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TECHNICAL PAPER

Technological aspects of a new micro-electro-mechanical actuation principle: nano-e-drive

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Abstract This paper presents the technological aspects of a newly demonstrated actuation principle, the so-called nano-e-drive. Using this principle, cantilevers can be moved in or out of chip plane. In this paper, only the out-of-plane version of the nano-e-drive will be presented. Wafer topography is the main feature on which the nano-e-drive principle is based. From a technological point of view, the challenge is to generate a user-defined topography and then to optimize all technological steps for the previously defined topography. Layer deposition, lithography and etching are the main technological steps to be optimized during the processing of the nano-e-drive actors. The process is a mixture of surface and bulk technology. Nano-e-drive actuators with different topographies are fabricated and characterized electrically. The results are presented and discussed in detail.

1 Introduction

Electrostatic actuation (Bell et al. 2005) is a well-known principle and is widely used due to its simplicity, energy efficiency, quick response and compatibility with standard micro electro-mechanical-systems (MEMS) fabrication technologies (Ghodssi 2011). This principle, however, is prone to the so-called pull-in effect (Zhang 2014, Nathanson et al. 1967, Elata and Bamberger 2006), i.e., at a certain applied voltage the electrodes of the actuators will come into contact due to the electrostatic forces acting between them. Pull-in is normally undesired, because it limits the actuation only to a certain fraction of the distance between the electrodes. Therefore, for applications where large deflections are required, large gaps between the electrodes are necessary, which in turn means that higher voltages are required during actuation.

Recently Conrad et al. (2015) published a first paper on a new actuation principle for micro-electro-mechanical systems, the so-called nano-electrostatic drive (NED). The NED is less prone to the pull-in effect, meaning that NED-actuators can achieve deflections larger than the gap between the electrodes. Depending on the technological implementation, the NED is capable of actuating e.g., a cantilever in or out of the MEMS wafer plane. In this paper, only the out-of-plane version of the NED actor will be considered, also called vertical NED (VNED).

Figure 1 shows the basics of the VNED principle. The VNED actuators consist of two main parts: a cantilever and a layer stack. The cantilever is the actuated element on top of which the layer stack is added. The layer stack is composed of a separation layer (SL, Fig. 1: 1), a bottom electrode (BE, Fig. 1: 2), isolation islands (IIs, Fig. 1: 3), a sacrificial layer (SacL, Fig. 1: 4), and a top electrode (TE, Fig. 1: 5).

The separation layer is the interface between the layer stack and the cantilever. It does not need to be electrically isolating or conductive. However, it should be suitable as a stopping layer for dry-etching processes, so that the structuring of the bottom electrode is made possible without attacking the cantilever underneath.

The top and bottom electrodes must be electrically conductive, so that a potential difference between them can be applied. In contrast to the electrodes, the isolation islands

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