# AN OVERVIEW OF JAPANESE MANUFACTURING OF SAW DEVICES

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## Summary

Japanese manufacturing of SAW devices is overviewed here. Japanese market of SAW devices has been limited mainly to consumer electronics such as TV and VCR. Three kinds of basic materials have been widely used. New designing method has been developed for every application, and manufacturing process including packages has been improved to make economical massproduction.

## Introduction

Japanese manufacturing of SAW devices began 10 years ago mainly for consumer market of FM stereo and TV receivers. 10.7MHz SAW filters for FM stereo tuner were first manufactured by Murata in the world in 1975 using PZT piezoelectric ceramics substrates.[1] Fig. 1 shows this outline and substrates.

In the next stage, 45MHz SAW filters for USA color TV and 58MHz SAW filters for Japanese color TV were manufactured by Toshiba and many other TV manufacturers. Three kinds of basic materials have been used for this market. LiNbO3 single crystals were generally used by Hitachi, Sanyo and several other companies, but Toshiba developed LiTaO3 single crystals with better temperature characteristics and lower cost than LiNbO3.[2]

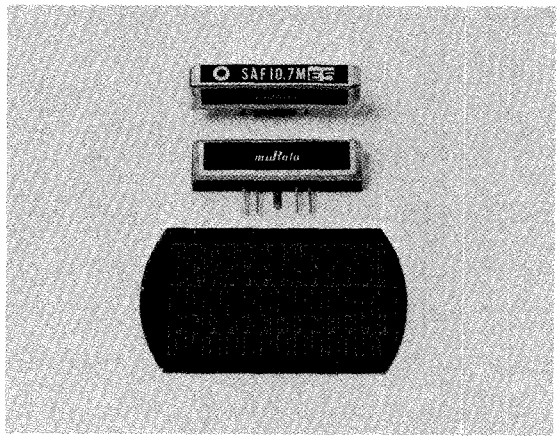


Fig. 1 Outline and substrate of 10.7 MHz SAW filters for FM stereo tuner.

PZT piezoelectric ceramics substrates were developed by Murata and Kyocera, but these materials were quite different from ordinary PZT ceramics for bulk wave devices.

Murata originated development and mass-production of ZnO thin films on glass first cooperation of Kyoto University. This unique technology was achieved by the use of planar magnetron for sput-



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tering from ZnO ceramic target. The accumulated number of SAW filters produced so far for TV exceed one handred million. Matsushita also developed similar technology.

SAW resonators using quartz crystals have been manufactured by Toyocom [3] and other companies mainly for VCR and CATV converter applications.

## Materials

Table 1 shows constants of each basic material for SAW devices developed for the Japanese consumer market. All constants in Table 1 satisfy the requirement for SAW filters of color TV, however, none of the materials provide ideal economy.

Each constant has distribution effecting yield in mass-production process. Generally, the distribution of single crystals is the smallest, thin film is middle, and piezoelectric ceramics is the largest. Especially, PZT ceramics has Curie point of about 300°C which is very low comparing to LiNbO3 and ZnO, and the piezoelectric constants of PZT are effected by polling and aging.

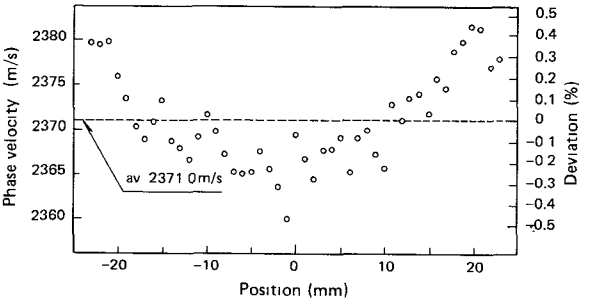


Fig. 2 Acoustic inhomogeneity in SAW velocity on PZT ceramic wafer.

Fig. 2 shows an example of SAW velocity distribution in one wafer of PZT ceramics. [4] This wafer has no porosity due to its fine grain size of less than a few micron and temperature coefficient of SAW velocity below 25 ppm/°C.

The mass-production and unifomity of ZnO film on glass were achieved by the use of planar magnetron and planetary motion of substrate for sputtering from ZnO ceramic target as shown in Fig. 3. Some impurities like Mn and Fe were useful to make stable and reliable thin films.

Table 1. Properties of typical substrate materials for SAW devices

| Materials | Cut Angle (degree) | Propagation Direction (degree) | Velocity v(m/s) | Coupling Coefficient $k_s^2$(%) | TCD (ppm/°C) | Permittivity $\varepsilon_r$ |
|---|---|---|---|---|---|---|
| ST-quartz | 42.75Y | X | 3157 | 0.16 | 0 | 4.5 |
| $LiNbO_3$ | 128°Y | X | 4000 | 5.5 | 72 | 39.1 |
| $LiTaO_3$ | X | 112°Y | 3295 | 0.64 | 18 | 44 |
| $Li_2B_4O_7$ | 28°X | Z | 3470 | 0.8 | 0 | 9.3 |
| p-ZnO/IDT/Glass | | | 2576 | 1.4 | 11 | 10.8 |
| $Pb(Sn_{1/2}Sb_{1/2})O_3$-$PbTiO_3$-$PbZrO_3$ | | | 2420 | 2.4 | 38 | 270 |

We have succeeded recently in developing trimming method of center frequency for both PZT and ZnO thin film substratses.It is possible to increase or decrease the center frequency by overcoating organic materials on the substrates.

