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# The measurement of electrostriction coefficients of some $XH_2PO_4/H_3BO_3$ binaries by interferometric technique

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**Abstract.** A new optical interferometric technique to measure the electrostrictive coefficients of $XH_2PO_4/H_3BO_3$ binaries (where X = Na, K and $NH_4$) is reported. This direct method is found to be advantageous in measuring the positive as well as the negative sign of the electrostrictive coefficients. Design of the apparatus and its merits are discussed. In $XH_2PO_4/H_3BO_3$ binaries the addition of boric acid is found to decrease the value of binary electrostriction coefficient in comparison to their pure samples.

**Keywords.** Electrostriction; interferometric technique.

## 1. Introduction

Deformation of dielectric materials under the influence of an electric field is known as electrostriction. This effect is known to be quadratic in nature (Mason 1949). Since the values of electrostrictive coefficients are very small their measurements involve considerable difficulty, and are usually measured from indirect methods (Kay and Vousden 1949; Bond *et al* 1951; Caspari and Mertz 1951; Mertz 1953; Kay 1955). However, the electrostrictive coefficient of ferroelectric materials in ferroelectric region attains a high value because of the high degree of spontaneous polarization (Zheludev and Fotchenkov 1958). The authors present here an optical interferometric technique of measuring the electrostrictive coefficients. In continuation of the systematic studies, using this new technique, we now report the electrostrictive coefficients of $XH_2PO_4/H_3BO_3$ binaries at ambient temperature.

## 2. Experimental

The deformation of the specimen was measured using an interference fringe technique. He–Ne laser (5430 Å) was used as light source. The specimen was excited by a dc voltage source. To produce a homogeneous electric field the sample was sandwiched between two conducting glass electrodes. The distance between the electrodes can be varied by a mechanical arrangement. One of the electrodes was fixed while the other was varied by a screw arrangement. This enabled the measurement of various thickness of the different specimens. A dc power supply provided the necessary field. The maximum voltage that was drawn from the power supply was 1·5 kV. The schematic diagram of the experimental set-up is given in figure 1.

The fringe pattern was obtained by forming a wedge between two optical flats of which, one was fixed while the other rested on the sample. The variation in the wedge angle was proportional to the shift of the fringe pattern which in turn was proportional to the deformation of the specimen. The fringe pattern was viewed through a microscope eye piece. The microscope eye piece was oculated as hundred divisions

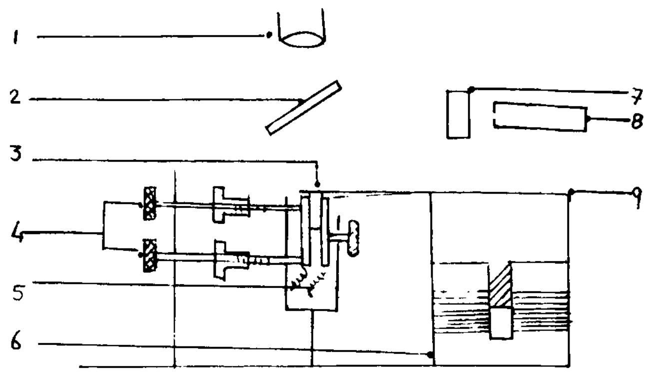


**Figure 1.** Schematic diagram of the experimental set-up. (1. Microscope eyepiece, 2. glass plate, 3. sample, 4. screws to move electrode, 5. wires to supply, 6. adjustable screw, 7. beam expander, 8. laser (He-Ne) and 9. optical flats).

in one centimeter, allowing to measure the fraction of a fringe. The number of fringes shifted across a fixed point were counted. This set-up enabled to detect the elongation as well as the contraction in mechanical disturbance of the material along a chosen direction parallel to the applied field. The accuracy of this set-up was calculated to be $10^{-18} m^2/V^2$. Electrostrictive coefficient of ammonium dihydrogen phosphate (hereafter abbreviated as ADP) is reported (Hruska 1965) in literature. Our measurements on ADP crystal using this set-up, are in good agreement with the reported value.

## 3. Results and discussion

The electrostriction coefficient $R_{ijkl}$ is a fourth order tensor (Zheludev and Fotchenkov 1958) and is measured using the relation

$$R_{ijkl} = A/l,$$

where $A$ is

$$\frac{(\lambda \times \delta l \times t^2)}{2 \times V^2},$$

where $\lambda$ is the wavelength of the light source, $l$ the length of the sample, $\delta l$ the change in the length of the sample, $t$ the thickness of the sample and $V$ the applied voltage. The measured independent electrostrictive coefficients of all the pure as well as binaries of $XH_2PO_4/H_3BO_3$ are given in table 1.

