Published in final edited form as:

Phys Lett A. 1968 February 12; 26(6): 217–218. doi:10.1016/0375-9601(68)90609-9.

ULTRASONIC PROPAGATION VELOCITY IN KTaO_3 *

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Abstract

Ultrasonic velocity measurements in KTaO_3 between 2° and 300°K are reported. No evidence for a phase transition was observed.

Potassium tantalate (KTaO_3) is a cubic perovskite similar in many respects to strontium titanate (SrTiO_3). The dielectric constant of both materials at high temperatures approximately follows a Curie Weiss law, but probably neither material makes a transition to a ferroelectric phase. However SrTiO_3 does make a transition near 103°K from the cubic (or nearly cubic) high temperature phase to a tetragonal paraelectric phase [1]. The most striking evidence for this transition may be found in the elastic properties of SrTiO_3 [2]. Upon cooling through the transition the elastic constants change by about 10% and the ultrasonic attenuation increases by two orders of magnitude and remains large to 4.2°K or less. Similar anomalies in the elastic properties of another perovskite, KMnF_3 , have recently been observed by Aleksandrov et al. [3]. Thus it might be expected that other perovskites, in particular KTaO_3 , would show similar transitions. Indeed, Shirane et al. [4] have recently found some evidence for a phase transition near 10°K in KTaO_3 using neutron scattering.

The measurements reported in this paper were performed primarily in an effort to observe such a phase transition. The ultrasonic propagation velocity was measured using a coherent pulse -C. W. technique, as described by De Klerk [5], with a measurement frequency of about 200 MHz. The ultrasound was generated by a CdS transducer evaporated onto a [100] cleavage face of the sample. The end faces were flat to less than one optical fringe and sufficiently parallel that a good exponential ultrasonic echo train could be obtained up to several hundred megacycles. The sample, supplied by A. Linz of M. I. T., was grown by pulling from a flux. It was optically clear and contained no intentional dopants.

The results obtained are summarized in fig. 1 and table 1. It is evident from fig. 1 that no abrupt changes in velocity occurred. The minimum detectable fractional change in velocity varied from 5×10^{-6} to 5×10^{-5} depending on the attenuation and hence on the temperature. The longitudinal attenuation is large and showed an unusual temperature dependence, being particularly rapid below 20°K, but it did not show any abrupt changes. The slight kink in the longitudinal velocity near 20°K seems to be dispersion associated with the large attenuation. The transverse attenuation is considerably lower than the longitudinal attenuation and does not show any strong temperature dependence. (In SrTiO_3 , both longitudinal and transverse

*This work is supported in part by the Joint Services Electronics Program and by the Raytheon Research Division.

**Raytheon Doctoral Fellow.

attenuation are discontinuous at 103°K). The attenuation measurements in KTaO_3 will be reported separately.

Of particular interest is the fact that the transverse velocity in fig. 1 is quite flat at low temperatures, varying only 0.04% from 2° to 40°K. This is in marked contrast to the measurements of Shirane et al. further out along the TA branch. No definite explanation can be offered for this discrepancy. However it should be noted that the sample used by Shirane et al. was intentionally doped with 200 ppm of Fe and it is known [6] that small Fe additions can alter the dielectric properties of KTaO_3 .

In summary, measurements of ultrasonic velocity and attenuation along a [100] direction have revealed no evidence for a phase transition within the range 2° – 300°K.

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Fig. 1.
Ultrasonic propagation velocity along the [100] direction in KTaO_3 (not corrected for thermal expansion).

Table 1

Summary of ultrasonic velocity measurements in KTaO_3 . $l(T)$ denotes the sample length at temperature T and α is the linear thermal expansion coefficient at 300° . All data refer to the $[100]$ direction.

Quantity	300°K	2°K
$v_{\text{longitudinal}} \times 10^{-5} \text{ (cm/sec)}$	7.492 ± 0.02	$[7.842 \pm 0.02] \times (l(2^\circ)/l(300^\circ))$
$v_{\text{transverse}} \times 10^{-5} \text{ (cm/sec)}$	3.909 ± 0.01	$[3.943 \pm 0.01] \times (l(2^\circ)/l(300^\circ))$
$c_{11} \times 10^{-12} \text{ (dyne/cm}^2\text{)}$	3.936	$4.312 \times [l(300^\circ)/l(2^\circ)]$
$c_{44} \times 10^{-12} \text{ (dyne/cm}^2\text{)}$	1.071	$1.090 \times [l(300^\circ)/l(2^\circ)]$
$-\frac{dc_{11}}{dT} \text{ (dyne/cm}^2\text{K)}$	$1.2 \times 10^9 + ac_{11}$	$< 1 \times 10^8$
$-\frac{dc_{44}}{dT} \text{ (dynes/cm}^2\text{K)}$	$6.5 \times 10^7 + ac_{44}$	$< 3 \times 10^6$