APPLICATIONS

MEASUREMENT OF FLUORESCENCE PHENOMENA FROM YTTRIUM AND GADOLINIUM OXYSULFIDE PHOSPHORS USING A 45-MeV PROTON BEAM

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Since 1989, Alabama A&M University and Nichols Research Corporation have been actively involved in research to determine proton-induced damage and its effect on relative scintillation efficiency for various yttrium and gadolinium oxysulfide phosphors. The phosphor materials were selected for high efficiency, fast prompt fluorescence reponse, and minimal delayed fluorescence. Real time, in-situ measurements of the fluorescence spectra permitted observation of the spectral characteristics for the deterioration of scintillation yield due to particle induced damage.

In December 1992, six different phosphors compounds (Gd_2O_2S:Pr, Gd_2O_2S:Tb, Gd_2O_2S:Eu, Y_2O_2S:Eu, YAG:Ce and ZnS:Ag) were exposed to a 45-MeV proton beam at the Indiana University Cyclotron Facility (IUCF) using the High Energy Materials Irradiation Chamber (HEMIC) located in the K600 spectrometer cave. The HEMIC will provide physicists and material scientists the capability of exposing a variety of phosphor samples in a controlled temperature environment to ion bombardment with energies from 45 to 200 MeV.

The HEMIC consists of a specially constructed 6-way stainless-steel cross 504-mm long and 101.6-mm in diameter. The incident beam impinges on a phosphor sample painted on a 51-μm thick and 25-mm wide copper ribbon. The phosphor ribbon can be translated to any one of 16 different irradiation positions that are each 13 mm apart. The ribbon is maintained in a slightly stretched condition to avoid gravity sag and provide a smooth sample surface. Samples are applied to the copper ribbon using spray technology with a polysiloxane paint binder.

A crossed Czerny-Turner design Jerrell Ash Monospec 18 grating spectrometer with an EG&G type 1453A 1024-element linear silicon photodiode array is used to detect the spectral output from the phosphor being irradiated. A 300 groove/mm diffraction grating was used to center the resulting fluorescence spectra at a wavelength of 500 nm. The spectrometer was mounted on an x-y translation stage to provide accurate sample alignment at IUCF.

An Omega Engineering OS42 temperature transducer with a close focus head was used to detect the temperature from the back of the phosphor coated ribbon. The back of the ribbon was painted with a lampblack-based polysiloxane paint to increase the emissivity of the sample to allow for simple measurement of the sample temperature. The use of the OS42 provided a non-contact method to measure the ribbon temperature at the irradiation position. A zinc selinide infrared window with a hard optical coating was used as a vacuum seal for the HEMIC chamber. The vacuum integrity of HEMIC was tested to pressures of less then 10^{-6} Torr which is sufficient for use at IUCF.

Beam current and the subsequent total proton dose hitting the copper ribbon is measured at a facility-supplied Faraday cup and current integrator. All resulting spectroscopic, temperature, and beam data were collected, stored, and analyzed using a Macintosh IIfx computer system running the LabView 2 Software program from National Instruments Corporation.

The development of HEMIC is a natural outgrowth of previous efforts completed by the authors in 1989 to 1991 with the development of the Fluorescent Materials Test Chamber (FMTC) for low-energy (around 3 MeV) protons at the Alabama A&M University Pelletron accelerator laboratory.

Data obtained at IUCF indicated that the measured proton dose required to reduce the fluorescence brightness to half its original value (half-brightness dose) at 45 MeV is between 2 and 22 times larger when compared to corresponding values measured previously by the authors at 3 MeV. Although fewer protons interact with the phosphor at 45 MeV, each of the individual particles that do interact causes more damage to the material than equivalent protons at 3 MeV. The average incident beam current at IUCF was about 170 nA over an area of 7 mm^2.

The measured 45 MeV half-brightness proton dose at 150 °C is between 0.1 and 1.5 times larger than equivalent data observed at ambient temperature. The difference in proton half-brightness dose due to elevated sample temperature at 3 MeV is similar to the data taken at IUCF. The wavelength, net shape and amplitude of individual phosphor peaks is similar at 45 MeV when compared to equivalent data taken previously by the authors at 3 MeV. Experimental data also suggest that the magnitude of fluorescence light emitted at 150 °C is smaller than was observed at ambient temperature at both 3 and 45 MeV. One particular Gd_2O_2S:Tb irradiation measurement indicates that the magnitude for the resulting fluorescence was increased about 63 times when the temperature was reduced from 150 °C to 113 °C.

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