Efficient UV-Emitting X-Ray Phosphors: Potassium Hafnium-Zirconium Phosphates $K_2Hf_{1-x}Zr_x(PO_4)_2$ and $KHf_{2(1-x)}Zr_{2x}(PO_4)_3$

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Abstract

Potassium hafnium-zirconium phosphates, $K_2Hf_{1-x}Zr_x(PO_4)_2$ and $KHf_{2(1-x)}Zr_{2x}(PO_4)_3$ are broad-band UV-emitting phosphors. At room temperature, they have emission peak maxima at approximately 320 nm and 300 nm, respectively, under 30 kVp molybdenum X-ray excitation. From preliminary studies, both phosphors demonstrate luminescence efficiencies that make them approximately half as bright as commercially available $CaWO_4$ Hi-Plus. $K_2Hf_{1-x}Zr_x(PO_4)_2$ and $KHf_{2(1-x)}Zr_{2x}(PO_4)_3$ could, therefore, be useful in medical or other diagnostic imaging applications. The lower X-ray absorption of these UV-emitting phosphors suggests that they may be suitable for two-sided mammography screen systems. The solid state and flux synthesis conditions, and X-ray excited UV-luminescence of these two phosphors will be discussed.

Overview

X-ray phosphors are solid-state inorganic materials used in medical X-ray imaging applications[1, 2]. The purpose in using these phosphors is to reduce the exposure of the patient to X-rays while maintaining the structural features of the X-ray image. Phosphor "intensifying screens" absorb X-ray photons and convert each photon's energy into hundreds of visible- or UV-light photons that are then recorded by a detector, such as a piece of photographic film. Good X-ray phosphors must fulfill several challenging requirements[1, 2, 3]: good X-ray absorption in the diagnostic medical energy range (15-100 keV), high luminescence efficiency or "speed", emission in the green to near-UV region, proper crystallite size and shape, air and water stability, and easy large-scale production.

Replacement of visible-light emitting phosphors with UV-emitting M'-$YTaO_4$ was found to significantly improve radiographic image sharpness[4, 5]. There are two reasons for the improvement in image quality. First, the UV light is more highly attenuated within the intensifying screen and the image emanating from the screen (i.e., the cone of emission) is sharper than that of comparable visible-light emitting screens. Second, "print-through" is virtually eliminated because the UV light emitted from the intensifying screen is more efficiently absorbed by the silver halide emulsion, and, in addition, any remaining UV light that transmits through the emulsion is attenuated by the film base[2].

These advantages over visible-light emitting phosphors focussed R&D efforts on finding other UV-emitting X-ray phosphors (i.e., those with emission less than 400 nm). Attention was given to hafnium-oxide based phosphors because HfO_2 and hafnate compounds have good X-ray absorption and relatively large band gaps. Recently, we reported the synthesis, structure, chemistry, and luminescence of a highly efficient UV-emitting X-ray phosphor, $BaHf_{1-x}Zr_x(PO_4)_2$ (x = 0-0.2)[6].

Here, we discuss two other UV-emitting hafnium-phosphate phosphors that were discovered in the course of our research.

References

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