

Density and Thermal Expansion of Manganosite

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Determining the density, coefficient of thermal expansion of Manganosite across range of 300 K to 1500 K is principal goal of the investigation. Coefficient of temperature dependence of density and volume thermal expansion coefficient of the compound is assessed. Additionally, the research has been broadened to evaluate the linear attenuation coefficient at various γ -energies over a temperature range using mass attenuation coefficient.

Keywords: Linear attenuation coefficient, density; thermal expansion; volume thermal expansion coefficient.

1. Introduction

Thermo physical properties, including density (ρ), thermal expansion (α , β), serve to define the characteristics of materials across a range of temperatures. Beyond assessing thermal characteristics, thermal expansion of solids is significant in the selection of materials for various applications. These applications encompass coolant substances, fuel materials pertinent to nuclear reactor safety assessments, and the analysis of heat transfer in molten structural materials following an accident. A comprehensive understanding of temperature variations in many other properties relies significantly on investigating the temperature dependence of above mentioned fundamental characteristics.

Interaction of γ - photons with material over a range of temperature is always a subject of considerable interest and holds significance across multiple scientific fields.

To determine the thermo physical properties of Manganosite, γ -radiation attenuation is analyzed at various temperatures using the concept of Drotning [1]. The mass attenuation coefficient (μ_m) for any γ -energy determined in the research makes it easier to analyze the linear attenuation coefficient (μ_l), at any γ -energy, compound's thermo physical characteristics over a range of temperatures.

A study on the temperature dependency of manganosite's ultrasonic attenuation and associated parameters was previously conducted by Raju [2]. The density and elastic constants are helpful to compute velocities of ultrasonic waves, as well as to provide information about the material's intrinsic structure, and an harmonic qualities. Phase diagram and other thermodynamic properties of manganosite were previously reported [3-4]

A dilatometric approach has been employed to compute the thermal expansion of manganosite over a variety of temperatures [5].

Manganosite is vital due to its broad range of uses in industry, medicine, biology also extensively used in the production of food additives, glass, ceramics, fertilizers, poultry, textile printing, and lithium-ion batteries. Interesting manganosite applications and study on manganosite at different temperatures are not available. This is the reason behind this study.

2. Experimental Details

21 grams of manganosite powder is compressed using a hydraulic press. This results in a pellet of 1.35 cm thick. In-depth discussions of the experimental approach and setup specifications have been provided by the authors [6]

To ascertain the (μ_m) values at the energies, the sample is exposed to the γ -radiation from ^{241}Am , ^{137}Cs and ^{60}Co sources. The intensities transmitted are recorded before introducing (I_0) and after introducing (I) the sample during ten minutes using detection equipment.

The temperature dependency of (ρ), (μ_l), and (α , β) of manganosite has been investigated using (0.66 MeV) photons over a spectrum (300K-1500K) in accordance with the experimental approach given [6]

2.1. Computational Details

Employing Equation (1) of [6], the mass attenuation coefficients (μ_m) for different photon energies are determined. Equations (1–12) of [6] are employed to determine aforementioned thermo physical parameters over a spectrum of temperature. The Coefficient of temperature of density and volumetric thermal expansion coefficient is reported.

3. Results and Discussion

In the current study of Manganosite for aforementioned γ -energies, the (μ_m) values are determined using empirical relation (1) of [6] and are presented in Table-1 together with the calculated values and values from NIST X-Com. The (μ_m) does not depend on the physical state of the sample; it is also unaffected by temperature. The increase in incoming energy of the photon, reduces the risk of absorption. Taking into account various elements, the estimated uncertainty ($\Delta\mu_m$) [6], in (μ_m) value in the experimental observations is approximately about 1.26%.

The values of (μ_l) as a function of energy, temperature and (ρ) as a function of temperature have been reported for the first time, no data is available in the literature for comparison.

From Table 2, it can be noticed that μ_i decreases with the increase in incident photon energy and temperature. These variations of μ_i with temperature and at different γ - energies, in the order of increase in energy are obtained from

$$(399.9) + (2.40 \times 10^{-1})T + (-3.12 \times 10^{-4})T^2$$
$$(33.13) + (1.98 \times 10^{-2})T + (-2.59 \times 10^{-5})T^2$$
$$(24.99) + (1.49 \times 10^{-2})T + (-1.95 \times 10^{-5})T^2$$
$$(23.42) + (1.404 \times 10^{-2})T + (-1.83 \times 10^{-5})T^2$$

Manganosite (ρ) declines from 5180 kgm⁻³ to 687.323 kgm⁻³ over a range of Temperature (Table-2 & Fig.1), can be evaluated from

$$(4539) + (2.722)T + (-3.543 \times 10^{-3})T^2$$

As the mass stays constant while the volume rises with temperature, this leads to a reduction in density.

