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Temperature Dependence of Elastic Compliances of Garnet

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The effect of temperature on the elastic behaviour of garnet has been studied in the temperature range −183 °C to +300 °C. The experimental technique employed is the composite piezoelectric oscillator method. All the three constants (S_{11}, S_{12} and S_{44}) increase with temperature.

Introduction

Garnets form a series of isomorphous crystals, belonging to the cubic system. They belong to the space group *Ia3d*. They are alike in habit and the predominant habits are trapezohedron and dodecahedron forms. Chemical analysis reveals that they can be represented by the general formula, $R_3''R_2'''(SiO_4)$ where R'' stands for Ca, Mg, Fe, Mn and R''' for Al, Fe, Cr and Ti. There are three prominent groups, having various constituents under each group (Dana & Ford, 1959). The three groups are: Group I: Aluminium garnet, Group II: Andradite and Group III: Uvarovite. Since they vary very much in composition, the physical properties vary very widely from specimen to specimen.

Experimental

The elastic behaviour of garnets is characterized by three independent elastic compliances, S_{11}, S_{12} and S_{44}. Hence, three independent measurements along three known directions are needed. The elastic stiffnesses of a number of garnets have been determined by Ramachandra Rao (1945) by the wedge method.

The specimen employed in this investigation is a well-developed natural crystal with dodecahedral habit. The faces in the zone [001] cut from the crystal are very distinct and free from twinning. The effective longitudinal and torsional compliances along the directions employed are given in Table 1.

Table 1. *Effective longitudinal and torsional compliances*

	Effective compliance	
Direction	Longitudinal	Torsional
[100]	S_{11}	$4S_{44}$
[110]	—	$(S_{11}-S_{12}+2S_{44})$

The torsional mode of a [110] rod is preferred over its longitudinal as it reduces considerably the error in evaluating S_{12}.

The experimental technique employed in the present study is the composite piezoelectric oscillator method (Jayarama Reddy & Subrahmanyam, 1959). The densities of all the sections are measured at laboratory temperature by hydrostatic methods. The lengths and densities of these sections are taken to be the same at high and low temperatures also, since their expansion is negligibly small. The high temperature furnace and the low temperature cryostat are described elsewhere (Jayarama Reddy & Bhimasenachar, 1964).

Results and discussion

The measurements made on one rectangular bar and two cylindrical rods at room temperature are given in Table 2.

Table 2. *Measurements at room temperature on one rectangular bar* (1) *and two cylindrical rods* (2, 3)

No.	Orientation of the bar	Length (cm)	Frequency (kc/s)	Mode*	Effective compliance
1	100	2·33	165·89	L	$3·94\times10^{-13}$
2	100	2·27	107·13	T	10·04
3	110	2·01	120·77	T	10·10

* L = Longitudinal. T = Torsional.

From measurements on bars 1 and 2 we obtain S_{11} and $4S_{44}$ directly. The value S_{12} is deduced from the measurement on bar 3, and this works out to be $-1·14\times10^{-13}$. Hence the three elastic compliances are $S_{11}=3·94\times10^{-13}$, $4S_{44}=10·04\times10^{-13}$ and $S_{12}=-1·14\times10^{-13}$, all in units of $cm^2.dyne^{-1}$.

Ramachandra Rao has determined the elastic stiffnesses of the almandite group of garnets of different densities. The crystal used in the present investigation has a density of 4·203 g.cm^{-3}, a value lying between the two specimens of density 4·13 and 4·32 used by Rao. His values of C_{ij} for these two specimens have been converted into S_{ij} using standard conversion formulae. These values are compared with the elastic compliances directly measured for the specimen under investigation in Table 3. The table shows that the values are of the proper order; more than this cannot be expected in view of the uncertain influences of a large number of factors.

Table 3. *Comparison of present measurements with values calculated from Rao's results*

S_{ij} are in units of 10^{-13} cm^2.dyne^{-1}

Density (g.cm^{-3})	S_{11}	S_{12}	$4S_{44}$	Reference
4·13	6·32	−2·31	14·7	Rao
4·32	3·86	−1·06	11·24	Rao
4·203	3·94	−1·14	10·04	Authors

Table 4. *Elastic compliances at various temperatures*

In units of 10^{-13} cm^2.dyne^{-1}

Temperature	S_{11}	$-S_{12}$	$4S_{44}$
−180 °C	3·84	1·17	9·81
−150	3·84	1·16	9·83
−125	3·85	1·16	9·85
−100	3·86	1·16	9·87
−75	3·87	1·15	9·90
−50	3·88	1·15	9·92
−25	3·90	1·15	9·95
0	3·92	1·14	9·99
+30	3·94	1·14	10·04
+50	3·95	1·14	10·08
+75	3·97	1·14	10·12
+100	3·99	1·14	10·16
+125	4·01	1·14	10·20
+150	4·03	1·14	10·25
+175	4·05	1·13	10·29
+200	4·07	1·13	10·34
+225	4·09	1·12	10·37
+250	4·11	1·11	10·42
+275	4·14	1·10	10·45
+300	4·17	1·09	10·49

The values of S_{ij} at other temperatures in the range, −180 °C to 300 °C are presented in Table 4.

The values S_{ij} are plotted in Fig. 1, against temperature. Both S_{11} and S_{44} increase with rise in temperature. The increase is gradual in the case of

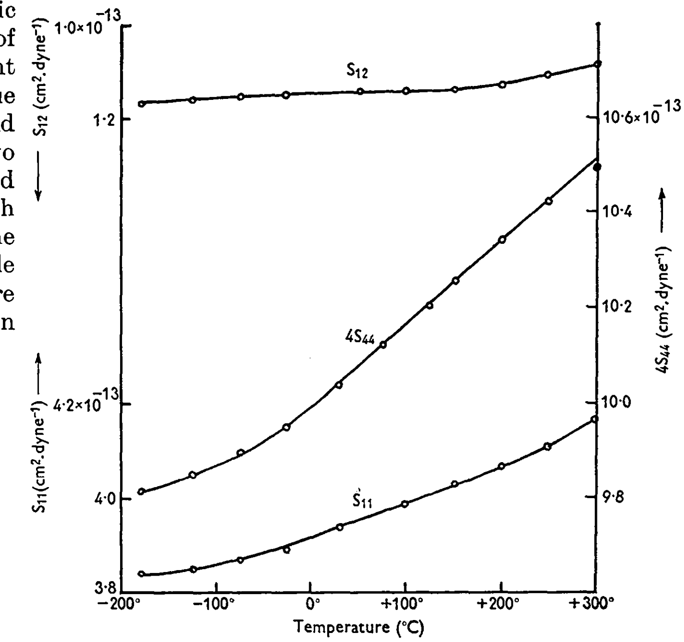

Fig. 1. Temperature dependence of S_{11}, S_{12} and $4S_{44}$.

S_{11} whereas in the case of S_{44}, though the increase is rather slow up to about −50 °C, it is perfectly linear above that temperature up to 300 °C. The value of S_{12} turns out to be almost constant, though a trend to increase with temperature is seen in the second decimal place of the numerical values in Table 4.

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