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EXPERIMENTAL DETERMINATION OF COMPTON SCATTERING
FROM PYROLYTIC GRAPHITE AND GLASS-LIKE CARBONS

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ABSTRACT

In pyrolytic graphite, PG, the X-ray scattering from a Bragg reflection is all Compton modified radiation. A comparison of direct measurements shows that the Compton fraction in the scattering from disordered carbons, e.g. glassy carbon, can be calculated from measurements on PG and the adsorption coefficient of the disordered carbon.

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1. Introduction

It has been demonstrated^{1,2} that in order to obtain line profiles appropriate for analysis, the observed x-ray line profile of glass-like carbon (GC) materials must be corrected for Compton scattering, distortion caused by low specimen absorption and for Small Angle X-ray Scattering (SAXS) prior to making the usual corrections for the angular variation of the atom scattering factor and the Lorentz polarization factors.

The corrections which cause some difficulty are those for SAXS and Compton Scattering.³ In this work measurements of the Compton fraction of the intensity from pure carbon samples are compared with data obtained from measurements of the background intensity far from an interference maximum in a specimen of Pyrolytic Graphite, PG. It is shown that the second method can be used to replace the first.

2. Experimental

For the direct measurements the Compton fraction of the total intensity was determined using the balanced (Co-Ni) filter method described by Short⁴. The Co-Ni filters were balanced at the CuK_β line⁵ because this is the position of highest undesirable background intensity.

3. Data Reduction

For the direct measurements the fraction of the Compton scattering in the total intensity is given by

$$\frac{I_{\text{inc}}}{I_{\text{TOTAL}}} = \left(\frac{I_o^P - I_o^S}{I_o^P} \right) \frac{\exp(-\mu_{\text{coh}} T)}{[\exp(-\mu_{\text{coh}} T) - \exp(-\mu_{\text{inc}} T)]} \quad (1)$$

where I_0^P and I_0^S are the observed intensities when the filters are placed in the primary and secondary beam respectively; μ_{coh} and μ_{inc} are the coherent and incoherent linear absorption coefficients; and T is the thickness of the specimen.

The second method is based on the assumption that the background in crystalline carbon samples e.g. PG, is essentially all Compton Scattering except near an intensity maximum and the demonstration that the effective volumes for coherent and incoherent scattering are equal⁶. Thus, when modified to take account of the density ρ and polarization, the background intensity is

$$I_{inc}(2\theta) = \frac{A}{2\mu} \rho C_1 \left(\frac{1+\cos^2 2\theta}{2} \right) \frac{i_{inc}}{R} \left[1 - \exp \left(\frac{-2\mu T}{\sin\theta} \right) \right] \quad (2)$$

where $i_{inc}(2\theta)$ is the atomic incoherent scattering for carbon in electron units,⁷ C_1 is a constant, and A is cross-sectional area of the direct beam. With appropriate substitutions and combinations of equation (2) from measurements on PG and (GC) one obtains

$$I_{inc}^{GC}(2\theta) = I_{inc}^{PG}(2\theta) \left(\frac{\rho_{GC}}{\mu_{GC}} \right) \left(\frac{\mu_{PG}}{\rho_{PG}} \right) \left[\frac{1 - \exp \left(\frac{-2\mu T}{\sin\theta} \right)_{GC}}{1 - \exp \left(\frac{-2\mu T}{\sin\theta} \right)_{PG}} \right] \quad (3)$$

To generate the complete incoherent scattering curve for the GC samples, equation (3) is used to calculate I_{inc}^{GC} at a large $\sin\theta/\lambda$ (i.e. 2θ 140°), and from a knowledge of $i_{inc}(140^\circ)/R$ for carbon (from tables)⁸, equation (2) is used to obtain a constant $[(A/2)(\rho/\mu)_{GC}C_1]$.

This constant is used with $i_{inc}(2\theta)/R$ to generate the values for $I_{inc}^{GC}(2\theta)$, where R is the Breit-Dirac recoil factor.⁹

4. Results and Discussion

Wide range uncorrected patterns for some carbon materials are shown in Figure 1. Here the strong basal texture of PG is reflected in the intense 006 and 008 peak whereas only a weak (11) hk reflection is evident for the GC samples. In Figure 2 the total intensity and Compton scattering for the three samples measured at several points are shown. It can be seen that in PG the background intensity far from a Bragg reflection is essentially all incoherent scattering, but near or under a peak the fraction is very low compared to the total intensity. Table 1 shows the results in which direct measurements and data calculated from measurements on PG are compared. These results show that at very large 2θ the fraction of incoherent scattering in GC is very high and decreases with decreasing $\sin\theta/\lambda$.

5. Conclusion

The agreement between direct determinations of I_{inc} on GC and data calculated from measurements on PG are seen to be generally good at large angles. This agreement confirms that in PG and GC the background is virtually all incoherent scattering at very large $\sin\theta/\lambda$. However, the agreement is poor in regions of GC where there are broad overlapping lines. To solve this then the incoherent scattering in PG is measured at large 2θ where the scattering is all incoherent and this value is used along with equations (3) and (2) to estimate the incoherent scattering and contribution to the total intensity in GC at all angles.

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TABLE 1. COMPTON INTENSITY DETERMINATIONS

MATERIAL	2 θ deg	$\frac{I_{inc}}{I_{TOT}}$	$I_{TOT}(\text{meas.})$ c/s	$I_{inc}(\text{meas.})$ c/s	$I_{inc}(\text{calc'd})$ c/s
<u>Pyrolytic Graphite</u>	$\pm .005$				
$\mu T = 1.16$	140.00	.995	190	189	-
$\mu = 8.91 \text{ cm}^{-1}$	128.50	.519	320	166	165
$T = 0.125 \text{ cm}$	120.00	.857	160	137	148
$\rho = 2.11 \text{ gm/cm}^3$	90.00	.748	140	105	114
$(\mu/\rho) = 4.22 \text{ cm}^2/\text{gm}$					
<u>GC 1000 - 1</u>					
$\mu T = 1.06$	140.00	.945	185	170	185
$\mu = 6.43 \text{ cm}^{-1}$	128.50	.829	165	137	162
$T = 0.165 \text{ cm}$	120.00	.817	150	123	145
$\rho = 1.52 \text{ gm/cm}^3$	90.00	-	160	-	113
$(\mu/\rho) = 4.22 \text{ cm}^2/\text{gm}$					
<u>GC 2700 - 2</u>					
$\mu T = 1.00$	140.00	.980	185	176	182
$\mu = 5.58 \text{ cm}^{-1}$	128.50	.778	165	125	159
$T = 0.180$	120.00	.569	150	85	143
$\rho = 1.32 \text{ gm/cm}^3$	90.00	-	160	-	111
$(\mu/\rho) = 4.22 \text{ cm}^2/\text{gm}$					

Figure Captions

Fig. 1. X-Ray line profiles of PG and GC ($\text{CuK}\alpha$ radiation).

Fig. 2. X-Ray line profile of PG and Compton scattering in GC ($\text{CuK}\alpha$ radiation).

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Fig. 1

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Fig. 2

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