TABLE III Composition boron determined by 14.5 MeV neutron activation

Method	Boron composition (wt%)	
	Alloy A	Alloy B
Neutron Activation		
Run 1	2.4	14.8
Run 2	2.6	14.2
Run 3	2.9	14.7
Run 4	2.2	15.2
Run 5	2.5	15.4
Run 6	2.6	15.6
Average	2.5	15.0
Chemical analysis	2.3	15.2

and the standards must be free from high-energy activites from other alloying elements. Oxygen, as seen from Table I could cause interference since it produces 6–7 MeV gamma rays through a (n, p) reaction. In the present study no evidence of oxygen interference was found in the alloys investigated. The mass spectroscopy analysis of oxygen showed that its presence was less than 20 ppm. However, careful attention should be given in analysing very-fine powdered materials. For example, when powdered boron was used as a standard, the concentrations were lower than those shown in Table III.

Further analysis of this standard by mass spectroscopy showed the presence of significant oxygen, while X-ray diffraction analysis showed the presence of the oxide phase. To support this result, it has been reported that boron can indeed oxidize on standing and this can lead to the formation of boric acid [2]. Further work with the boron powder was discontinued and boron chips and boron carbide were used as standards instead.

It was found that 1 mg of oxygen will produce 2 counts min^{-1} of activity in the 6–7 MeV energy range. From this, it can be estimated that the presence of 1 wt% of oxygen will cause a 5% error in the boron measurement. In pure metallic alloys, the oxygen content seldom exceeds 0.02 wt% due to its very low solid solubility and, hence, should not present any significant problem to the analysis of boron.

In summary, the neutron activation technique provides a unique method for the accurate determination of the boron content in metallic alloys. This method is rapid and non-destructive and needs no prior sample preparation, in contrast to other conventional techniques. This technique can be routinely used to control the boron melt chemistry during the production of alloys on an industrial scale.

Acknowledgements

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X-ray studies on the thermal expansion of silver thiogallate

In a programme undertaken to obtain detailed information on the temperature variation of the lattice parameters and the coefficients of thermal expansion of some chalcopyrite ternary semiconducting compounds, the results on the thermal expansion of $AgInSe_2$ [1] and $AgGaSe_2$ [2] have been previously reported. Results of a similar study on $AgGaS_2$ will be presented in this note. Silver thiogallate ($AgGaS_2$) is isotypic with chalcopyrite and exhibits some interesting physical properties [3, 4]. In a study of this compound, Korczak and Staff [5] measured the linear expansion using a macroscopic method and reported a

TABLE I Lattice parameters of $AgGaS_2$ at room temperature

Source	a (Å)	c (Å)
Wyckoff [6]	5.743	10.26
Tell and Kasper [7]	5.757	10.305
Cook [8]	5.7566	10.3016
Pamplin et al. [9]	5.755	10.28
Present study	5.7556	10.2989
	± 0.0001	± 0.0002

negative expansion parallel to the c-axis. However, they have only given the aggregate expansion curves and the details of the computational procedure and the accuracy of the results have not been mentioned. Hence the precision lattice parameters and coefficients of thermal expansion of this compound have been determined at various temperatures using the X-ray method.

The sample used in the present study was supplied by Dr B. Tell, Bell Laboratories, USA. The crystal sample was crushed to a powder of appropriate particle size and it was found necessary to heat the sample to about 300° C to obtain well resolved, sharp lines in the high angle region. The specimen for the study was prepared by filling a thin walled quartz capillary with powder. Using a Unicam 19 cm high temperature powder camera and CuKα radiation, powder photographs were taken at different temperatures ranging from room temperature (30° C) to 394° C. The precision lattice parameters at different temperatures were determined by measuring the four unambiguously indexed reflections: $(3110)\alpha_1$, $(3110)\alpha_2$; $(2012)\alpha_1$, $(2012)\alpha_2$; $(552)\alpha_1$, $(552)\alpha_2$ and $(460)\alpha_1$, $(460)\alpha_2$ recorded in the Bragg angle region 60 to 75°. The experimental details and the computational procedure for the evaluation of the lattice parameters and the coefficients of

TABLE II Lattice parameters of $AgGaS_2$ at different temperatures

Temperature (° C)	a (Å)	c (Å)
30	5.7556	10.2989
116	5.7602	10.2932
175	5.7633	10.2860
234	5.7668	10.2772
282	5.7701	10.2701
346	5.7746	10.2639
394	5.7785	10.2584

thermal expansion have been described in an earlier paper [1].

