmeter, microgripper and electromechanical filters.

Comb-drive consists of a set of moving and a set of fixed fingers. The movement of moving comb is controlled by the stiffness of spring attached to it and applied electric field (Fig. A.7.1). In addition the performance of the comb-drive is governed by the number of comb fingers, air gap between the fingers and height of the comb-drive. In this work comb-drive is designed using serpentine spring and the other parameters as shown in Fig. A.7.1 to deliver 2.5 μm displacement at 100 volts DC and force > 100 μN.

The most challenging part of DXRL is the fabrication of X-ray mask as we need 1:1 mask for contact printing. It involves UV lithography, Ni and Au electroplating, development of polyimide membrane. A polyimide-Au X-ray mask is developed for fabricating <= 800 μm high comb-drive structures of Poly(methylmethacrylate) (PMMA), an X-ray resist. Following the UV lithography of comb-drive patterns on positive resist coated brass wafer, 10 μm Au is electroplated over 500 nm thick Ni on cleaned brass wafer. To support the electroplated Au patterns, 50 μm thick polyimide membrane is made over the Au patterns. Later stainless steel ring is glued on the top of the polyimide membrane and brass wafer is etched in 67 vol% nitric acid. In this way polyimide-Au X-ray mask for comb-drive is developed.

PMMA is used as an X-ray resist and the polyimide-Au X-ray mask is fitted over the resist on the scanner stage of experimental hutch at BL-07. The thickness of PMMA sheet is 800 μm and 2333 mA.min X-ray dose is deposited from the SR source.

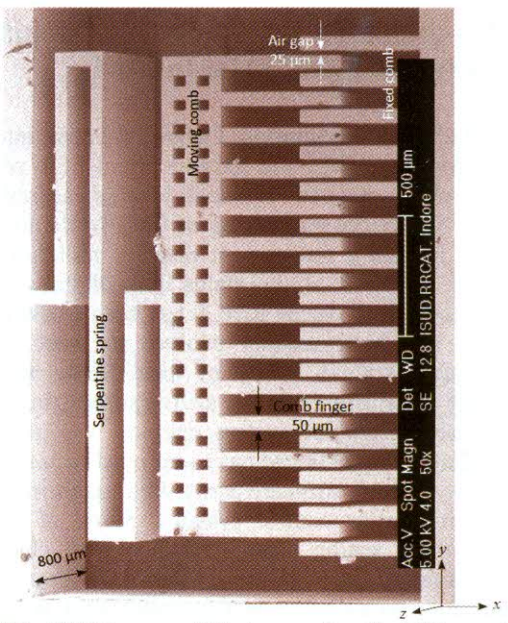

Fig.A.7.1: SEM image of high aspect ratio (32) comb-drive fabricated by one-step DXRL at BL-07 in Indus-2. The comb-drive is 800 μm high (z-direction) with air gap between the comb finger of 25 μm and comb finger 50 μm wide.

The development of the exposed PMMA is done in the GG developer for 72 hours without any thermal and mechanical excitation. The fabricated comb-drive structures are rinsed in the rinser solution followed by DI water. The drying is done very carefully to avoid any breakage due to the presence of capillary force in the critical regions of the comb-drive structure (e.g. air gap between the comb fingers). An SEM image of the high aspect ratio comb-drive structure is shown in Fig. A.7.1. The moving comb, fixed comb, serpentine spring, air gap and relevant dimensions are shown in Fig. A.7.1. For both sensing and actuation conducting electrodes are made over the fabricated PMMA microstructure of comb-drive. To obtain the conducting electrodes, metallization of the comb-drive structures of PMMA is selectively done from 250 nm thick gold using RF sputtering technique.

Comb-drive of aspect ratio 32 by one-step DXRL at Indus-2 is fabricated. The displacement of 2.5 μm is achieved for 100 Volts DC in x-direction. For fabrication of comb-drive structures polyimide-gold X-ray mask is developed. Using the X-ray mask the exposure is done at BL-07 at Indus-2 on 800 μm thick PMMA substrate. GG developer is used for the development of exposed comb-drive patterns. The response of the comb-drive is observed under DC and AC electric field. For details please refer; Shukla R. et al., Microsystem Technologies, 20, 1273-180, 2014.

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