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by

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The methods used previously to generate and detect surface elastic waves piezoelectrically[1] have involved the mechanical coupling of a compressional or shear wave transducer to the body on which the surface waves are to propagate. We report here <u>direct</u> piezoelectric surface wave transduction by a spatially-periodic electrode on the plane surface of a piezoelectric plate. A periodic electric field is produced when an RF source is connected to the electrode, thus permitting piezoelectric coupling to a traveling surface wave. Direct coupling has a number of advantages described below. Also described here are measurements of surface wave velocity in quartz, and the surface wave attenuation produced by thin cadmium sulfide films.

Direct coupling to a surface elastic wave is possible at the boundary of a piezoelectric solid if any of the components of strain at the surface is piezoelectrically active. For example, consider a wave propagating along the top of the crystalline quartz plate of Fig. 1a. There will be components of particle displacement in the x and y directions; both components vary with x, becoming negligibly small at a distance of about one wavelength beneath the surface. The xy strain component (S_6) is coupled piezoelectrically to the y component of electric field, and the xx (S_1) strain is coupled to the x component of electric field.[3] Thus an oscillator or receiver connected to an electrode on the quartz plate having the configuration shown in Fig. 1b will be coupled piezoelectrically to a propagating surface wave. The period, p, of the pattern is made equal to the surface wavelength at the frequency of operation. The electrode pattern will also operate at integral multiples of its fundamental frequency.

This method of surface wave transduction somewhat resembles the use of the comb transducer,[1, 2] for both involve the creation or detection of spatially-periodic surface displacements. (The comb transducer consists of a block, typically of metal, upon whose plane upper surface a compressional wave transducer is mounted and whose serrated lower surface provides spatially-periodic contact to the body on which surface wave propagation occurs.)

We have observed the direct piezoelectric coupling described above at 15 and 45 mc with the arrangements illustrated in Fig. 1a. The electrode pattern used at both frequency (see Fig. 1b) was produced by photoetching in a dilute NaOH solution a 1000-Angstrom thick aluminum film which had been vacuum-deposited on the quartz bar. Standard photo-resist processes were used to mask the surface prior to etching. The electrode pattern was used either as a source or as a receiving transducer, while a comb transducer mounted elsewhere on the bar served as the companion transducer for transmission measurements. Pulses from the receiving transducer were identified as being surface waves both by their phase velocity as determined from the transducer separation and the pulse transit time, and by the large attenuation of the pulse produced when a drop of acetone was placed on the surface between transucers. It is also possible with RF input pulses of long duration to observe the characteristic trapezoidally-shaped received pulse resulting from the finite time of transit of the wave across an extended tranducer.[1]

The pulse amplitude obtained using one electrode pattern and one comb transducer was about the same as that obtained using two identical comb transducers for generation and detection. The relative responses of the two types of transducer depends upon many factors including the number of periods of each transducer, the type of piezoelectric material used with each, and the means used to couple the comb transducer to the surface (eg. pressure alone, or pressure together with an oil film).

The advantages of direct piezoelectric coupling include the following: it does not require contact pressure and so produces no surface damage or distortion; the transducer may be operated at extreme temperatures or in a vacuum; the transducer may be easily handled and precisely fabricated; and the electrode pattern may be extended in the direction of wave propagation so as to increase the active transducer area and the energy density of the surface wave, without resulting in the substantial coupling of energy back away from the surface which results when comb transducers are made very long.[1] The most apparent disadvantage is the limitation to suitably oriended piezoelectric materials. However, both the electrode pattern and a piezoelectric film (eg. cadmium sulfide) could be deposited on a non-piezoelectric substrate.

Surface wave velocities (necessary for design of most surface wave transducers) were measured in fused silica and in crystalline quartz. Velocities were computed from the measured change in phase delay of a pulse produced by one comb transducer as a second comb transducer was moved a known distance along the surface. The values obtained were: fused silica, velocity $3.37 \pm 0.08 \times 10^5$ cm/s; quartz, propagation along surface parallel to x-axis, normal to y-axis, velocity $3.20 \pm 0.06 \times 10^5$ cm/s; quartz, propagation along surface parallel to y-axis, normal to x-axis, velocity $3.25 \pm 0.06 \times 10^5$ cm/s.

