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A. G. GIBSON
I. M. WARD
Department of Physics

B. N. COLE
B. PARSONS
Department of Mechanical Engineering,
University of Leeds,
Leeds, UK

Thermal expansion of zinc carbonate

In the course of X-ray investigations on calcite-type compounds, the authors have determined the precision lattice parameters and the coefficients of thermal expansion of a number of carbonates [1-3], nitrates [4, 5] and borates [6]. A perusal of the literature shows that the thermal expansion of zinc carbonate, which has the same structure as calcite, has not so far been studied. Hence, it is thought worthwhile to also include zinc carbonate as a part of a programme of X-ray studies on calcite-type compounds.

Transparent single crystals of zinc carbonate of rhombohedral shape were crushed to powder and the specimen for the study was prepared by coating the powder on to a quartz fibre with Quickfix. Using the Unicam high temperature camera, powder photographs were taken at different temperatures, in the temperature range 30 to 265° C with Cu*K* radiation from a Raymax-60 demountable X-ray unit. Five reflections, $(3.0.12)_{\alpha_1}$, $(416)_{\alpha_1}$, $(416)_{\alpha_2}$, $(2.1.16)_{\alpha_1}$ and $(2.1.16)_{\alpha_2}$ recorded between 56 and 73° Bragg angles were used in evaluating the lattice parameters at different temperatures. The experimental details and the method of evaluating the precision lattice parameters and the coefficients of thermal expansion were described in an earlier paper [1].

TABLE I Lattice parameters of $ZnCO_3$ at different temperatures

Temperature (° C)	*a* (Å)	*c* (Å)
30	4.6646 ± 0.0004	15.1232 ± 0.0013
78	4.6659 ± 0.0004	15.1363 ± 0.0013
128	4.6692 ± 0.0004	15.1608 ± 0.0013
165	4.6722 ± 0.0004	15.1844 ± 0.0013
215	4.6737 ± 0.0004	15.1978 ± 0.0013
232	4.6740 ± 0.0004	15.2005 ± 0.0013
265	4.6753 ± 0.0004	15.2137 ± 0.0013

TABLE II Lattice parameters of $ZnCO_3$ at room temperature

Author	*a* (Å)	*c* (Å)
Swanson *et al.* [7]	4.6533	15.028
Graf [8]	4.6534	15.027
Present study	4.6646	15.1232

The lattice parameters determined at different temperatures are given in Table I. The lattice parameters at room temperature obtained in the present investigation are compared with the earlier values in Table II.

The temperature dependence of the coefficients of thermal expansion is represented by the following equations.

$$\alpha_{\parallel} = 23.001 \times 10^{-6} + 2.002 \times 10^{-8}T + 1.591 \times 10^{-11}T^2 \quad (1)$$

$$\alpha_{\perp} = 8.976 \times 10^{-6} + 3.179 \times 10^{-9}T + 2.567 \times 10^{-11}T^2 \quad (2)$$

TABLE III Coefficients of thermal expansion of $ZnCO_3$ at different temperatures.

Temperature (° C)	$\alpha_{\parallel} \times 10^6$		$\alpha_{\perp} \times 10^6$	
	Obs.	Calc.	Obs.	Calc.
40	23.47	23.83	9.11	9.14
60	24.14	24.25	9.33	9.26
80	25.13	24.70	9.43	9.39
100	25.79	25.16	9.54	9.55
120	25.79	25.63	9.65	9.73
140	25.79	26.61	9.86	9.92
160	26.12	26.61	9.97	10.14
180	26.78	27.11	10.72	10.38
200	27.77	27.64	10.72	10.64
220	28.43	28.17	10.72	10.92
240	28.76	28.72	11.25	11.22

where T is the temperature in °C. The observed coefficients of expansion at different temperatures are given in Table III along with the calculated values obtained from Equations 1 and 2.

The lattice parameters at room temperature obtained in the present study are higher than the values obtained by other investigators. The thermal behaviour of zinc carbonate is similar to the other compounds of calcite type in having a relatively large coefficient of expansion along the c-axis which is normal to the CO_3 layers and a small coefficient of expansion in the perpendicular direction.

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K. V. KRISHNA RAO
K. SATYANARAYANA MURTHY
Physics Department,
Osmania University, Hyderabad-500007,
India

The strain-rate and temperature dependence of yield of polycarbonate in tension, tensile creep and impact tests

Previous investigations [1-3] have shown that the yield stress of polycarbonate, measured in isothermal tension tests, increases linearly with the logarithm of the strain-rate and fits an Eyring-type equation, provided one operates within a definite range of temperatures located between the α and β transitions. We intend, in this range, to extend the study of the tensile yield stress of polycarbonate to strain-rates which cannot be reached in tension tests. Using tensile creep and impact tests, it is possible to measure the yield stress related to strain-rates varying from 10^{-8} to 10^{2} sec^{-1}.

The material and the specimens were the same in the different types of tests. They were described previously as well as the equipment used in tension tests [1]. Tensile creep tests were performed under dead-weight loading inside an environmental chamber provided with windows. Strain was measured with a dial gauge. The impact testing was carried out on a Frank tension impact machine of the pendulum type. The test-piece was placed inside a little oven located in the anvil. One end was clamped in the machine base and coupled with a load cell operating a storage oscilloscope, so that a load-extension curve was visualized and the yield stress measured.

Fig. 1a is an example of the stress-strain curve related to a tension test. The point Y_t corresponding to the maximum of the curve is taken as the yield point. The stress σ_Y related to this point, fits with accuracy the following Eyring-type equation derived from the theory of non-Newtonian viscosity [4]:

$$\frac{\sigma_Y}{T} = A\left(\ln 2C\dot{\epsilon} + \frac{Q}{RT}\right) \qquad (1)$$

where Q denotes the activation energy of the yield process, T the absolute temperature, $\dot{\epsilon}$ the constant strain-rate (proportional at this point to the cross-head speed); A and C are constants and R is the universal gas constant.

A typical creep curve at constant load is shown in Fig. 2a. From A_c to B_c, the strain is increasing at constant strain-rate, while the stress may still be considered as constant. Mindel and Brown [5], have suggested that the mechanism during the yielding in a tension test is the same as that during homogeneous creep. The question of the choice of the yield point may still be raised. In order to characterize the yielding in creep in a similar manner as in tension, we have chosen as the yield point, the inflexion Y_c of the creep