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Diagnostic Phosphors for Photon Beams at the ALS and APS*

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Some tests have been made of phosphors for photon beam diagnosis. Plasma sprayed coatings were checked for damage and decay during a period of several ampere-hours of irradiation from the NSLS Xray ring. Surface temperatures were measured and extrapolated to give an indication of the temperatures expected in more powerful photon beams. Based on our findings we have chosen plasma-sprayed coatings of Europium-doped Yttrium Oxide as the best candidate for use on masks and flags in 'white' photon beams of the new facilities.

Introduction

Plasma-sprayed ceramic coatings on metal are known to be resilient, and compatible with ultra-high vacuum.

We have plasma-sprayed three ceramic phosphor powders (emitting blue, green and red light) onto copper sample pieces and tested them in an undulator beam (X13) and in a wiggler beam (X17) at the National Synchrotron Light Source. We have evaluated the color of the visible light, the surface temperature during irradiation in UHV and looked for damage to the phosphor after exposure to the beam.

1. Materials and coating

Phosphor powders designed for use in color televisions were purchased from GTE Sylvania [1]. Three powders were tested:

- 1) Copper and silver activated zinc sulfide (P31) emitting green light.
- 2) Silver activated zinc sulfide (P22) emitting blue light.
- 3) Europium activated yttrium oxide (P22) emitting red light

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Figure 1, provided by GTE, shows the photon wavelengths below which the phosphors begin to respond and the wavelengths at which they emit.

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Copper sample pieces were coated with these materials by a commercial plasma-coating company [2]. The plasma spray process involves blasting the

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surface of the copper samples with alumina powder, for roughening, followed by plasma spray of the phosphor. We specified a single pass of the spraying head, and obtained a coating of typically $15\mu\text{m}$ thickness, appearing barely opaque.

Vacuum properties were good. There was no measurable contribution from the samples (4cm^2) to the base pressure (9×10^{-10} Torr) of our 4" diameter beamline chamber. Samples were also baked to 400°C in a vacuum furnace and showed no effects.

2. Color of visible light

A series of tests were carried out at X13, which is a ten period undulator on the Brookhaven Xray ring. The samples were placed 15m from the source and the undulator beam was approximately 0.75cm in diameter at this point. The undulator gap was set to give $K=1.65$ resulting in 30Watts of beam power. Bend magnet radiation was present on either side of the undulator beam.

Incident on an uncoated sample, the bend magnet light has a visible component with a blue color. For this reason we preferred the red or green phosphor over the blue emitter and we will not consider the blue further. We particularly preferred the red P22, because it responds only to photons at UV wavelengths, and shorter. All of the phosphors were excited by the bend magnet radiation and they were excited so brightly in the center of the undulator beam that filters were needed in order to observe the light with a TV camera.

3. Surface temperature

We employed a commercially available infrared telescope [3] to view the surface of the phosphor during irradiation.

By choosing a device operating at $5\mu\text{m}$ wavelength we could measure through a commercially available sapphire window. Bench tests allowed us to obtain a correction to the measured infrared intensity for the absorption of the window, which was a factor of the order of 15%. The dark current from the infrared detector in the telescope corresponded to a base temperature of about 50°C .

The undulator produced a power density on the samples (mounted with the surface-normal at 30° to the beam direction) of about 0.5 Wmm^{-2} with 200mA of electron current in the storage ring. The copper sample pieces were fastened to a large piece of copper acting as a heat sink. Upon irradiation, the temperature of the phosphor surface were seen to rise immediately to 80 or 90°C . Extrapolating to the ALS, where the phosphors will

be coated on a water cooled grazing incidence (18°) copper surface 15m from the source, and irradiated by undulator beams giving power densities on the surface up to about 2 Wmm^{-2} , we anticipate local temperatures on the ceramic surface up to about 300°C .

3. Damage and light output

Light output from the red and green phosphors was monitored by means of an imaging, color sensitive, light meter [4]. We made readings over a period of 48 hours of continuous irradiation in UHV at X13. Motion of the electron beam in the storage ring was the principle source of noise in these measurements. Figure 2 shows the results. The red P22 showed no significant change in efficiency. This was verified by moving the sample after the measurement so that a fresh piece of surface was illuminated, the light output was not affected. The green P31 showed indications of loss of efficiency after irradiation (20%), and when a fresh part of the surface was irradiated the original efficiency was recovered.

Visual inspection of the phosphor after irradiation showed the red P22 to be clean. The green P31 and the blue P22 showed marks where the beam had been incident.

Further tests were carried out in a beam of hard x-rays from the super-conducting wiggler. During these tests the wiggler field was set to 4.4 T, resulting in a critical photon energy of 18.58 keV. The red and blue phosphor ceramic coatings were exposed in the X17b hutch, in air and without cooling. The samples were illuminated by the wiggler white beam, downstream of the exit beryllium window, with surface-normal at 45° , and about 3.5 Wmm^{-2} surface power density. The exposure lasted 1 to 2 hours. The sample fluorescence flux and color were measured with the 'chromameter' [4]. The results show that the P22 red provided about 25 times higher visible fluorescence flux than the P31 green. The red exhibited flat flux response versus exposure time. The P31 fluorescence flux decreased rapidly during the first several minutes of exposure by about 50%, then leveled off.

Acknowledgement

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References

- [1] GTE Products Corp., Chemical and Metallurgical Division, 6505 E. Gayhart St., Commerce, CA 90040
- [2] Plasma Coating Corp., 15331 S. Avalon Blvd., Gardena, CA 90248
- [3] M67S from Mikron Instrument Co. Inc., 445 W. Main St, Wyckoff, NJ 07481
- [4] "Chromameter" from Minolta Corp., 30,2-Chome, Azuchi-Machi, Higashi-Ku, Osaka 541, Japan

Figure Captions

- 1. Excitation functions and emitted spectra, versus photon wavelength, for the three phosphors (after GTE Sylvania).
- 2. Light output efficiency during irradiation at X13.

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Figure 1.

Figure 2.

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