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DEVELOPMENT AND CHARACTERISATION OF A POINT ULTRASONIC DETECTOR BY ACOUSTIC MICROSCOPY

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Résumé - Nous présentons les résultats obtenus avec une nouvelle technique pour imager les vibrations d'un résonateur piezoelectrique à l'aide d'un microscope acoustique. Cette technique a été utilisée pour caractériser la réponse d'un transducteur ponctuel fait à partir d'un grand transducteur de LiNbO₃ dont l'une des électrodes prend la forme d'un fil très fin. Une application à l'étude de l'atténuation dans un liquide est présentée.

Abstract - We show results for a new technique used to image the vibrations of a piezoelectric resonator using an acoustic microscope. This method is used to characterise the spatial response of a point POGO detector used as one electrode on a LiNbO₃ transducer. Possible application to attenuation measurements in liquids is demonstrated.

We have recently developed a new technique for studying the vibration characteristics of acoustic resonators (1). The method involves scanning the focussed ultrasound beam of an acoustic microscope over the surface of the resonator and using the resonator as the detecting element for the microscope, so that we essentially make a transmission image of the resonator itself. Such piezoelectric resonators are known to have very complex mode patterns (2),(3). Depending on the crystal cut, electrode configuration and supporting arrangement we can excite longitudinal, shear and flexural vibrations giving rise to a complex standing wave pattern in the crystal which we can image directly with the acoustic microscope to visualise the positions of the nodes and anti-nodes.

An example of this technique is shown in fig. 1 for a rectangular longitudinally cut 30 MHz LiNbO₃ transducer. The transducer is supported in cantilever fashion and the part observed in the figure is free standing and fully electroded over both surfaces. A very regular mode pattern is observed and we have verified that the fringe spacing decreases regularly with frequency in experiments at 30, 90, 150 and 210 MHz.

In the present work we have applied this technique to the development and characterisation of a "point" ultrasonic detector using a 30 MHz longitudinal LiNbO₃ circular transducer. The ground side of the transducer is fully electroded and...
the bare crystal surface (non metallised) is exposed on the other side. An electrode is defined by the position and contact surface of a spring loaded POGO contact of about 300 microns diameter. Images obtained using the acoustic microscope technique at 30 MHz and 150 MHz are shown in fig. 2 and fig. 3. At 30 MHz the diameter of the POGO can be discerned in the central part of the image and following previous work we associate the intensity variations around the center to flexural vibrations. At higher frequencies as in fig. 3 the flexural vibrations are less excited and we observe only the thickness vibration at the position of the POGO and the spot diameter corresponds roughly to that of the POGO. In order to examine this more quantitatively we have done line scans over a diameter of the crystal to obtain the intensity variation of the detected pulse as a function of position; an example is shown in fig. 4 at 90 MHz. We note that in this configuration the effect is essentially reversible so that the same image is obtained if the transducer is used as either source or detector.

The point detector has proved useful in ultrasonic investigations of liquids. The acoustic radiation patterns are often studied using miniaturized hydrophones.
which give a negligible perturbation to the sound field at sufficiently low frequencies. More recently a point capacitive detector has been developed for acoustic emission studies (4). In our case we are interested in making attenuation measurements in liquids using a pair of fixed transducers. As is well known the two transducer faces must be maintained parallel to within a high precision for otherwise phase changes occur over the wave front leading to a non exponential decay pattern (5). This effect can be diminished by decreasing the surface area of the detecting transducer to as small a value as possible, hence the interest of the point transducer. An example of this application is shown in fig. 5 for measurements of the attenuation in ethanol at 30 MHz. In fig. 5 (a) there is generation from a standard LiNbO$_3$ transducer (center electrode 3 mm in diameter) and reception by a POGO detector. The decay pattern is perfectly exponential at the beginning although there are spurious variations in echo height near the end of the echo train. This latter fact can be explained as a consequence of diffraction of the incident beam leading to spurious reflections which eventually come back into the sound field.
central sound field.

Fig. 5 (b) corresponds to emission and reception by the POGO detector in reflection mode. In this case the wave front should be approximately spherical in the central zone and should remain so after successive reflections leading to very small phase variations across the wave front in the region of the detector. This appears to be the case as the decay pattern remains perfectly exponential out to the last detectable echo. Finally in fig. 5 (c) the echo pattern for the transducer with 3 mm central electrodes in reflection mode is shown and we see that the decay pattern is not even approximately exponential.

In conclusion the present work has shown that it is possible to develop a "point" ultrasonic detector using a large transducer. The application to the study of attenuation in liquids appears to be extremely promising. The system could also be used for studying the radiation pattern from transducers into solids and liquids by performing a mechanical displacement of the point over the surface of the receiving transducer. A final aspect that is not yet determined is the smallest point that can be used in this method; under present conditions we have obtained spot sizes of the order of 100 microns. On general grounds we believe that this limit will be of the order of either the acoustic wavelength in the transducer or its thickness. Work at higher frequencies and detection at much higher harmonics of a 30 MHz transducer is planned to investigate this question.

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References

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