Assessment of the acoustic shear velocity in SiO_2 and Mo for acoustic reflectors

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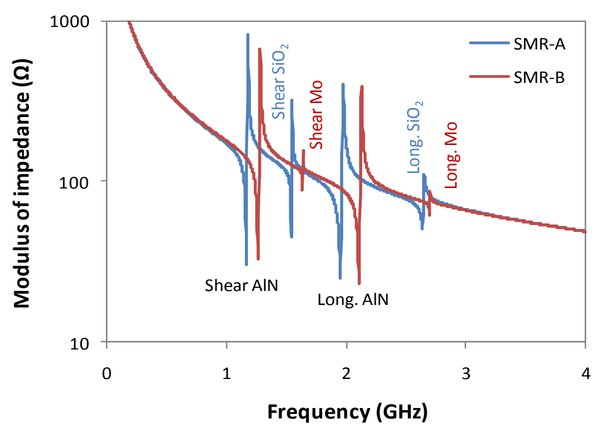
During the last years, the scientific community has shown an increasing interest for acoustic resonators operating in the shear mode. Contrary to resonators operating in longitudinal modes, shear resonators do not suffer a significant degradation of the *Q* factor when operating in liquid environments, owing to the movement of their particles parallel to the surface of the liquid. This property, added to a high frequency of operation, robustness and low losses, makes AlN-based solidly mounted resonators (SMR) operating in the shear modes excellent candidates for biosensing purposes. The design of such devices requires a precise knowledge of the acoustic properties of the materials composing the whole structure, and especially of the shear velocities of the high and low impedance layers composing the acoustic reflector, in order to guarantee the confinement of the shear wave in the piezoelectric stack. In this work, we propose a straightforward method for assessing the acoustic shear velocity through the resonances induced in the high and low acoustic impedance layers of the acoustic reflector of an SMR. It basically consists in measuring the effects of a half-wavelength resonance induced in a given layer of the reflector on the electrical response of the resonator made on it.

Tilted AlN films were grown by pulsed DC-sputtering of a 6'' Al cathode on silicon wafers held at 400 ºC and covered with acoustic mirrors formed by $\lambda/4$ alternated layers of Mo and porous SiO_2. Two sets of samples were fabricated with enlarged thicknesses (from 0.8 µm to 1.5 µm) of the uppermost layers of SiO_2 or Mo for the assessment of their acoustic longitudinal and shear velocities. The growth of the inclined AlN grains was stimulated by combining a thin AlN seed layer and off-axis sputtering.



Electrical response of two resonators on the Bragg mirror with an enlarged uppermost SiO_2 layer of 1.2 µm (A) and uppermost Mo layer of 1.3 µm (B)

Apart from the longitudinal and shear resonances corresponding to the AlN films, the frequency response of the SMRs revealed that longitudinal and shear $\lambda/2$-resonances were also excited in the uppermost SiO_2 or Mo layers with frequencies related to their thickness, mass density and sound velocities (see figure). After assessing the thickness and mass density (using x-ray reflectance) of all the layers, the fitting of the electrical response in a wide frequency range with Mason's model provided accurate values of both longitudinal and shear velocities. Low acoustic impedance SiO_2 exhibited a shear velocity of 3130 m/s, whereas that of high acoustic impedance Mo was 3333 m/s. These values are 65% and 54% of the longitudinal velocity of SiO_2 and Mo, respectively.