Surface wave propagation and piezoelectric interaction with electrons in piezoelectric semiconductors has been considered, and preliminary measurements have been made of the attenuation of surface wave propagating along a fused silica plate on which a very thin cadmium sulfide film has been deposited. Substantial attenuation was observed: for films ranging in thickness from 2 to 5 microns and having electrical resistivities between 200 and 2000 ohm-cm, attenuation as high as 80 db/cm was measured at 15 mc, even though the ratio of film thickness to wavelength (in the fused silica) was 2.2×10^{-2} or less. In contrast, attenuation less than 1 db/cm was produced by deposited aluminum films of comparable thickness. The origin of the high loss in the CdS films is not yet clear. The loss is not determined entirely by film resistivity, as a change in illumination produced virtually no change in loss even though the films were moderately photoconductive.

Stoneley[4, 5] has shown that true surface wave propagation is not always possible in an anisotropic solid. It is interesting to note that the elastic constants of CdS satisfy both the criterion developed by Stoneley[4] for surface wave propagation along a plane normal to the hexagonal axis, and the analogous criterion for propagation along a plane parallel to that axis. Thus in CdS, the piezoelectric coupling of electrons to surface waves should be possible with either of these orientations. The velocity for the first orientation, as computed from Stoneley's determinantal equation upon substitution of elastic constants for CdS,[6] is 1.70×10^5 cm/s. Experiments with deposited electrode transducers on CdS single crystals are in progress. Electrically non-conducting glass comb transducers (photoetched in HF after application of KMER Photo-Resist with Additive D) are also being used in this study.

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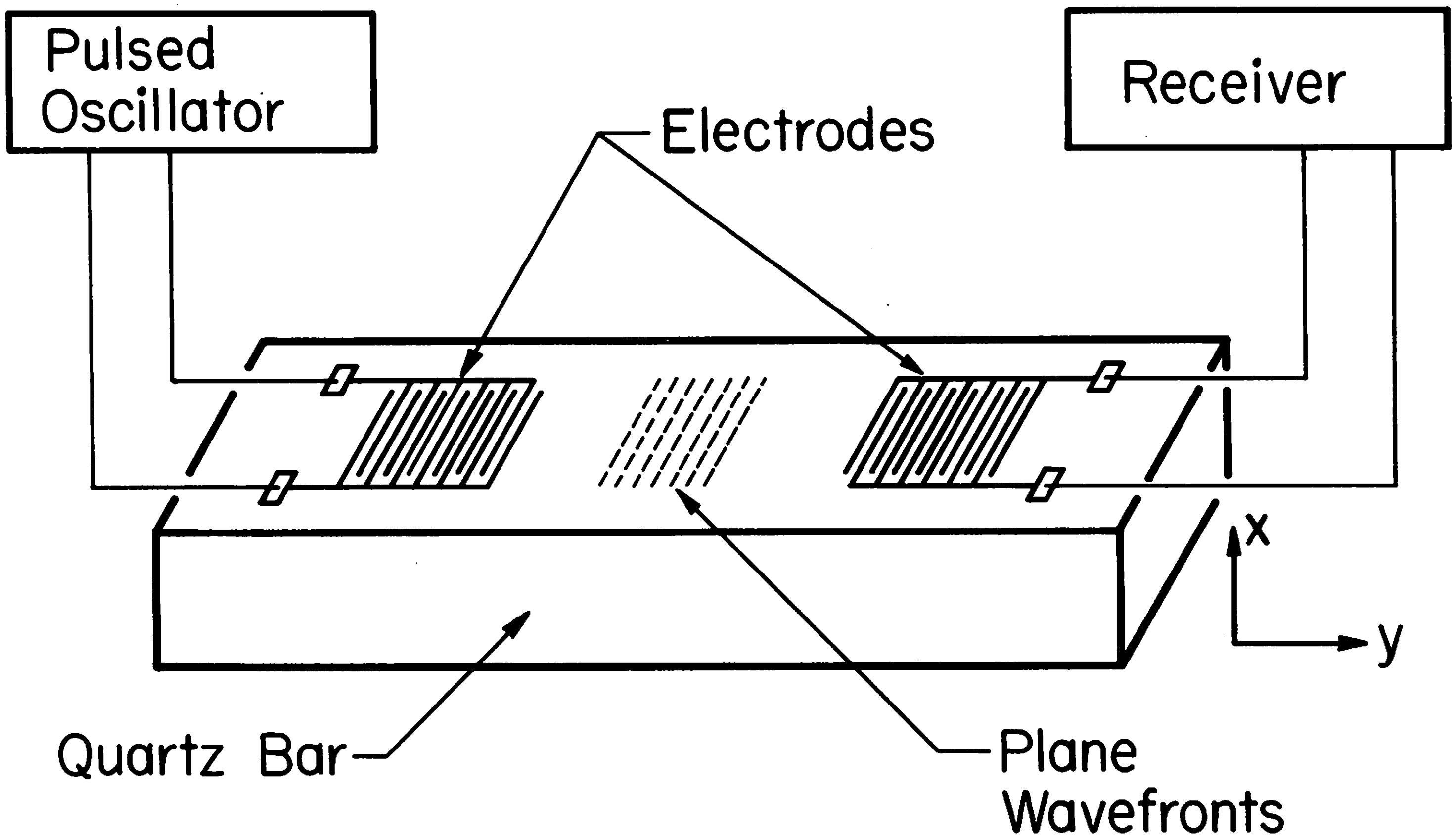

Fig. 1a. Arrangement for surface wave transduction by electrodes on crystalline quartz bar.

