70/93

BRITISH ACOUSTICAL SOCIETY

Acoustic Delay Lines Meeting

June 24th, 1970

THE DESIGN of DISPERSIVE SURFACE WAVE DELAY LINES

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Love wave and Rayleigh wave, propagating in a stratified wave guide composed of a substrate and a layer of different acoustic properties, can be used for the design of dispersive delay lines whose bandwidth ranges from 2 to 100 MHz or more [1, 2, 3].

THEORETICAL SUMMARY

In stratified isotropic media, Love wave and Rayleigh wave involve mechanical displacements which are respectively perpendicular to the sagittal plane, and belonging to the sagittal plane. These waves are then easily separated by proper excitation. To obtain "pure" propagation modes in stratified crystalline media, i.e. whose mechanical displacements are identical to those of the isotropic case, it is shown [4, 5] that the sagittal plane must be in the two crystals, either perpendicular to a binary axis or a plane of symmetry. If the media are piezoelectric, in the first cas the Love wave is stiffened and the Rayleigh wave is not, whereas in the second case, the Rayleigh wave is stiffened and the Love wave is not.

DEVICING PROBLEMS AND APPLICATION FIELD

The devicing problems which occur when realizing dispersive delay lines are the selection of materials, the deposit of the layer and the surface wave excitation.

The materials will be quite different depending on the frequency. In the frequency range inferior to 100 MHz, materials would be polycrystalline. Among the most interesting pairs we find: Cu/Be, Al/Be, Ge/Be, W/Be. The couple will be chosen according to the relative bandwidth which can vary between 25 and 100 per cent. For higher frequencies the materials should be amorphous or monocrystalline to present low propagation losses. Because of technical difficulties in obtaining monocrystalline layers, it is perhaps better to choose amorphous layers. The choice is then limited either to fused silica (1 dB/mm at 1 GHz) or to certain "slow" glasses having a small absorption coefficient. Among the most interesting crystals to be used as substrates we find Si, MgO, Al_2O_3 and the piezoelectric crystals ZnO and $LiNbO_3$.

The deposit of the layer is one of the most important problem as propagation losses depend on its crystalline nature. The best method seems to be cathodic sputtering for adhesion, mechanical properties and crystalline structure of the layers. However in the particular case of a layer of silica on a silicon crystal, a thermal oxidation will give a good amorphous structure.

The surface wave excitation depends on wheter the substrate is piezoelectric or not. In the latter case, the Love or Rayleigh wave can be excited by means of transducers directly bonded or deposited on the layer, Fig. 1, on which an excitation electrode is engraved near the edge. This electrode should be approximately $\lambda/2$ wide at the center frequency so that the transducer is omnidirectionnal and a great amount of transmitted energy is "trapped" in the layer and converted into a surface wave. This method ensures a large relative bandwidth excitation and is also sufficiently efficient (cf. experimental results). In the case of a piezoelectric substrate, the excitation of the surface wave is simply obtained by electrode gratings on the surface.

Dispersive delay lines using Love or Rayleigh waves in polycrystalline materials can have bandwidths ranging from 2 to 40 MHz with a compression ratio of several hundreds.

For higher frequencies, the most interesting couples like silica/Si, silica/Al_2O_3, silica/MgO, glass/$LiNbO_3$, should allow to realize dispersive delay lines with bandwidths as large as several hundreds MHz. The problem in obtaining a high compression ratio ($\geq$ 1000) could be resolved with the couple silica/Si ; for example a delay line with a time delay variation of 6.6 µs in a 150 MHz bandwidth around 300 MHz would be only 13 cm long approximately, and a very uniform layer, 2.4 µm thick, could be deposited along such a distance by thermal oxidation.

EXPERIMENTAL RESULTS

These are experimental dispersive delay lines using the propagation of Love waves in the frequency range of 4 to 200 MHz.

In all these examples, surface wave excitation has been obtained by the use of piezoelectric ceramics bonded on the wave guide surface, and the layers were sputtered.

