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Thermal expansion of strontium fluoride

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The alkaline earth fluorides are important crystals because of their optical properties and their use as laser host lattices. There is considerable information about several physical properties of these crystals, but there is only sketchy information on their thermal expansion, particularly at elevated temperatures.

This paper deals with the thermal expansion of strontium fluoride (SrF_2). The thermal expansion of SrF_2 was first determined by Sirdeshmukh and Deshpande [1] by the X-ray method over the range 298 to 523 K. Subsequently Bailey and Yates [2] carried out measurements from low temperatures up to about room temperature. Recently, White [3] has also determined the thermal expansion of SrF_2 in the low temperature range. Murat *et al.* [4] and Falzone and Stacey [5] made measurements near about room temperatures. An estimate of the room temperature coefficient of SrF_2 was made by Sirdeshmukh [6] on the basis of the theory of ionic crystals. The values of the coefficient of thermal expansion near about room temperature obtained by these workers are collected in Table I. It can be seen that there is good agreement between the values of the coefficient of thermal expansion obtained in all the bulk measurements and also the theoretical estimate. On the other hand, the value obtained by the X-ray method is lower than all the other values by about 15%. Further, Bailey and Yates [2] comment that "the high temperature results of . . . Siredeshmukh and Deshpande . . . do not appear as a smooth continuation" of their (Bailey and Yates) results. As such, a remeasurement of the thermal expansion of SrF_2 by the X-ray method seemed desirable. The results of such a study are reported here.

From a very pure single crystal of SrF_2 supplied by Optovac, a small piece was cleaved out. This was ground into fine powder which was further sieved through a 350 mesh screen. This powder was used for making a sample for obtaining X-ray back reflection photographs with the help of a symmetric focusing camera. Using filtered copper radiation, five well-resolved doublets were recorded. Photographs were obtained at several temperatures from room temperature to 613 K. The lattice constant was obtained by the extrapolation technique using the error function $\phi \tan \phi$ where ϕ is a complement of the Bragg angle. The accuracy in the measurement of various quantities is:

$$a : \pm 0.000\,01\ \text{nm}$$

$$T : \pm 0.5\ \text{K}$$

$$\alpha : \pm 0.5 \times 10^{-6}\ \text{K}^{-1}$$

The values of the lattice constants at different temperatures are given in Table II. These values have been fitted to a three term polynomial by a least squares treatment. The polynomial is given below:

$$a_T = 5.7681 + 1.005 \times 10^{-4} T + 6.7896 \times 10^{-9} T^2 \quad (1)$$

TABLE I Literature data on the linear coefficient of thermal expansion of SrF_2 at about room temperature

Source	Method	T(K)	$\alpha(10^{-6}\ \text{K}^{-1})$
Sirdeshmukh and Deshpande [1]	X-ray	313	15.7
Bailey and Yates [2]	Interferometer	270	17.5
White [3]	Capacitance dilatometer	285	17.8
Murat *et al* [4]	Quartz dilatometer	298–513	19.2
Falzone and Stacey [5]	Capacitance micrometer	352	19.3
Sirdeshmukh [6]	Theory	300	19.6

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TABLE II Values of the lattice parameters of SrF_2 at different temperatures

Temperature (K)	a (nm)
305	0.579 94
327	0.580 12
363	0.580 51
387	0.580 84
403	0.580 96
423	0.581 21
443	0.581 41
483	0.581 82
523	0.582 20
563	0.582 68
613	0.583 24

Here T is the temperature in K. The coefficient of thermal expansion defined by $\alpha = (1/a_{300})\,(\mathrm{d}a/\mathrm{d}t)$ is obtained by differentiation of Equation 1. The temperature variation of the expansion coefficient is linear and is given by

$$\alpha = 17.34 + 2.34 \times 10^{-3}\,T (\text{in units of } 10^{-6}\,\mathrm{K}^{-1}) \quad (2)$$

The value of the coefficient of thermal expansion at room temperature (300 K) is $18.04 \times 10^{-6}\,\mathrm{K}^{-1}$. This value is higher than the value reported by Sirdeshmukh and Deshpande [1] but is in good agreement with all the other values given in Table I. The values of the coefficient of expansion obtained by Sirdeshmukh and Deshpande [1], Bailey and Yates [2] and in the present investigation are shown in Fig. 1. There is a considerable difference in the temperature variation of thermal expansion reported by Sirdeshmukh and Deshpande and that obtained in the present work. The rate of increase of the thermal expansion coefficient is much less in the present work than observed by Sirdeshmukh and Deshpande. The values obtained in the earlier study are lower than those obtained now up to 450 K whereafter the trend is reversed. It is to be noted that the present values at elevated temperatures form a smooth continuation of the low temperature results of Bailey and Yates [2] unlike the earlier X-ray values.

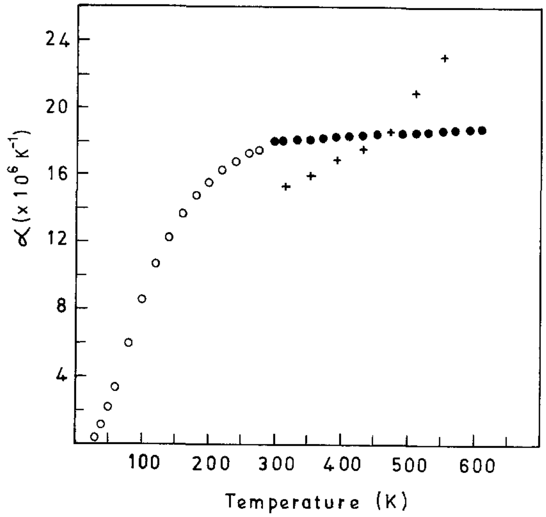

Figure 1 Temperature variation of thermal expansion of SrF_2. ○ Bailey and Yates [2], ● Present work, + Sirdeshmukh and Deshpande [1].

Apparently the results reported by Sirdeshmukh and Deshpande [1] were affected by some unidentified source of error and the present results appear to be more consistent.

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