The density decline is caused by an increase in the equilibrium concentration of thermally generated Schottky defects. Radiation from γ -rays can cause defects. The linear thermal expansion coefficient obtained in this research aligns closely with results from other methods in the literature within the same temperature range (Table-2 & Fig. 2). The (α) values obtained in this study are compared with reported values through other method [5]. This indicates that γ -ray radiation has no impact on the density fluctuation. In this research, the (30 mci) source strength and the (~6hrs) irradiation do not seem to have affected the equilibrium concentration of defects in MnO. The coefficient of temperature dependence of density is (-3.657 Kg m⁻³K⁻¹).

Rise of coefficient of linear thermal expansion (α) can be defined as

$$10.80 + (3.074 \times 10^{-3})T + (1.21 \times 10^{-6})T^2$$

Average distance between molecules grows with increase in temperature due to increase in molecular vibrations amplitude, the (α , β) values consistently increases. Rise of coefficient of volume thermal expansion (β) can be defined as

$$29.24 + (-9.47 \times 10^{-2})T + (1.214 \times 10^{-6})T^2$$

The average coefficient of volumetric thermal expansion is estimated as (7.23 x 10⁻⁴ K⁻¹).

Table-1 Comparison of (μ_m) values

$\mu_m [10^{-3} \text{ m}^2 \text{ kg}^{-1}]$				
Value/ γ -Energy (MeV)	Am	Cs	Co	
	0.0595	0.66	1.173	1.332
Expt.	88.111	7.299	5.505	5.16
X-Com	88.117	7.301	5.507	5.161
Empirical	88.1952	7.30153	5.50606	5.16162

Table-2 Thermophysical parameters over a spectrum of temperature

T [K]	μ_i [m^{-1}]				ρ [kgm^{-3}]	α [10^{-6}K^{-1}]		β [10^{-4}K^{-1}]
	0.0595M eV	0.66 MeV	1.173 MeV	1.332 MeV		[PW]	[5]	
275							11.4	
300	456.41	37.81	28.52	26.73	5180	11.47	11.5	1.64
325	454.54	37.65	28.4	26.62	5158.695	11.65	11.7	1.65
350	452.66	37.5	28.28	26.51	5137.391	11.83		1.65
375	450.45	37.32	28.14	26.38	5112.35	12	12.1	1.95
400	448.25	37.13	28.01	26.25	5087.31	12.18		1.96
425	445.7	36.92	27.85	26.1	5058.352	12.35	12.4	2.28
450	443.15	36.71	27.69	25.95	5029.395	12.53		2.29
475	440.26	36.47	27.51	25.78	4996.641	12.65	12.7	2.61
500	437.37	36.23	27.33	25.61	4963.888	12.77		2.62
525	434.14	35.96	27.12	25.42	4927.226	12.89	12.9	2.95
550	430.91	35.7	26.92	25.24	4890.564	13.01		2.98
575	427.32	35.4	26.7	25.03	4849.836	13.14	13.2	3.33
600	423.74	35.1	26.47	24.82	4809.109	13.27		3.36
625	419.79	34.77	26.23	24.58	4764.345	13.37	13.4	3.72
650	415.85	34.45	25.98	24.35	4719.581	13.48		3.76
675	411.54	34.09	25.71	24.1	4670.721	13.58	13.6	4.14
700	407.24	33.73	25.44	23.85	4621.861	13.68		4.18
725	402.56	33.35	25.15	23.58	4568.816	13.78	13.8	4.59
750	397.89	32.96	24.86	23.3	4515.77	13.88		4.64
775	392.84	32.54	24.54	23.01	4458.411	13.98	14	5.08
800	387.78	32.12	24.23	22.71	4401.051	14.09		5.15
825	382.34	31.67	23.89	22.39	4339.349	14.18	14.2	5.61
850	376.91	31.22	23.55	22.07	4277.647	14.28		5.69
875	371.06	30.74	23.18	21.73	4211.294	14.4	14.4	6.2
900	365.21	30.25	22.82	21.39	4144.941	14.53		6.3
925	358.95	29.73	22.43	21.02	4073.83	14.65	14.7	6.86
950	352.68	29.22	22.03	20.65	4002.72	14.77		6.98
975	346.01	28.66	21.62	20.26	3926.944	14.87	14.9	7.57
1000	339.33	28.11	21.2	19.87	3851.168	14.98		7.72
1025	332.21	27.52	20.76	19.46	3770.383	15.1	15.2	8.39
1050	325.09	26.93	20.31	19.04	3689.597	15.23		8.57
1075	310.4	25.71	19.39	18.18	3522.804	15.37	15.4	18.1
1100	295.7	24.5	18.47	17.32	3356.011	15.53		18.9
1125	281.01	23.28	17.56	16.46	3189.218	15.68	15.7	19.9
1150	266.31	22.06	16.64	15.6	3022.425	15.8		20.9
1175	251.61	20.84	15.72	14.74	2855.632	15.91	16	22.1
1200	236.92	19.63	14.8	13.87	2688.839	16.09		23.4
1225	222.22	18.41	13.88	13.01	2522.046	16.26	16.3	24.8
1250	207.52	17.19	12.97	12.15	2355.253	16.4		26.5
1275	192.83	15.97	12.05	11.29	2188.46	16.54	16.6	28.3
1300	178.13	14.76	11.13	10.43	2021.667	16.73		30.5
1325	163.43	13.54	10.21	9.571	1854.874	16.91	17	33
1350	148.74	12.32	9.293	8.71	1688.081	17.13		36
1375	134.04	11.1	8.375	7.85	1521.288	17.35	17.4	39.5
1400	119.35	9.886	7.456	6.989	1354.495	17.56		43.9
1425	104.65	8.669	6.538	6.129	1187.702	17.76	17.8	49.3
1450	89.953	7.452	5.62	5.268	1020.909	17.95		56.2
1475	75.257	6.234	4.702	4.407	854.116	18.14	18.2	65.4
1500	60.561	5.017	3.784	3.547	687.323	18.41		78.1

