Research Paper Engineering

Thermal Properties of Sb, Bi And Sn in Solid Phase by Gamma Ray Attenuation Technique

* Kalvala Gopal Kishan Rao ** Ammiraju Sowbhagya Madhusudhan Rao *** Kethireddy Narender **** Nallacheruvu Gopi Krishna ***** K. Ashoka Reddy

* Central Instrumentation Centre, Kakatiya University, Warangal, (A.P) -506009 -India.

** Varadha Reddy College of Engineering, Hasanparthy, Warangal(A.P)- 506009 –India

*** Government Junior College, Hanamkonda,Warangal(A.P)- 506001 –India

**** Department of Physics, Kakatiya University,Warangal , (A.P) -506009 – India

***** Kakathiya Institute of Technology & Science,Warangal, (A.P) India.

ABSTRACT

The gamma ray densitometer was designed and fabricated to carry out gamma ray attenuation studies and determine changes in linear attenuation coefficients (µl) of Sb, Bi and Sn as a function of temperature in the range 298K-873K. The variation of density with temperature of Sn in solid phase in the temperature range 298K- 448K has been reported. The temperature dependence of density of Sn has been represented by linear equation and it's coefficient of volume thermal expansion has been determined. The experimental results on variation of density with temperature in solid phase of Sn have been extrapolated into liquid phase for comparison.

Keywords: Linear attenuation coefficient, Density, Thermal expansion.

1.Introduction

Metals and alloys constitute basic engineering materials for innumerable applications in day to day life. It is very interesting to investigate the variation of gamma attenuation coefficients of engineering materials as a function of temperature and this study can be used for determination of thermo-physical properties of materials which are useful in a variety of scientific and technological applications

The gamma radiation attenuation technique has been widely used to study the variation of density as a function of temperature for several materials [1-4]. This technique also been extended for the measurement of thermal expansion of isotropic solids at very high temperatures [5]. In this technique the gamma beam is used as a probe which is not in thermal or physical contact with the sample under investigation. This non contacting feature makes this technique a very advantageous one for high temperature studies, since the thermal losses are minimized and probe sample compatibility problem does not arise. We have undertaken γ-ray attenuation studies on the pellets of Sb, Bi, and Sn. The variation of density of Sb, Bi with temperature by using γ-ray attenuation technique was reported [6]. In present communication, the variation of linear attenuation coefficients (µl) of the metals with temperature by using mono energetic gamma photon with energy 0.662 MeV has been reported and the density variation of Sn with temperature has been studied.

2. Experimental Details

The samples studied in the present work were in the form of pellets. In all the cases, the pellets were prepared under different pressures out of the same quantity of powder to obtain pellets of different thicknesses. These pellets were subjected to γ – attenuation studies and it was observed that the density remained the same for all the pellets involving the same quantity of powder irrespective of thickness of the pellet. Such trials were conducted for all the metals in the present work. The pellets were prepared using a carborundum steel die set. A hydraulic press was used for compressing the powder samples.

For preparing the pellet, fine metal powder was put into cylinder of the die set above the pin, with its polished surface facing the metal powder and then the piston was introduced into the cylinder of the die set over the powder sample. The die set was placed in position under the hydraulic press piston and locked. The lever of the hydraulic press was slowly operated increasing the pressure on the piston. The applied pressure on the sample can be read from a pressure gauge mounted on the oil sump of the hydraulic press. After reaching the required pressure, the die set was unlocked and the metal pellet formed was taken out from the cylinder. The thickness and weight of the pellets were measured carefully. The cylinder and piston of the die set were cleaned properly every time for its use to prepare pellets of other samples. In this fashion metal pellets were prepared in all the cases with a diameter of 20mm with varying thicknesses.

The surface of the metal pellets was cleaned before mounting it on the sample holder. The pellet was then mounted on the round sample holder made of flat stainless steel strip whose two ends are fixed firmly in a stainless steel tube. The sample temperature was measured using a thermocouple sensor whose tip was mounted on the sample holder ensuring a perfect physical contact with the sample for recording precise sample temperature. The sample holder and the tube along with the metal pellet and the thermocouple was then slid through a cork into an air tight quartz tube and was fixed firmly. A diffusion pump was then connected to the quartz tube for evacuation and then argon gas was introduced into the quartz tube for inert atmosphere. Then the quartz tube assembly along with the sample was introduced into the PTC(Programmable Temperature Controlled) furnace and fixed at the appropriate position marked earlier for ensuring a perfect alignment of collimation on either sides.