Prof. Shimizu of Tokyo Institute of Technology recently discovered a new cut angle (what he calls "LST") of quartz crystals for zero temperature coefficient of leaky surface acoustic wave propagation. (5)

Nippon Mining Co. has started manufacturing of Li2B4O7 which has high coupling and small temperature coefficient of SAW propagation.

## Designing

The design target for components of cusumer electronics is to make light weight, thin thickness, small configulation and low cost. Multi-strip coupler is suitable to eliminate TTE between input and output electrodes of SAW filters of color TV. However, all Japanese makers do not use the coupler because it needed large chip size. Murata made minimum chip size using various methods like split and apotized IDT for input and output electrodes.

Prof. Yamanouchi at Tohoku University has developed many unique technologies to make unidirectional electrodes

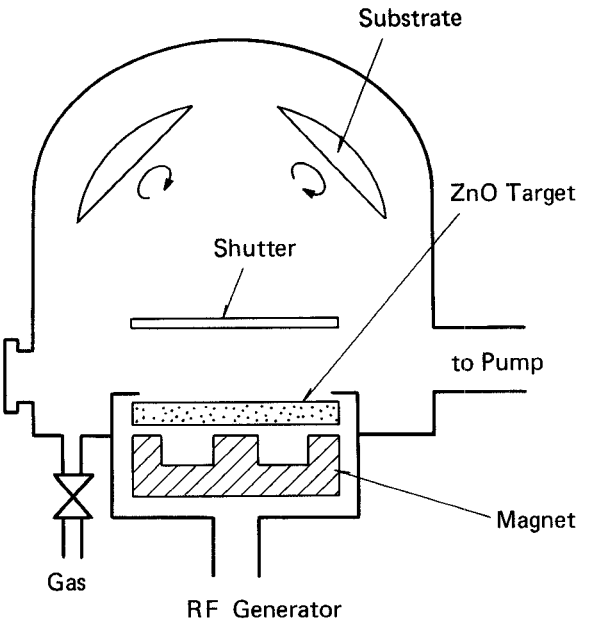


Fig. 3 Shematic diagram of a planar magnetron sputtering equipment.

which improve the insertion loss of SAW filters.

800 MHz SAW filters for mobil telephone have been developed by NTT, Hitachi and others. (6) Maximum allowable input power level is most important for 800 MHz SAW filters because they are also used for transmitters as duplexers. Hitachi has suceeded in developing 800 MHz SAW filters for mobil telephone by the use of Al-Cu electrodes instead of ordinary Al or Au.

Applicable frequency range of SAW devices is stretching out year after year. Accordingly fine pattern technique to make smaller gap IDT is progressing. Sub-micron accuracy for IDT patterm and design method to use higher harmonics are required for SAW filters in

SHF frequency range.

Matsushita has reported to have developed 4 GHz SAW filters using Sezawa mode of ZnO thin films on sapphire substrates, which have about 5% coupling coefficient of the first harmonics, which compares with 1% in fundamental mode.[7]

In the field of 800 MHz mobil telephone and 1 GHz DBS tuner, SAW filters are expected to replace ordinary dielectric ceramic filters in Japan.

## Manufacturing

All manufacturing processes of SAW devices are quite similar to semiconductor manufacturing process. Automatic assembling equipment like die bonder, wire bonder, measuring and sorting have been developed.

Japanese National Comittee of IEC has proposed recently the standard of SAW filters including terms, definitions, measuring method and outlines. The Elastic Wave Comittee of Japan Society for the Promotions of Science has been the leading review group for these SAW devices in Japan.

## Conclusion

Japanese manufacturing of SAW devices was overviewed. The estimated production volume in Japan is more than 80 million pieces in 1985 and expected to be more than 150 million pieces in 1990 mainly for consumer market.

## References


(1) S.Fujishima, H.Ishiyama and A.Inoue, "10.7MHz Surface Acoustic Wave Ceramic Filters," Proc. Japan Acoustic Society, May(1975)

(2) H.Hirano, T.Fukada, S.Matsumura and S.Takahashi,"$LiTaO_3$ Single Crystals for SAW Device Applications, "Proc. 1st Meeting of Ferroelectric Materials and Their Applications, pp.81-90(1977)

(3) M.Tanaka, T.Morita, K.Ono and Y.Nakazawa,"Narrow Bandpass Filter using Double-Mode SAW Resonators on Qurtz," Proc. 38th Annual Frequency Control Symp., pp.286-293(1984)

(4) J.Kushibiki and N.Chubachi, "Material Characterization by Line-Focus-Beam Acoustic Microscope," IEEE Transa.on Sonics and Ultrasonics, pp.189-212 March(1985)

(5) Y.Shimizu and M.Tanaka, "New Cut of Quartz for SAW Devices with extremely small Temperature Coefficient," Electronics Letters, 14th March 1985, pp.225-226(1985)

(6) Y.Kinoshita, A.Nakagoshi, H.Kojima and M.Hikita, "High Power SAW Filter for Antenna Duplexer," Proc. 1983 Ultrasonics Symp. pp.83-86(1983)

(7) T.Mitsuyu, O.Yamazaki and K.Wasa, "A 4.4GHz SAW Filter using a single crystal ZnO Film on Sapphire," Proc. 1981 Ultrasonic Symp. pp.74-77(1981)