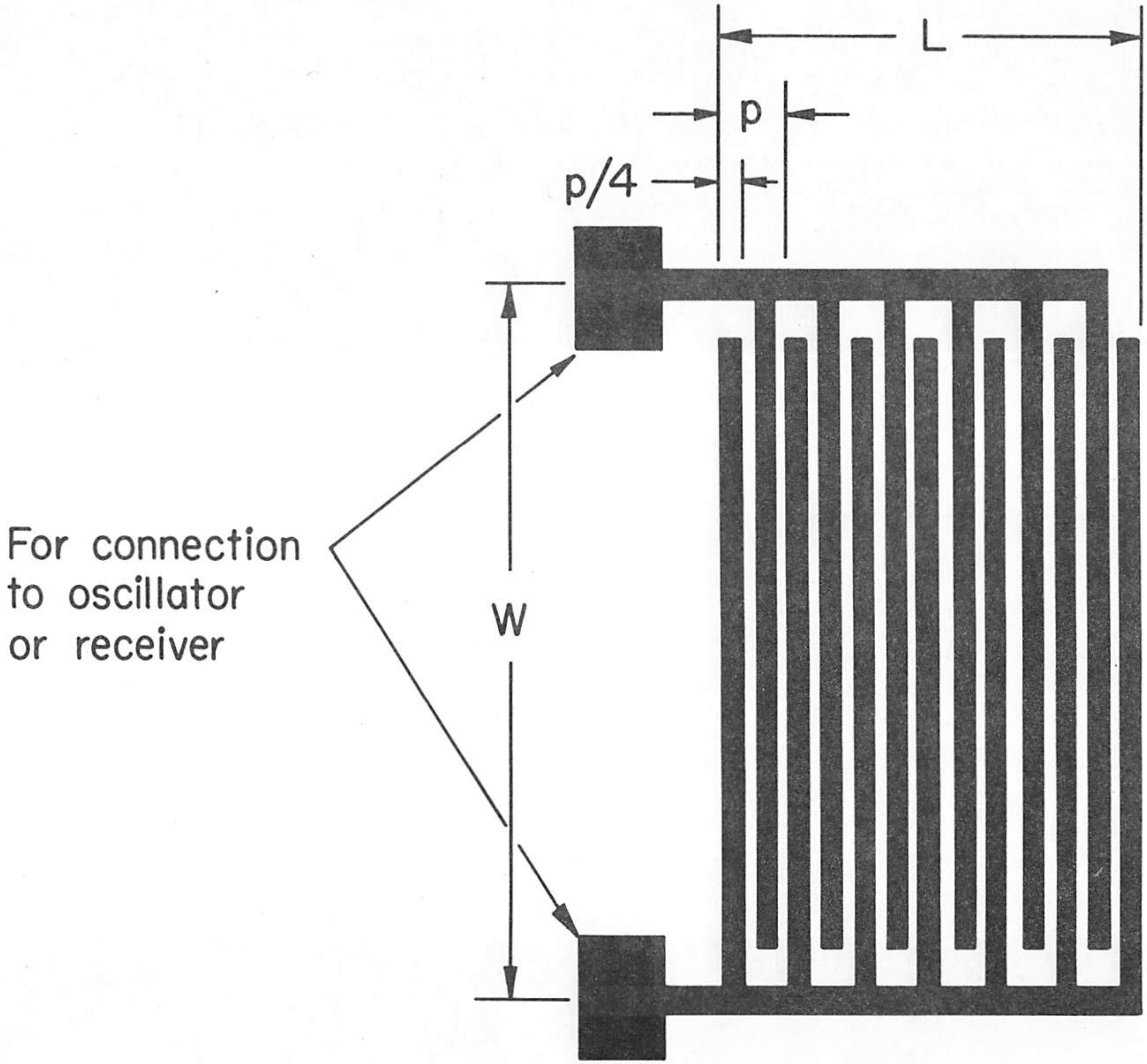

Fig. 1b. Electrode pattern used in (a) at 15 and 45 mc.