The PTC furnace was programmed in such a manner that the furnace temperature is incremented by 25K in every step from room temperature and stabilizes at that point for a certain length of time. At each temperature, γ- counts with sample [I] and without sample [I0] were detected and recorded using a multi-channel analyzer. . This process was repeated at every temperature for at least nine times. The counts were recorded while heating and cooling the sample. This procedure was repeated until the desired temperature range was covered in each case. All the pellets were sintered at required temperatures before the actual experiment. All measurements on all the samples were made in solid phase only. The source for gamma radiation 137 Cs with energy 661.6 Kev is used.

3. Theory

The data on all the samples have been analyzed using the analytical method given by Drotning [5]. The basic equation which defines the gamma attenuation is

$$I_{(T)} = I_{O(T)} \exp\left[-\mu \rho_{(T)} l_{(T)}\right] \quad (1)$$

I0(T) and I(T) are the gamma intensities before and after passing through the sample material, ρ(T) is the sample density, l(T) the sample length along the γ -ray path, T the temperature of the sample and (μ) the mass attenuation coefficient of the sample material.

The mass attenuation coefficient of the material at room temperature is obtained by experimentally recording the gamma counts through length 'l' of the material using the relation

$$\mu = \frac{1}{\rho l} \ln\left(I_O / I\right) \quad (2)$$

Coefficient of volume thermal expansion is $\alpha_\rho = \frac{\rho_2 - \rho_1}{(\Delta T)\rho_1}$ (3)

Equations mentioned in Theory were used to calculate the quantities mentioned in Table.1.

4. Results and Discussion.

a) Sb pellets

The study of linear attenuation coefficient of antimony at various temperatures is given in table 1. The measurements have been made in the temperature range from 298 K to 873K. The variation of linear attenuation coefficient is negative linear function of temperature is shown in Figure 1. The value decreases with temperature from a value 5.076 m-1 at 298 K to 4.967m-1 at 873 K. The variation of density of Sb, with temperature has been reported [6]. The coefficient of temperature dependence of density - dρ/dT is 0.3074 Kg m-3K-1 in the temperature range from 298K to 873K. The coefficient of volumetric thermal expansion of Sb is 0.46x10-4 K-1.

b) Bi pellets

The study of linear attenuation coefficient of Bismuth pellets at various temperatures is given in table 1. The measurements have been made in the temperature range from 298 K to 473K. The variation of linear attenuation coefficient is negative linear function of temperature is shown in Figure 2. The value decreases with temperature from a value 10.994 m-1 at 298 K to10.916 m-1 at 473K. The variation of density of Bi with temperature has been reported [6].The coefficient of temperature dependence of density - dρ/dT is is 0.4132 Kg m-3K-1 in the temperature range from 298K to 473K. The coefficient of volumetric thermal expansion of Bi calculated from the coefficient of temperature dependence of density is0.42 X 10-4K-1

c) Sn Pellets

The study of linear attenuation coefficient of Tin pellets at various temperatures is given in Table 1. The measurements have been made in the temperature range from 298 K to 443K. The variation of linear attenuation coefficient is negative linear function of temperature is shown in Figure 3. The value decreases with temperature from a value 5.518m-1 at 298 K to 5.429 m-1 at 443K.

The variation of density as a function of temperature is shown in Figure 4. The density decreases with temperature from a value of 7.310x103 Kgm-3 at 298 K to 7.192X103Kgm-3 at 448 K. The density shows a negative linear variation with temperature and it can be represented by a linear equation in the above temperature range as

ρ(T) = (7.567 x103 ± 15.810) - (0.8314 ± 0.0420) T (4)

The coefficient of temperature dependence of density -dρ/dT is 0.8314 Kgm-3K-1 in the temperature range from 298 K to 448 K. The coefficient of volumetric thermal expansion of tin calculated from the coefficient of temperature dependence of density is 1.14x10-4K-1. The experimental results on variation of density with temperature in solid phase of Sn have been extrapolated into liquid phase for comparison [7-14] as shown in Figure 5.

Table-1 About here

Variation of linear attenuation coefficients of Sb, Bi, Sn and variation of density of Sn with Temperature

Sb(Antimony)		Bi(Bismuth)		Sn(Tin)		
Temperature (K)	μ l (m-1)	Temperature(K)	μ l (m-1)	Temperature(K)	μ l (m-1)	ρkgm-3
298	5.076	298	10.994	298	5.518	7310
323	5.073	323	10.981	323	5.515	7306
373	5.063	348	10.974	348	5.495	7280
423	5.049	373	10.960	373	5.478	7257
473	5.039	398	10.948	398	5.462	7236
523	5.027	423	10.936	423	5.445	7214
573	5.016	448	10.926	448	5.429	7192
623	5.005	473	10.916	-	-	-
673	4.991	-	-	-	-	-
723	4.980	-	-	-	-	-
873	4.967	-	-	-	-	-