Our previous X-ray results (Madhu Mohan and Haranadh 1994) revealed that ADP/boric acid binary belong to space group $P4_222$ of point group $D_4$ at room temperature. Hence it follows that this point group yields seven independent electrostrictive coefficients and they are (Narasimhamurty 1981)

$$R_{1111} = R_{2222}, R_{1122} = R_{2211}, R_{1133} = R_{2233},$$
$$R_{3311} = R_{3322}, R_{3333}, R_{2323} = R_{3131} \quad \text{and} \quad R_{1212}. \qquad (1)$$

**Table 1.** Electrostrictive coefficients.

| Sample | Measured coefficient | Value( $\times 10^{-19}m^2V^{-2}$) |
|---|---|---|
| ADP | $R_{1133} = R_{2233}$ | 7·9 |
| ADP binary | $R_{1133} = R_{2233}$ | 3 |
| KDP | $R_{1111} = R_{2222}$ | 40 |
| KDP binary | $R_{1111} = R_{2222}$ | 20 |
| NaDP binary | $R_{1111} = R_{2222}$ | 500 |
| | $R_{1133} = R_{2233}$ | 230 |

The value of $R_{1133} = R_{2233}$ coefficient was measured for both the pure and the binary system.

Potassium dihydrogen phosphate (here after abbreviated as KDP)/boric acid binary was reported (Haranadh and Madhu Mohan 1992) to belong to either $D_{4h}$ or $C_{4v}$ point group at ambient temperature. Either of these point groups exhibit seven independent electrostrictive coefficients which are given in (1). $R_{1111} = R_{2222}$ coefficient has been measured for both pure and binary system.

Sodium dihydrogen phosphate (hereafter abbreviated as NaDP)/boric acid binary was reported (Haranadh and Madhu Mohan 1992) to belong to tetragonal system at ambient temperature with $C_{4h}$ or $C_4$ point group symmetry. Hence these point groups evolve ten independent electrostrictive coefficients which are given in (2).

$$R_{1111} = R_{2222}, R_{1122} = R_{2211}, R_{1133} = R_{2233}, R_{1112} = -R_{2212}$$

$$R_{3311}, R_{3333}, R_{2323}, R_{2331} = -R_{3123}, R_{1211} = -R_{1222} \text{ and } R_{1212}. \quad (2)$$

The electrostrictive coefficients measured are $R_{1133} = R_{2233}$ and $R_{1111} = R_{2222}$.

It was noticed from our study that the value of electrostriction coefficient was more in pure samples compared to their respective binaries. The addition of boric acid decreased the value of electrostrictive coefficient. Earlier it has been proposed by us (Haranadh and Madhu Mohan 1992; Madhu Mohan and Haranadh 1994) that all these three binaries form a substitutional solid solution with boric acid. Furthermore from PXRD studies a decrease in the unit cell volume of ADP (424·699 Å) and KDP (387·03 Å) compared to their respective binaries (384·648 Å) and (287·5 Å) is observed. The packing index of pure ADP (1·235) and KDP (4·753) is markedly small when compared to their respective binaries (2·103) and (6·416). The higher the packing index the higher will be the bonding strength. Since the binaries have higher packing index the lower electrostrictive coefficient is justified. Furthermore from the decrease in the unit cell volume of the binaries the inference drawn that the molecular bonding in binaries is smaller is proved to be correct as evidenced by the electrostriction results.

KDP and NaDP were reported (Hendricks 1927; Haranadh and Madhu Mohan 1992) to belong to same crystallographic system. Microhardness studies on KDP and NaDP binary (Anubukumar *et al* 1986; Madhu Mohan 1993) are available in the literature. Vicker's hardness number (VHN) at 50 g is almost twice for KDP (161 kg/mm$^2$) compared to that of NaDP binary (80·99 kg/mm$^2$). Higher value of VHN indicates stronger binding of atoms in the sample, which in turn possess lower value of electrostrictive coefficients. Thus the higher electrostrictive coefficient values of NaDP binary in comparison to that of KDP is in concurrence with the microhardness studies as well.

## 4. Conclusions

(i) It was observed that the value of electrostrictive coefficients of ADP binary and KDP binary are lower when compared to their respective pure samples.

(ii) Of all the three $XH_2PO_4/H_3BO_3$ binaries, $KH_2PO_4/H_3BO_3$ has the lowest electrostrictive coefficient value while $NaH_2PO_4/H_3BO_3$ has the highest electrostrictive coefficient value.

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## References

Anubukumar S, Vasudevan S and Ramaswamy P 1986 *J. Mater. Lett.* **5** 224
Bond W L, Mason W P and Mcskimin H J 1951 *Phys. Rev.* **82** 442
Caspari M E and Mertz W J 1951 *Phys. Rev.* **80** 1082
Haranadh C and Madhu Mohan M L N 1992 *Bull. Mater. Sci.* **15** 385
Hendricks S B 1927 *Am. J. Sci.* **14** 269
Hruska K 1965 *Sov. Phys. Cryst.* **10** 351
Kay H F 1955 *Rep. Progr. Phys.* **18** 230
Kay H F and Vousden P 1949 *Philos. Mag.* **40** 230
Madhu Mohan M L N 1993 *X-ray and optical investigations in electro-optic binary crystalline compounds*, Ph.D. thesis, Nagarjuna University, Nagarjunanagar
Madhu Mohan M L N and Haranadh C 1994 *Bull. Mater. Sci.* **17** 205
Mason W P 1949 *Piezoelectric crystals and their application to ultrasonics* (Moscow: IL) p. 255
Mertz W J 1953 *Phys. Rev.* **91** 513
Narasimhamurty T S 1981 *Photoelectric and electrooptic properties of crystals* (New York: Plenum Press) p. 662
Zheludev I S and Fotchenkov A A 1958 *Kristallografiya* **3** 308