Oxygen-Doped ZnTe Phosphors for Synchrotron X-ray Imaging Detectors

Z.T. KANG,[1,2,4] H. MENKARA,[2] B.K. WAGNER,[2] C.J. SUMMERS,[1] R. DURST,[3] Y. DIAWARA,[3] G. MEDNIKOVA,[3] and T. THORSON[3]

1.—School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0245. 2.—Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0826. 3.—Bruker AXS 5465 East Cheryl Parkway, Madison WI 53711. 4.—E-mail: zhitao.kang@gtri.gatech.edu

ZnTe:O powder phosphors were successfully prepared by a dry synthesis process using gaseous doping and etching media. It was found that dry doping by O_2 through ball-milling was an effective way to synthesize ZnTe:O powder phosphors and produced a red emission centered at 680 nm with a decay time of 1.1 μs. The emission intensity of dry O_2-doped samples was three times more intense than from ZnO-doped samples, possibly due to a more uniform distribution of oxygen substitution on tellurium sites. The samples annealed in a 95% N_2/5% H_2 forming gas atmosphere exhibited a x-ray luminescent efficiency five times higher than did powders annealed in vacuum or N_2 atmosphere. This enhancement was attributed to the removal of surface tellurium oxides. ZnTe:O phosphor screens were prepared with x-ray luminescence efficiencies equivalent to 56% of ZnSe:Cu,Ce,Cl and 76% of Gd_2O_2S:Tb screens under 17-keV radiation. An x-ray imaging resolution of 2.5 lines/mm was resolved, the same as that measured for commercial ZnSe:Cu,Ce,Cl and Gd_2O_2S:Tb screens. These results indicate that ZnTe:O is a promising phosphor candidate for synchrotron x-ray imaging applications.

Key words: Phosphor, photoluminescence, x-ray imaging, ZnTe

INTRODUCTION

Traditional x-ray phosphors such as Gd_2O_2S:Tb are widely used in x-ray intensifying screens and fluorescent screens for radiographic applications[1] and recently in charge coupled device (CCD)-based synchrotron x-ray area detectors developed for structural biology applications.[2–5] Macromolecular crystallography, such as atomic structure of biological cells, proteins and ribosomes with high diffraction resolution, can be realized using these CCD area detectors.[4] It has been reported that the structure of the large ribosomal subunit can be obtained with a resolution of 2.4 Å using a front-illuminated 3×3 mosaic CCD detector.[5] The current generation of x-ray area detectors are mosaic arrays of individual modules, each consisting of a phosphor and a fiber-optic taper to couple the light into the CCD sensor that converts light into an electronically readable format. However, the currently available detectors are not as fast, sensitive, or efficient as desired. Because the powder-phosphor screen is a key component to improve the performance of these detectors, higher-quality x-ray phosphors are required.

Bruker AXS, Inc. (Madison, WI) has recently developed ZnSe:Cu,Ce,Cl phosphors that exhibit higher energy-conversion efficiencies than any other known x-ray phosphor and incorporated them into commercial CCD detectors.[6] They reported that the ZnSe:Cu,Ce,Cl phosphor screens were ~1.7 times brighter than equivalent Gd_2O_2S:Tb screens, the conventional middle- to high-energy x-ray phosphor used for chemical crystallography detectors.[7] Furthermore, it was reported that the light output from the ZnSe phosphor was ~1.3 times higher, and its radiation hardness 3–4 orders of magnitude better than CsI:Tl, which is widely used in detectors for x-ray introscopy and tomography in the energy range of 30-80 keV.[8] However, the ZnSe phosphor is not applicable for selenium-derivatized protein crystal diffraction measurements because the data must be recorded at the selenium K edge, and the presence of selenium in the phosphor layer makes it unsuitable for such applications.[9] As the counterpart of ZnSe, ZnTe can avoid this problem and

(Received October 17, 2005; accepted December 22, 2005)