M.3: Development of Chromox ceramic for Hydrogen ion beam detection

Chromium-doped Al_2O_3 (Chromox) scintillator ceramic screens are extensively used for electron and proton beam diagnostics in accelerator programs. At present, such screens are largely imported. The present activity at Photonic Materials Technology Section, carried out in collaboration with Proton Linac Development Division, RRCAT, aims to develop indigenous Chromox scintillator screens with a diameter of 70–75 mm and a thickness of 3-4 mm for hydrogen ion beam detection.

Chromox powder with 0.5 at.% Cr^{3+} doping was synthesized via a conventional solid-state reaction route using high-purity aluminium oxide and chromium oxide. The powders were calcined at 1200 °C, compacted into pellets of 90 mm diameter, and sintered at 1650 °C under high vacuum (~5×10^{-6} mbar). Dense ceramic disks with a diameter of ~72 mm and thickness of ~3.0 mm were obtained (Fig. M.3.1a). The sintered samples exhibited well-defined grains with an average grain size of ~5 µm (Fig. M.3.1b). The sintered pellets were lapped and optically polished prior to detailed structural and optical characterization.

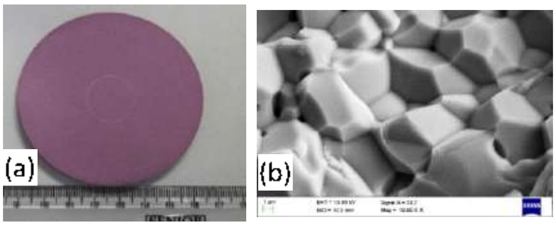

Fig. M.3.1: (a) As sintered Chromox ceramic screen (b) SEM of fractured surface

X-ray diffraction analysis confirmed the formation of a single-phase hexagonal close-packed α-Al_2O_3 structure with no detectable impurity phases (Fig. M.3.2). Photoluminescence measurements exhibited two prominent emission peaks at 694.3 nm and 692.7 nm, corresponding to the characteristic ^2E to $^4A_2$ transition of Cr^{3+} ions (Fig. M.3.3a). The measured luminescence lifetime for this transition was approximately 3×10^{-3} sec (Fig. M.3.3b). The

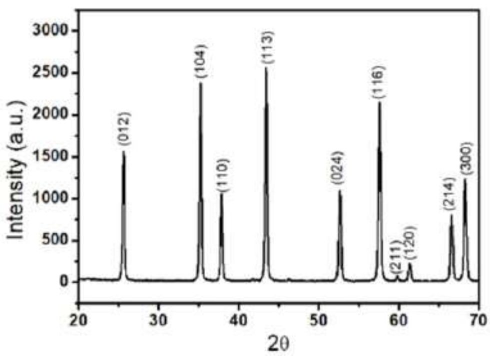

Fig. M.3.2: Powder X-ray diffraction of sintered ceramic

observed emission wavelengths and lifetime closely match reported literature values, thereby validating the optical quality of the synthesized Chromox ceramics.

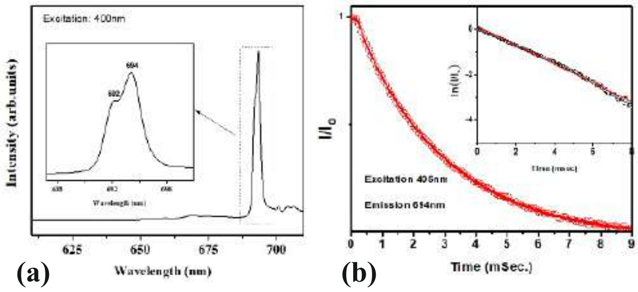

Fig. M.3.3: (a) Photo-luminescence spectra and (b) Plot of intensity versus time for Chromox.

For beam diagnostics, the Chromox scintillator screen was mounted inside a diagnostics chamber under vacuum at a distance of 300 mm from the last ground electrode. A hydrogen ion beam generated using an ECR plasma source was accelerated to an energy of 25 keV and directed onto the Chromox screen mounted at an angle of 45° using a CF100 flange. The scintillation image was transmitted through a quartz window and recorded by a high-sensitivity camera positioned at 90° to the beam axis outside the chamber.

Beam images recorded using the Chromox scintillator screen at microwave powers of (a) 200 W, (b) 500 W, and (c) 800 W, at a fixed hydrogen gas pressure of 1.6×10^{-5} mbar and beam energy of 25 keV, are shown in Fig. M.3.4. Visible scintillation emission was first observed at a microwave power of ~200 W.

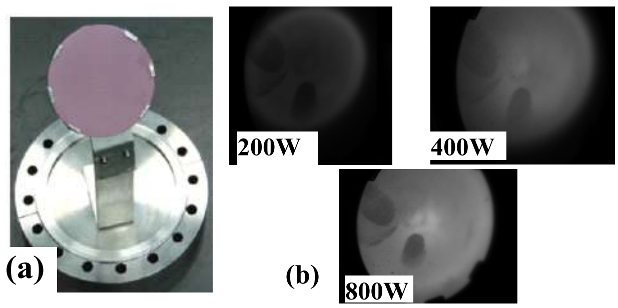

Fig. M.3.4: (a)Mounting arrangement of the Chromox scintillator screen on the CF100 flange. (b) The images captured using Chromox scintillator screen at varying microwave power

With increasing microwave power, the beam spot exhibited enhanced brightness and improved sharpness, consistent with an increase in beam current and ionization efficiency. The Chromox scintillator screen produced stable and reproducible signals over the entire range of tested operating conditions and duty factors, demonstrating its suitability for hydrogen ion beam diagnostics in accelerator applications.

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