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This Week's Citation Classic

Hutson A R & White D L. Elastic wave propagation in piezoelectric semiconductors. *J. Appl. Phys.* **33**:40-7, 1962. [Bell Telephone Laboratories, Murray Hill and Wnippany, NJ]

In a piezoelectric semiconductor, the electric fields accompanying an elastic wave induce electronic currents and space charge which modify the wave velocity and attenuation. This paper develops a linear theory for this effect, taking into account drift, diffusion, and trapping of the semiconductor carriers. [The *SCI*® indicates that this paper has been cited over 305 times since 1962.]

A. R. Hutson
Bell Laboratories
Murray Hill, NJ 07974

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"My own work, which led to this paper, was concerned not with ultrasonics but with the semiconducting properties of II-VI compounds such as zinc oxide and cadmium sulfide. I had discovered an anomalously large phonon-drag effect in measurements of the temperature dependence of the Seebeck effect in zinc oxide. Phonon-drag had been discovered in germanium and was well understood on the basis of the deformation-potential interaction between electrons and phonons. However, this theory didn't fit my measurements.

"Since piezoelectricity is allowed by symmetry in II-VI compounds, I wondered if a piezoelectric electron-phonon interaction could be the mechanism for the phonon-drag. The idea looked attractive because this interaction differs by a factor of the acoustic wavelength from the deformation potential, enhancing the role of long wavelength phonons. The only trouble was that my zinc oxide phonon-drag date implied a very large piezoelectric constant—much larger than the known constant for zinc sulfide, which was regarded as typical.

"I proceeded to make direct measurements of the piezoelectric constants for ZnO and CdS. To do this I had to reduce the semiconductivity of the crystals by chemical compensation so that electric fields would not be shorted out at the measurement frequencies. These measurements confirmed my conjecture of a really large piezoelectric effect in ZnO and CdS. Just as these measurements were being completed, I read Nine's[1] account of a new photosensitive ultrasonic attenuation effect in CdS. From the directional dependence of his effect, I surmised that he was seeing the damping effect of electrons on the piezoelectric fields of his ultrasonic waves and I found that I could calculate the magnitude of his effect using the newly measured piezoelectric constants.

"I gave a seminar on these results to a Bell Labs group working on ultrasonic devices. At my seminar was Don White, coauthor of this paper, who had been considering the possibility of making an acoustic wave analogue of the traveling-wave tube. The enhanced long-wavelength coupling of electrons and acoustic waves provided by piezoelectricity prompted him to propose an ultrasonic amplifier. This was an exciting prospect!

"Since I wanted to publish the explanation of Nine's observation and we didn't want to divulge the ultrasonic amplifier until one was operated, we chose to write a theoretical paper which was as rigorous and as thorough as possible.

"Though the paper contains no mention of applied drift fields or amplification, we attempted to provide a framework which could be smoothly extended to this more exciting regime.

"Its many citations are no doubt due to the utility of this framework and its extension."

1. **Nine H D.** Photosensitive ultrasonie attenuation in CdS. *Phys. Rev. Lett.* **4**:359-61, 1960.