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Approach to high-frequency acoustic wave devices

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Tomoaki Karaki is a professor in Toyama Prefectural University, Japan. Tomoaki Karaki received the Ph.D. degree in electrical engineering from Kyoto University, Kyoto, Japan, in March 1996. From April 1993, he is with Toyama Prefectural University, Toyama, Japan. His research interests include: 1) growth of piezo- and ferro-electric single crystals, 2) preparation of lead-free piezoceramics, and 3) characterization of acoustic wave related physical constants in piezoelectric single crystals. He is recently researching on alternating current poling of lead-based relaxor-lead titanate piezoelectric single crystals.

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Wireless communication technology has evolved rapidly, and the communications industry has experienced huge leaps from 2G, 3G, 4G to 5G, and is moving towards 6G. Frequency filters based on piezoelectric materials directly determine the operating frequency band and bandwidth of the communication equipment, and plays a pivotal role in the communication devices. This lecture, the operating frequencies and principles from SAW (surface acoustic wave) to XBAR (transverse-electric-field excited bulk acoustic wave resonator) and the requirements for piezoelectric materials will be introduced.

The propagating speed of SAW of piezoelectric materials is less than 5000 m/s. Because the width of the (interdigital transducer) IDT electrode is limited about 0.5 μm, the maximum operating frequency of the SAW is less than 2.5 GHz. To increase the frequency, IHP SAW (incredible high performance SAW)，in which a piezoelectric film is prepared on a substrate with high acoustic speed, has been realized. In this case, the operating frequency has been increased to 3.5 GHz.

With the improvement of piezoelectric film preparation technology and precise control of film thickness, a SMR-BAW (solidly mounted resonator bulk acoustic wave) utilizing piezoelectric material thickness vibration has been proposed. The operating frequency of SMR-BAW is increased to 6 GHz.

The FBAR (film bulk acoustic resonator), which also utilizes the vibration of material thickness, is also mentioned in a wide range of applications. The operating frequency of FBAR is increased to 7 GHz.

The XBAR based on Lamb wave is newly proposed for applications around 8 GHz. The Lamb wave is one of the FPWs (film plate waves) mixed with a longitudinal wave (L) and a transverse vertical wave (SV) propagating in a thin plate (film). Smart Cut™ technology (He^+ cutting) has been developed for the fabrication of high quality $LiTaO_3$ and $LiNbO_3$ single crystal thin films, so called POI (piezo-on-insulator) substrates. This technology allows the manufacturing of high performance, integrated XBAR filter components that can meet the requirements of 5G and/or 6G in smartphone front-end modules.