ANALYSIS OF X-RAY EMISSION AND TRITIUM CONTENT FROM GLASS MICROSHELL INERTIAL FUSION TARGETS

S. M. Alexander and T. M. Henderson

"Work Supported by the U. S. Department of Energy under Contract No. DE-AC08-78DP40030."

ANALYSIS OF X-RAY EMISSION AND TRITIUM CONTENT FROM GLASS MICROSHELL® INERTIAL FUSION TARGETS

S. M. Alexander and T. M. Henderson

The inertial fusion program requires knowledge of the amount of gas contained within Microshell® targets. Beta particles from the decay of tritium in a DT-filled shell interact with the glass walls producing x-rays. Measurement of the intensity of the emitted x-rays yields information on tritium content and indirectly on total gas pressure in the shell.

The x-ray yield is influenced by fill pressure, shell wall thickness, shell composition, and shell diameter. Experimental results have been obtained relating effects of fill pressure as well as glass composition on x-ray production. These results have been compared with the energy deposition and secondary radiation as predicted by Monte Carlo code calculations.

X-ray spectra have been obtained with a Si(Li) detector. A qualitative measure of glass composition is obtained from the spectra: Si, Na, Al, K, Ca lines are clearly visible when present.

ANALYSIS OF X-RAY EMISSION AND TRITIUM CONTENT FROM GLASS MICROSHELL® INERTIAL FUSION TARGETS

Small spherical shells filled with fuel mixtures of deuterium, tritium and occasionally additional gases are required as targets for the inertial fusion experimental program. Accurate knowledge of the amount of tritium and other gases contained in the shell is necessary in studying the fusion process induced when the target is irradiated by a laser, or an e-beam or ion beam. A nondestructive method was needed to assay the target's fuel content just prior to a fusion experiment.

The assay procedure herein described utilizes x-rays emitted by the glass shell when struck by β-particles from tritium decay. The measurement concept was originally developed at LANSL by J. Fries and G. Farnum.[1] Our apparatus consists of two NaI detectors arranged to provide 4π x-ray collection from the shell. X-rays in a predetermined energy range are counted for an appropriate time period. From the x-ray count rate the tritium content contained within the shell can be calculated.

We have assayed shells ranging in diameter from 50 μm to 6 mm, with wall thicknesses 0.5 μm to 20 μm, at pressures of 1 atm to 120 atm, and numerous glass compositions. Each type of shell has a unique x-ray emission signature. For every different kind of shell assayed, the relationship of the x-ray emission to the tritium content is determined. This relationship is specified by x-ray counts per second per nanogram of tritium (called "conversion factor") over an energy window of 2.2 keV to 8.9 keV, the lower limit being determined by the type of detectors.

The conversion factor is found by first measuring the x-ray count rate with NaI detectors, then breaking the shell in a ionization sphere (connected to a vibrating reed electrometer) to measure the absolute mass of tritium.

Once this conversion factor is found through destructively testing a small sample of shells, any number of shells can be assayed nondestructively for tritium content. From the ratio of other gases in the shell to tritium content and the inside diameter of the shell, the total pressure contained in the shell can be calculated.

The relationship of x-rays emitted to tritium content is affected by fill pressure, wall composition and thickness, and shell diameter. We have endeavored to determine experimentally the influence and importance of these characteristics on the conversion factor.

Fill pressure or gas density appears to have the greatest effect on the conversion factors. Several sets of shells of identical composition and similar size but with a deuterium-tritium fill pressure ranging from 6 atm to 122 atm (at room temperature) were evaluated for x-ray emission vs tritium content. Figure 1 illustrates the results. The conversion factor decreases as the gas density increases indicating that self-absorption of the β-particles by the fuel gases contained within the shell is more significant at higher gas densities.

Effects of wall thickness on the conversion factor are shown in Figure 2. Thicker wall shells reduced the x-rays emitted. The correlation coefficient for wall thickness versus conversion factor was 0.83 for the data in Figure 2 with the average amount of tritium per shell equal to approximately 16 μCi of tritium. A similar correlation coefficient was obtained for a batch of shells containing approximately 8 μCi of tritium per shell. However for small shells with low fill pressure (containing about 2 μCi of tritium per shell) the data scatter was significant and no correlation could be made. Wall thickness effects were more discernable for shells with higher fill pressure or larger OD due to better measurement statistics obtained with increased amounts of tritium (i.e. 2 μCi vs 8 or 16 μCi of tritium).

Shell diameter showed a significant influence on conversion efficiency, with larger diameter shells providing fewer x-ray cps/ng T_2 than smaller shells. Table I shows some of the experimental findings.

To study the x-ray spectrum in more detail, individual shells were mounted on a plastic holder and placed in front of a Si(Li) detector. Shells with five different compositions were evaluated. Representative spectra are shown for two different shell compositions in Figure 3. Si, Na, K, Ca characteristic peaks are seen. These spectra correlated well with the glass compositions. A spectrum obtained from a shell with Ne added to the DT gas mixture indicated the presence of Ne.

Table II contains data taken from the x-ray spectrum of 5 different shell compositions. In a simplified analysis, the ratio of counts at the Na characteristic peak to counts at the Si peak was made. When this ratio is compared to the weight % Na : weight % Si ratio determined by atomic absorption analysis of a bulk sample, a definite correlation is evident. With more detailed analysis of the x-ray spectra, it appears possible to obtain an indication of elemental glass composition.

We wish to thank Paul Anderson for the Si(Li) detector x-ray spectra.

References

1. R. J. Fries and E. H. Farnum, Nuclear Instruments and Methods, 126, 285 (1975).