ELECTROSTATIC BENDING ACTUATORS WITH A LIQUID FILLED NANOMETER SCALE GAP

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ABSTRACT

We report a considerable improvement in the electrostatic actuation of silicon-based nano electrostatic drive (NED) structures [1] via the insertion of a liquid into the nanosystem. The dielectric liquid provides an insulating, high dielectric constant deformable medium in the electrode gaps that enhances the generated force per unit-applied volt performance. The study demonstrates that small volumes of liquids (microfluidics/nanofluidics) can be inserted into micro and nanoelectromechanical systems (MEMS/NEMS) to enhance systems' performances up to 2.75.

INTRODUCTION

The electrostatic approach is an excellent choice for actuation of micro and nanoelectromechanical systems (MEMS/NEMS) for several reasons: MEMS/NEMS processes which are used for the fabrication of electrostatic actuators are standard and compatible with CMOS technology. Also, in respect with the pull-in problematic [2], the inverse square relation between the generated actuation force and the electrodes' separation distance enables one – with a downscaling of the gap – to expand actuation possibilities that has advantages over other physical driving principles. In this paper, we propose the development of a MEMS/NEMS NED actuator using a fluid as a gap medium in order to improve its electrostatic actuation capabilities.

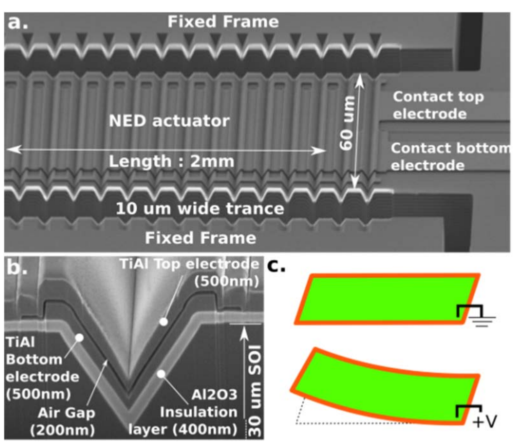

Figure 1: Scanning electron micrograph images (SEM) showing (a) the base of a NED actuator cantilever, (b) a zoom of a cross-section (obtained using focused ion beam) of a single actuation cell, and (c) a schematic diagram illustrating the bending behavior of the actuator.

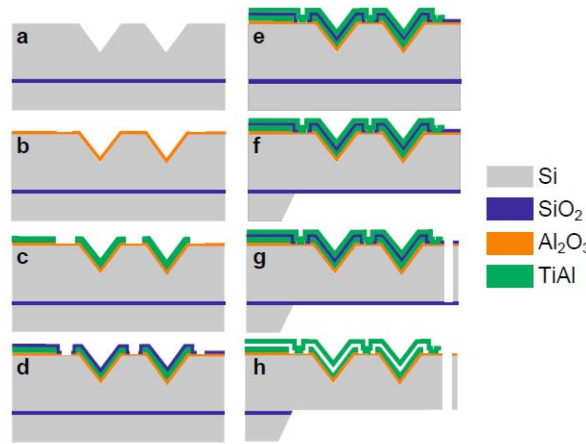

Figure 2: Fabrication process of the NEDs. (a) Wet etching (b) Atomic Layer Deposition of Al_2O_3 (c) Sputtering of 1st TiAl film (d) Chemical Vapor Deposition of SiO_2 (e) Sputtering of 2nd TiAl (f) Handle Silicon removal (wet etch) (g) DRIE etching and (h) HF vapor etch release.

DESIGN

The NED actuator (shown in Fig. 1) is composed of a number of facing electrodes, mounted on a cantilever and separated by electrically insulated spacer layers. When applying a potential difference to the electrodes, the electrostatic force attempts to pull down the top electrode to the bottom electrode. Due to the V-shaped topography of the electrodes, a lateral mechanical force is generated which induces a lateral strain in the surface of the cantilever causing a cylindrical bending of the cantilever. The well-established electrostatic force equation is as follows:

$$F = \varepsilon_0 \varepsilon_r V^2 A / 2d^2$$

This gives the linear relationship between the generated force F between the two electrodes of surface A, facing each other at a distance d at a potential difference V, and the relative permittivity ε_r of the medium to the vacuum permittivity ε_0. The fundamental idea of this study is to increase the value of the relative permittivity in the electrostatic gap by using a dielectric fluid – the performance enhancement in terms of actuation force is thus $\varepsilon_{liquid}/\varepsilon_{air}$.