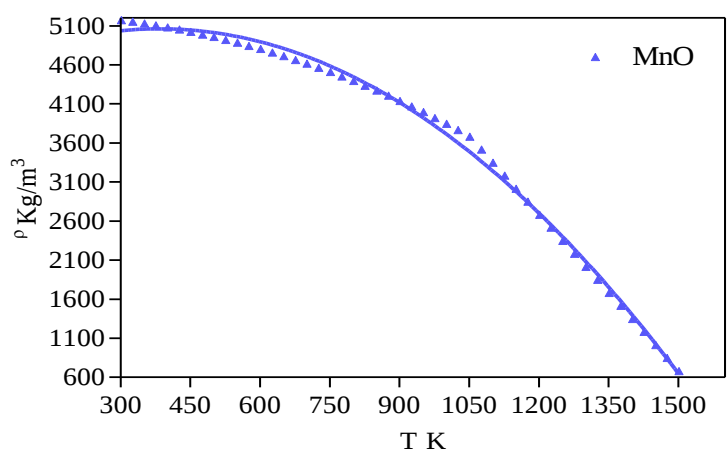


Fig.1. Temperature VS Density (ρ)

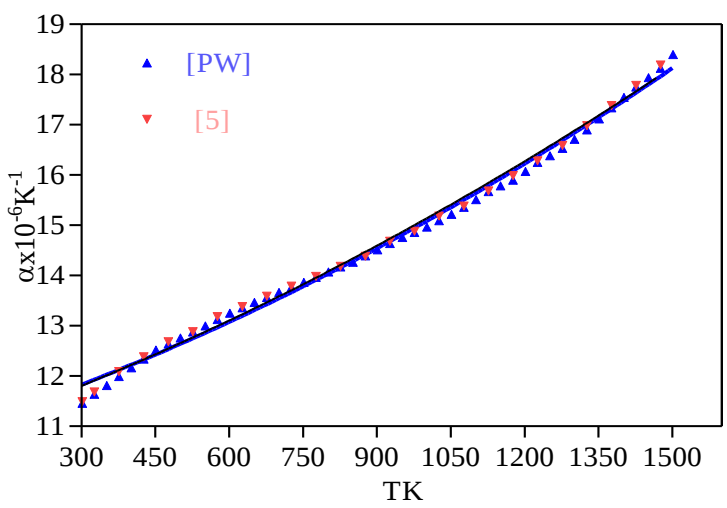


Fig.2. Comparison of temperature VS (α) of [PW] and reported data [5].

4. Conclusions

Manganosite sample pellet of thickness 1.35 cm has been prepared using hydraulic press. A transmitted beam approach is followed in experimental studies on the attenuation of gamma photons at various energies and over a temperature range. The values of (μ_m) at different photon energies were determined. The temperature dependence of values μ_i , ρ , α , β of the sample was presented. It was demonstrated that temperature influence on them through the non linear equations. The findings of (α) align well with earlier reported values.

γ -ray attenuation method has been used on manganosite for first time. This marks the initial occurrence of reporting the values of density and linear attenuation coefficient in relation to temperature.

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