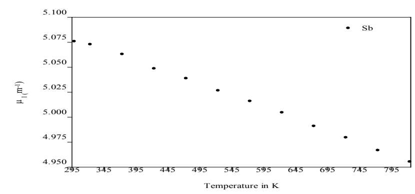


Figure 1 About here

Fig.1 : The Linear attenuation coefficient of Sb (pellet) at different temperatures

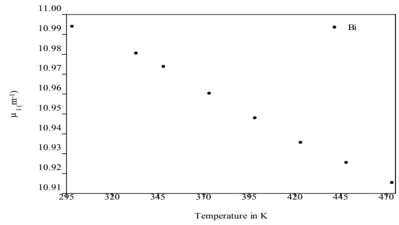


Figure 2 About here

Fig. 2. The Linear attenuation coefficient of Bi(pellet) at different temperatures

Figure 3 About here

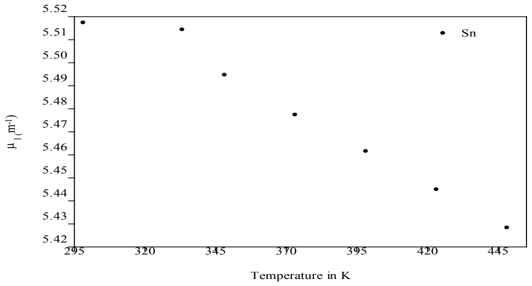


Fig. 3. The Linear attenuation coefficient of Sn (pellet) at different temperatures

Figure 4 About here

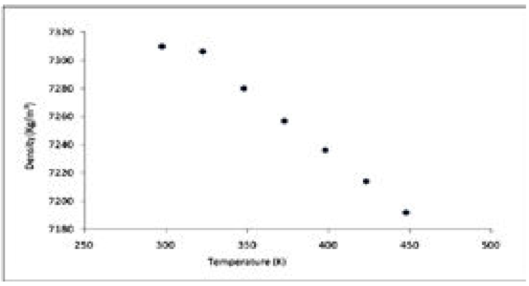
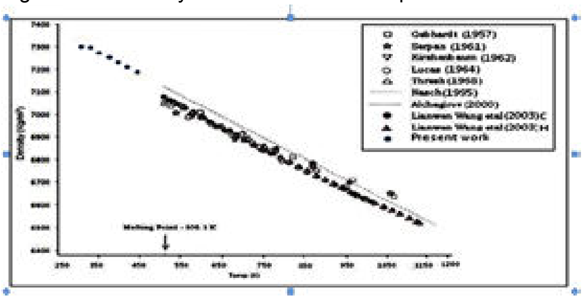


Fig. 4. The density of Sn (pellet) at different temperatures**Figure 5 About here**

Fig. 5 : The density of Sn at different temperatures from the



present work compared with selected data available in literature for Sn melt [Lianwen Wang et al. (2003)].

5.Conclusions:

The linear attenuation coefficients of Sb, Bi and Sn pellets as a function of temperature have been reported for the first time. The variation of density of Sn in temperature range 298K-443K have been determined by gamma ray attenuation studies.

REFERENCES

1. G.Dillon, F.E. Levert, P. A. Loretam, G.U. Menon, F.M. Siddiqui, and H.J. Tarng, Nucl. Tech.12 307-313 (1971). | 2. F.E. Levert, I.C. Dillon, and H.J. Tarng, Rev. Sci. Instrum, 44, 313-315 (1973). | 3. G.Doge, Z. Naturforschg, 21a, 266-269 (1966). | 4. William Drotning, International Journal of Thermo physics, Vol.6,No.6,1985. | 5. William Drotning,, Rev.Sci.Instrum., Vol.50, No.12, December 1979. | 6. K.Gopal Kishan Rao, K.Narender, A.S. Madhusudhan Rao, N. Gopi Krishna, Global Journal Of Science Frontier Research Physics And Space Science, Vol. 12, Issue 4, June 2012 | 7. Gebhardt.E and Kustlin.K, Z. Metallk. 48, (1957), 636. | 8. Serpan.C.Z and Witterbeng L J, Trans. Metall. Soc. AIME 221, (1961), 1017. | 9. Kirshenbaum.A.D and Cahill.J.A, Trans. ASM. 55, (1962), 845. | 10. Lucas.L.D, Mem. Sci. Rev. Metall. 21, (1964), 1. | 11. Thresh.H R, Crawley. A.F and White.D.W.G, Trans. Metall. Soc. AIME 242, (1968), 819. | 12. Nasch.P.M and Steinemann, Physics and Chemistry of Liquids : An International Journal, 29, Issue 1, (1995), 43. | 13. Alchagirov.B.B and Chochaeva.A.M, High Temperature, 38, No.1, (2000), 44. | 14. Lianwen Wang, Qiang Wang, Aiping Xian and KunQuan Lu, J. Phys. : Condens. Matter 15, (2003) , 777. | | | | | | | |