Embedded Nanotransducer for Ultrahigh-frequecy SAW Utilizing AlN/Diamond Layered Structure

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The article reports on the development and realization of ultrahigh-frequency, high-performance nano interdigital transducers (n-IDTs) for generation of surface acoustic wave (SAW) on AlN/diamond/Si substrates, where the metal fingers are embedded in the AlN film. The well-defined n-IDTs' resolutions down to 125 nm were obtained using electron beam lithography, ICP etching and lift-off processing. The fabricated devices exhibit response at a ultrahigh-frequency range, as high as 18.6 GHz, with minimal insertion losses. The good high-frequency characteristics of the embedded n-IDTs and compatibility with existing fabrication technologies open the way for the realization of advanced sensors and monolithic integrated MMICs on AlN/diamond/Si substrates.

Surface acoustic waves' (SAWs) unique properties make them suitable not only for electrical signal processing, but also for other application such as sensing [1]. For almost all SAW applications, there is a strong demand for higher frequencies, for example to enhance processing speed and to reach the quantum regime [2]. The promising substrates are expected from the AlN/diamond layered structures due to its high acoustic velocity, thermal properties, good electrical-optical properties, etc [3]. Compared with the conventional piezoelectric materials such as $LiNbO_3$, however, AlN has weak piezoelectric coupling coefficients. The generation of strong SAW fields on AlN requires IDTs with a large number of fingers, leading to SAW losses in IDTs due to an important issue of reflection. Two approaches have been proposed to reduce the losses. One is to reduce the acoustic mismatch between the metal-free and metal-covered regions by using a low-density metal for the fingers, but it doesn't work effectively in n-IDTs. The second one is the split-finger configuration, but the reduced feature size is a serious constraint for the lithographic techniques. Here, we report the generation and characteristics for the first time of ultrahigh-frequency SAW beams on AlN/diamond layered structure using single-finger IDTs with metal fingers embedded into the substrate to reduce the losses induced by metal transducers.

The process for fabricating embedding n-IDTs is CMOS compatible. Firstly, we transferred the interlocking comb-shaped patterns to the surface of AlN film by direct writing e-beam lithography. The widths of the finger varied from 125 nm to 500 nm. In order to overcome the charge accumulation, a chrome film was deposited after ZEP resist coating. Then, the ~50 nm finger embedding structure was achieved by an ICP etching step prior to the deposition of the IDT metal layer. Finally, a lift-off process is executed. The measurement of the fabricated devices was performed 'on-die' by an Keysight network analyzer equipped with Cascade probes.

The fabricated devices with embedded transducers exhibited highest operating frequencies up to 18.6 GHz with an insertion loss of 35 dB. And all novel devices exhibited a minimum stop band rejection of 23 dB. Compared to the conventional devices, we demonstrated the superior performance using embedded fingers to reduce Bragg reflection substantially. The embedded n-IDTs open a way for the generation of ultrahigh-frequency SAWs on weak piezoelectric substrates such as the conventional III-V semiconductors and make it possible for the realization of advanced sensors and monolithic integrated MMICs.

References

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