Integration of PZT Dielectric Films in MEMS Capacitative Switches

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Introduction

Much research in MEMS has focused on two major themes:
• adding greater 3-dimensionality to inherently 2D lithography-based fabrication
• adding new capabilities by incorporation of functional materials

This project is part of a programme aiming at the integration of capabilities within each of these themes, namely:
• 3D fabrication, e.g. by self-assembly of 2D patterned structures
• Electro-ceramic films for advanced electrical and electro-mechanical properties

In this work we have investigated integration of ferroelectric films with electroplated moving parts, and their associated release processes. The device is an electrostatic switching capacitor, used in an RF shunt switch. The piezoelectric layer is PZT (lead zirconate titanate), employed for its very high relative permittivity, to achieve a high switching ratio.

Device Concept

Shunt Capacitive RF MEMS Switch

Design features
• Electrostatic actuation
• Thin film-PZT dielectric layer for high isolation
• Low spring constant beam for low pull-down voltage
• Top contact electrode for reproducible contact area and minimising of surface roughness effects

Modelling

Lumped element RF modelling was used to calculate the increased isolation with a PZT dielectric layer (b) compared to SiNₓ (a) for the same dielectric thickness (0.3um) and device area (160 x 600µm). The insertion loss is independent of the choice of dielectric.

Materials and Fabrication

The thin film PZT cross-section is shown on the left. As seen in the XRD trace (right), full crystallisation was achieved with no sign of the parasitic pyrochlore (py) phase.

Process Flow

Si wafer is oxidised, then coated with Ti/Au-PZT-Ti/Pt stack (A). The Ti/Pt bottom electrode (8/100 nm), deposited by RF magnetron sputtering, and the sol-gel PZT, built up to 0.4 µm in 4 spin-bake cycles, are left unpatterned prior to deposition of Ti/Au(10/100 nm) top electrode.

Patterning of the stack (B) is by lift-off for the last layer, followed by the sequential reactive ion etching of PZT and Ti/Pt in CHF₃/Ar and Ar plasmas respectively.

Patterned wafer is then coated with a sacrificial and a gold layer successively (C). Finally (D), anchors are strengthened by electroplating, and sacrificial layer removed to release membrane.

Results

PZT films can be integrated with MEMS devices based on electroplated metal parts and dry release. Besides its piezoelectric properties, PZT also offers very high relative permittivity, and thus can realise high switching capacitance ratios with modest actuation distances. This will allow greater freedom in the optimisation space which trades off actuation voltage with suspension stiffness (and thus vibration sensitivity).

RF characteristics were corrupted in these first devices by the parasitic loading of the coplanar waveguides. This resulted from excessive substrate conductance, leading to high signal to ground capacitance. This also limits the measured RF performance. Work is currently underway on insulating substrates.

Removal of resist residue underneath the beams is not always complete, so further optimisation of this process is required.

PZT films in some cases suffered dielectric breakdown near the actuation voltages. New device designs will vary thickness ratios to diminish this problem.

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Conclusions and Future Work

RF modelling was used to calculate the increased isolation with a PZT dielectric layer (b) compared to SiNₓ (a) for the same dielectric thickness (0.3um) and device area (160 x 600µm). The insertion loss is independent of the choice of dielectric.