The lattice parameters at room temperature, obtained in the present study for $AgGaS_2$ are compared with earlier values in Table I. It may be seen that the agreement between the lattice parameters obtained by various investigators is not good. However, the values obtained in the present study are in agreement with those obtained by Cook [8] and Pamplin et al. [9] for the c and a parameters respectively. The lattice parameters determined at different temperatures are given in Table II and are shown graphically in Fig. 1. It can be seen from Fig. 1 that the a parameter increases while the c parameter decreases with increasing temperature. Both the parameters vary non-linearly. The mean standard error of the lattice parameters, in the temperature range 30 to 394° C is about 0.0001 Å in the a parameter and about 0.0002 Å in the c parameter.

The coefficients of thermal expansion, $\alpha_{\parallel}$ and $\alpha_{\perp}$, parallel and perpendicular to the principal axis, respectively, evaluated at various temperatures are shown in Fig. 2. The temperature depen-
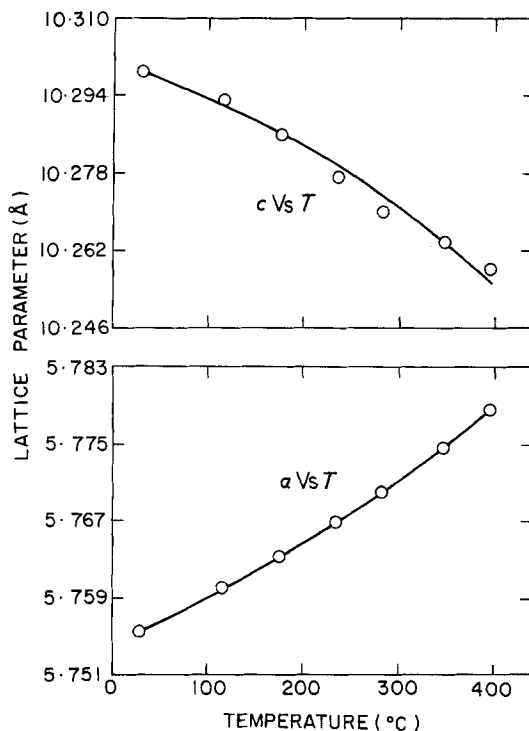

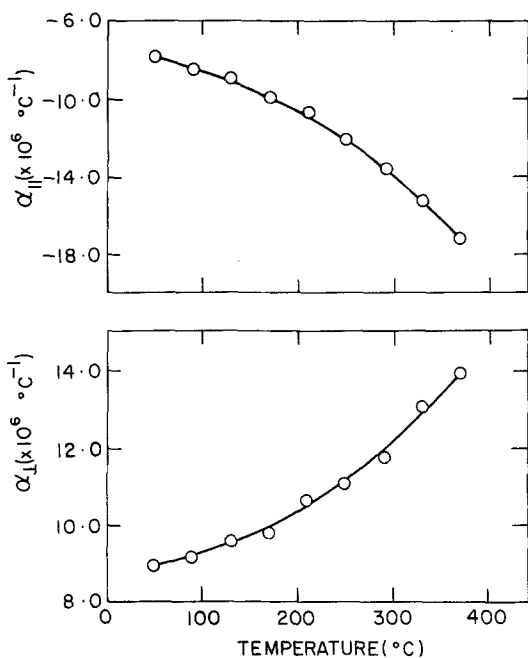Figure 1 Variation of lattice parameters of silver thiogallate with temperature.

Figure 2 Variation of coefficients of thermal expansion of silver thiogallate with temperature.

dence of these coefficients are represented by the following equations

$$\alpha_{\parallel} = -(7.6652 \times 10^{-6} + 1.5124 \times 10^{-9} T$$
$$+ 6.5514 \times 10^{-11} T^2) \qquad (1)$$

$$\alpha_{\perp} = (8.8576 \times 10^{-6} - 3.5404 \times 10^{-10} T$$
$$+ 3.7901 \times 10^{-11} T^2) \qquad (2)$$

where $\alpha_{\parallel}$ and $\alpha_{\perp}$ are expressed in $^{\circ}C^{-1}$ and T in $^{\circ}C$. The mean coefficients of thermal expansion of $AgGaS_2$ between 30 and 394° C obtained from the present data are $\alpha_{\parallel} = -10.80 \times 10^{-6}\,^{\circ}C^{-1}$ and $\alpha_{\perp} = 10.93 \times 10^{-6}\,^{\circ}C^{-1}$. It can be seen from Fig. 2, that the positive value of $\alpha_{\perp}$ increases non-linearly while the value of $\alpha_{\parallel}$ is negative at room temperature and its numerical value increases non-

linearly with increasing temperature as in the case of $AgGaSe_2$ [2].

Acknowledgements

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Internal field and photovoltaic effect in non-homogeneous ferroelectric SBN

Photorefractive and photovoltaic effects [1] and photocurrents [2] in ferroelectric single crystals of SBN have been studied. The results show that

the photovoltage measured externally (several volts cm⁻¹) does not correspond to the change in birefringence, equivalent to an electric field of hundreds of volts cm⁻¹. Photocurrents show a maximum around 320 mm.

In a previous paper [3] the results obtained in a