Non-destructive piezoelectric characterisation of Sc doped aluminium nitride thin films at wafer level

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Background, Motivation and Objective

Within the last years, Sc doped aluminium nitride (ScAlN) gained much importance due to its strongly enhanced piezoelectric response compared to pure AlN [1]. Furthermore, ScAlN films with more than 30% Sc possess not only a large piezoelectric response, but also a low dielectric constant, which makes them interesting for piezo-driven MEMS such as energy-harvesting devices [2] or piezo-driven gyroscopes [3] and mirrors. For volume manufacturing, maintaining excellent within-wafer uniformity of material and thin-film properties is fundamental. Therefore, a good uniformity and repeatability control of the properties is crucial. In this contribution, we compare different piezo-properties at wafer level for various Sc/(Sc+Al) concentration (0–33%).

Statement of Contribution/Methods

A magnetron sputtering process for ScAlN films was presented, providing the foundation for large-quantity production of piezoMEMS [4], [5]. At the last IUS we showed 200-mm wafer maps of the longitudinal and transversal piezoelectric coefficients of $Sc_{33}Al_{67}N$ films, $e_{31,f}$ and $d_{33,f}$ respectively [5]. The films are sputter deposited on Pt and Mo from pure Al or AlSc alloy targets. Film stress is tightly controlled and growth in the desired AlN wurtzite phase is confirmed by SEM and XRD. For characterisation, patterned Mo electrodes are applied. The dielectric constant ε_r is measured using plate-capacitor structures. The piezo coefficients $d_{33,f}$ and $e_{31,f}$ are determined with a double-beam laser interferometer on different pad sizes combined with finite element modelling [6]. Furthermore, $e_{31,f}$ is directly measured for verification using a 4-point-bending setup in direct mode [7]. In addition, the electro-mechanical coupling is determined by applying a new method, which is based on impedance measurements using a VNA (vector network analyzer). HBAR resonators consisting of the substrate and piezo layer, sandwiched between electrodes, are measured, as well as simulated using a multilayer transducer matrix formalism [8]. Through an iterative fitting algorithm, k_t^2 is obtained.

Results/Discussion

ScAlN films were deposited on a 200-mm sputtering system from single targets (pure Al or AlSc alloy). Material properties ($e_{31,f}$, $d_{33,f}$, k_t^2, ε_r, tanδ) are brought into relation to different Sc content (0–33%). The film properties are determined non-destructively at wafer level, which will be of great advantage for process development and device-design evaluation. 33% Sc containing films exhibit a piezoelectric response of $e_{31,f} = -2.3 \pm 0.1$ C/m^2 and $d_{33,f} = 11.8 \pm 0.2$ pm/V. For k_t^2 we expect values on the order of 16%, which is around 2.3 times larger than for pure AlN. The shown Al–Sc property–uniformity maps provide a good foundation for AlN/ScAlN based MEMS device design and manufacturing.

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