2.5 MHz bandwidth delay line

Fig. 2 gives the group time delay variation and the insertion loss of a 7 cm long Cu/Be delay line. The transducers were tuned so that their impedance reaches 50 ± 5 ohms in the whole band, the parallel reactive part being always higher than 400 ohms.

32.5 MHz center frequency delay line

Fig. 3 and 4 give the results of group time delay, linearity error and untuned insertion loss measurements on 7.5 cm long W/Be delay line. The time delay variation is approximately 8 µs for a bandwidth of 30 MHz.

Wideband silica/Si delay line

Fig. 5 gives the results of group time delay and untuned insertion loss of a 1 cm long silica/Si delay line. The sagittal plane used in the silicon crystal is a "100" plane and the Love wave propagates along the "010" direction.

The two piezoelectric ceramics were indium bonded and grounded to a final thickness of 14 µm ; the excitation electrode is 0.2 cm long and 10 µm wide. The time delay variation is 0.95 µs in a 100 MHz bandwidth. The insertion losses are high and the curve is not symmetric, however these features can be greatly improved, with better transducers soldering and machining techniques.

CONCLUSION

Love wave as well as Rayleigh wave can be used for the design of wideband dispersive delay lines.

Delay lines, up to 40 MHz bandwidth, have been implemented with polycrystalline materials.

The use of crystalline substrate and amorphous layers with bonded transducers like $LiNbO_3$ or $Ba_2NaNb_5O_{15}$ or deposited ZnO transducers, should allow to obtain large bandwidth dispersive delay lines ($\geqslant$ 100 MHz) and very high compression ratios ($\geqslant$ 1000).

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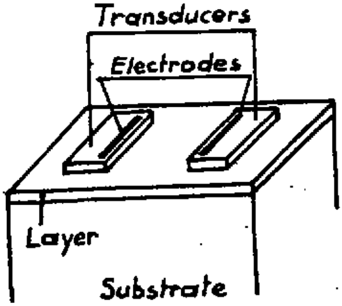

Fig. 1

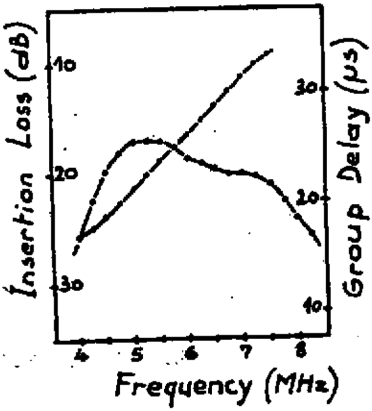

Fig. 2

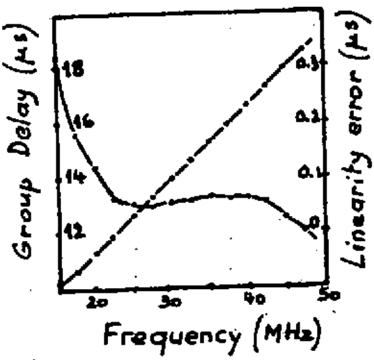

Fig. 3

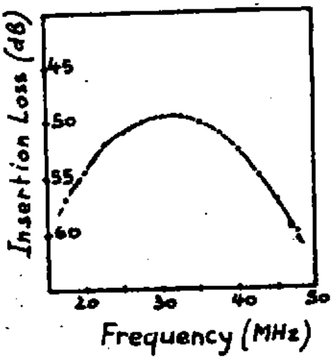

Fig. 4

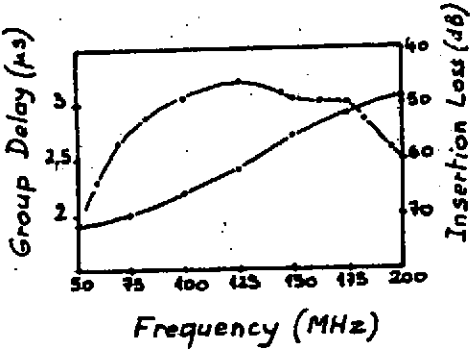

Fig. 5