2-1 Ultrasonic Amplification Influenced by High-Mobility Electrons in Piezoelectric Se-Te Alloy Crystals at Room Temperature

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§1 Introduction ****** The contribution of minority carriers to the interaction between ultrasound and charge carriers in piezoelectric semiconductor is theoretically investigated by C.A.A.J.Greebe et al..[1] The main point made in their paper is that the minority carriers cause ultrasonic amplification with the same extremal value as that of majority-carrier amplification in the absence of diffusion and recombination. Furthermore it was analytically shown that "this minority carrier amplification" is affected neither by diffusion nor recombination, provided certain not very restrictive conditions are satisfied.

The results suggest the possibility of avoiding acoustic-domain formation, and of coustructing an acoustic "two-way" amplifier as well as of improving the isolating properties of the conventional acoustic amplifier.

§2 Experimental ****** Single crystals in Se-Te system are highly piezoelectric,[2,3] and the acoustoelectric nonlinear conduction and ultrasonic amplification influenced by electrons have been studied for Se_5Te_{95}, $Se_{10}Te_{90}$, $Se_{15}Te_{85}$ & $Se_{20}Te_{80}$.[2,4)]

The composition dependence of the band gap width is shown in Fig.1, which tells that the width can be continuously controlled through the composition rate in the system. The expansion of band gap width enables the ultrasonic amplification or the acoustoelectric phenomena at room temperature, where it has been impossible for pure Te.

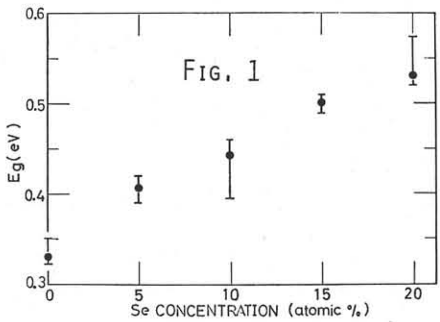


FIG. 1

Fig.2 shows the I-V characteristic obtained at room temperature. The mobilities of electrons (the minority) and holes obtained by the measurement of the threshold electric field for the acoustoelectric nonlinear conduction is shown in Table I, where it is notable that the mobility of electrons amounts to 10000 $cm^2/Vsec$ at room temperature.

The ultrasonic amplification was carried out at room temperature,[2] and the results are described here for the shear wave which is polarized // x and propagates along y-axis. Fig.3(a)

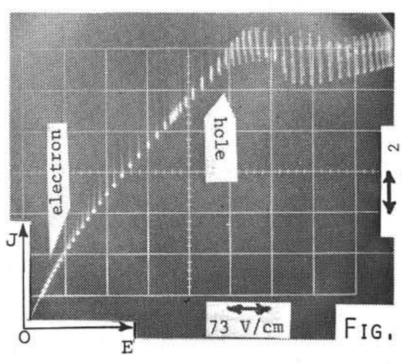
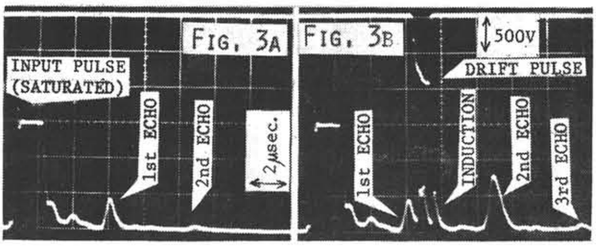


FIG. 2

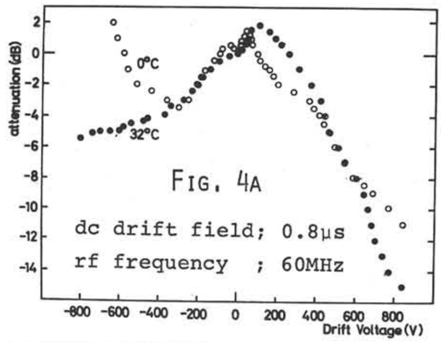
Table I *E.g.*, 0501Z sample means 5% Se and *J*// *z*-axis.

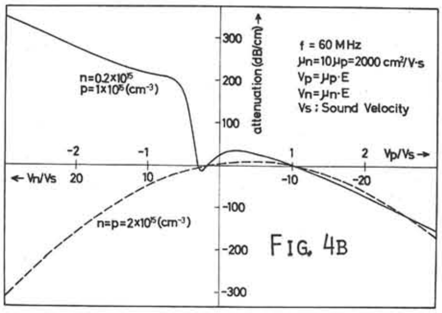
Sample No.	0501Z	0506Z	1005Z	1012Z	1002X	1504Z	1501X
μ_e ($cm^2/V\cdot s$)	10600	6500	4300	5000	6100	5900	4300
μ_h ($cm^2/V\cdot s$)	490	340	440	330	330	360	250

shows the ultrasonic echoes without applied electric field and Fig.3(b) shows the applied voltage wave form at a constant current and amplified echoes. Fig.4(a) shows the relative attenuation of detected echoes



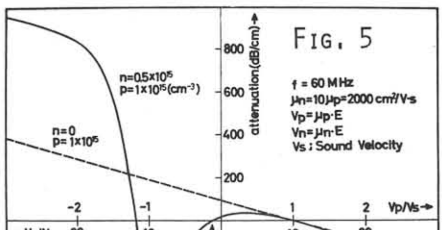
versus applied electric field, and Fig.4(b) shows the theoretical curves computed by the theory of C.Greebe et al, using the values deduced from the measurement of basic electrical properties. The piezoelectric constant e_{11} is obtained as 0.7 C/m^2 (±10%) from the experimental results. The value is considerably large and is nearly equal to 0.6 C/m^2 obtained for pure Te through ultrasonic amplification at 77K.[5]





§3 Possible feasibility for solid state devices ****** The merits of the "two carrier" amplification is summarized as follows, comparing the theoretical curve for two carrier to that for one carrier in Fig5.

(1) The ultrasonic attenuation at F=0 is considerably smaller than that of the extrinsic case. The difference is 60dB/cm. (2) When ultrasound propagates along the direction of drifting electrons, the positive gain appears at 65V/cm for electron mobility of 2000cm^2/V.sec. The gain of 100dB/cm is obtained at about 400V/cm using electron direction. (3) Applying the adequate external field, ultrasounds are amplified along the both direction at the same field. (4) Changing the direction and the amplitude of the applied electric field, switching for ultrasounds is possible. (5) The high field domain formation which is obstructive for ultrasonic amplification can be suppressed in the case of the crystals in which the condition $E_n < E_a < E_p$ is satisfied because the high field domain can not reach Ea at the external electric field which satisfied $E_n < E < E_a$.



References 1) C.A.A.J. Greebe and P.A. van Dalen: Philips Res. Rep. 24(1969)168; Phys. Letters 28A (1968) 455. 2) T. Shiosaki, S. Miyatake, T. Mitsuyu and A. Kawabata: to be published in Japan. J. appl. Phys. Vol.11, No.6. 3) K. Araki and T. Tanaka: Japan. J. appl. Phys. 11(1972) 472. 4) T. Shiosaki, H. Matsumoto and A. Kawabata: Japan. J. appl. Phys. 10 (1971) 1491. 5) T. Ishiguro and T. Tanaka: J. Phys. Soc. Japan 21 Suppl. (1966) 489.