Numerical and experimental investigations of higher-order modes on $Sc_xAl_{1-x}N$/Sapphire structure for high-temperature SAW applications

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Background, Motivation and Objective

AlN/Sapphire structure has been previously demonstrated as a major candidate to achieve high-temperature SAW sensors. However the limited piezoelectric properties of AlN restrict the field of applications. This drawback can be overcome by the partial substitution of Al atoms by Sc ones. Moreover, ScAlN films are softer than AlN ones, which provides the possibility, when combined with sapphire, to generate higher order modes with high velocity and strong electromechanical coupling coefficient K^2. Faster modes enable the design, for a given operating frequency, of thicker and wider IDT fingers for more robustness. In this paper, we investigate both numerically and experimentally the possibility to generate such modes with the ScAlN/Sapphire structure.

Statement of Contribution/Methods

Highly-textured c-oriented $Sc_{0.09}Al_{0.91}N$ and $Sc_{0.18}Al_{0.82}N$ films with thicknesses up to 3 µm were sputtered on sapphire substrates. Based on these structures, synchronous SAW resonators with Al electrodes and wavelengths of 6.5 and 13 µm were achieved by conventional photolithography. Admittance functions were simulated for resonators with Al or Cu grating arranged on top of ScAlN/Sapphire using the software SDA-FEM-SDA and reported constants of $Sc_xAl_{1-x}N$ films with different Sc content. These results were compared with measurements. Characteristics of acoustic modes were extracted from the calculated admittances as functions of the film and electrode thicknesses. The analyzed structures were optimized to allow the propagation with a negligible attenuation of the mode with a velocity between 9000 and 11000 m/s.

Results/Discussion

Experimental and numerical investigation of acoustic modes propagating in $Sc_xAl_{1-x}N$/Sapphire revealed that in addition to Rayleigh SAW and SH-SAW, high-velocity leaky SAW with sufficiently high K^2 can be generated in this structure when Sc content varies in a wide range. Its velocity is confined between the velocities of the longitudinal bulk waves in sapphire and in ScAlN, and leakage into the substrate vanishes at certain electrode and film thicknesses. For example, non-attenuated longitudinal wave can propagate with velocity 9000 m/s and coupling 0.6% in $Sc_{0.4}Al_{0.6}N$/Sapphire with Cu grating if the film and electrode thicknesses are optimized (Fig. 1). The behavior of the longitudinal LSAW with variation of Sc content will be also discussed.

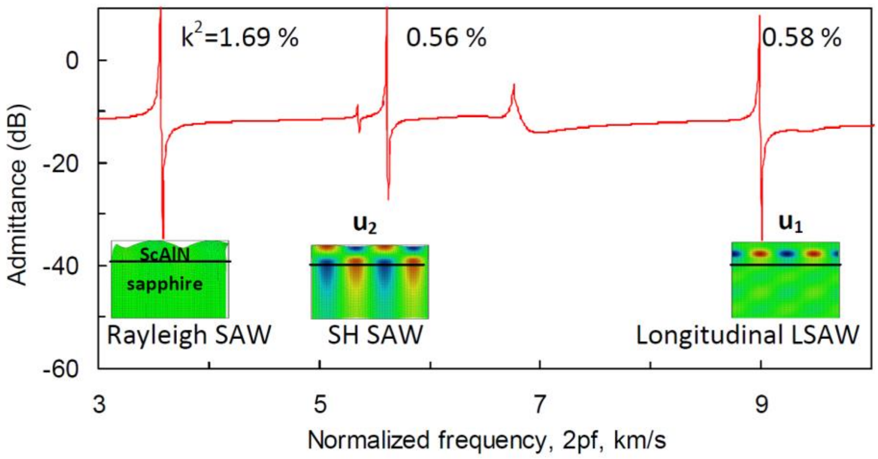

Fig. 1. Simulated admittance for Cu grating on $Al_{0.6}Sc_{0.4}N$ /sapphire with non-attenuated longitudinal LSAW mode.