Development of an Imaging Plate Radiation Detector

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The imaging plate is a reusable storage phosphor film, formed with a large area of thin plastic plate coated with photo-stimulable phosphor (e.g. BaFBr:Eu^{2+})$^{1)}$, which is sensitive to nuclear particle radiations as well as X-rays and energetic electrons and now widely used in various fields.

The latent images caused by irradiation of the imaging plate are usually read out by measuring the Eu^{2+} luminescence at about 390 nm stimulated by 633 nm light of a He-Ne laser scanner, and are reconstructed as two-dimensional dot images on a computer's display.

The imaging plate has many striking performances of radiation detection, such as a simple usage, a high position resolution (25-100 μm), a large detection area, a high detection sensitivity with good signal-to-noise ratio, long time dose accumulation, good dose linearity, extremely wide dynamic range of dose and easy erasing for reuse. In addition to these, we have reported previously that the imaging plate has a feature of good particle discrimination in itself, which is performed using two or more stimulation lights$^{2)}$.

As to the particle energy measurement with the imaging plate, two techniques have been proposed which are based on the absorber method$^{3-4)}$. No feature of energy determination in the imaging plate itself was expected there.

It has been widely conceived that the imaging plate itself can offer no information of incident particle energy, which comes from its character of two-dimensional optoelectronic film, usually formed of thin mono-layer phosphor, and read out by the aid of only superficial scanning with stimulation light. However, while re-examining optical properties of the imaging plate as to establishing particle discrimination for various nuclear particles of various energies, we found that the imaging plate has also a full potential ability to determine the incident particle energies with no additional means, keeping all the high performances of the imaging plate intact. Moreover, the range of the energy covered by the method is wide and the energy resolution is good, the reason of which is not yet clear. This energy determination is quite similar to the particle identification reported previously except that photo-bleaching is not applied in this method$^{2)}$.

The experimental procedures were as follows: 1] specimen: pieces of imaging plate of 10 mm×20 mm in size were cut out from a BAS3000-UR imaging plate (Fuji Photo Film

Co. Ltd.). The imaging plate was composed of 135 μm thick photo-stimulable phosphor layer of BaFBr:Eu^{2+} on a 230 μm thick supporting substrate and a 10 μm thick polymer film covering the surface of the phosphor layer for protection; 2] measurements of stimulation spectra: A light from a 50-W halogen lamp was dispersed by a grating monochrometer(JASCO CT-50) and was focused on the piece of imaging plate at an incident angle of 60° through a glass filter (Toshiba Y-45), but finally the light was a little diffused to elliptical shape of 4 mm×5 mm in shape at the imaging plate in order to reduce the surface light intensity for the convenience of multiple readout in the present. The photo-stimulated luminescence (PSL) was observed at a right angle with respect to the surface through an interference filter (IF-400, Vacuum Optics Corporation of Japan) which passes light of 390-410 nm full width at half maximum. The intensity of the luminescence was monitored with a Hamamatsu R955 photomultiplier. The output current of the photomultiplier was recorded in an NEC-9801 computer through an 16-bit A/D converter as a function of the wavelength of the stimulating monochromatic light. The intensity of the stimulating light was reduced by ND-filters to the extent that the readout fading of the PSL center was negligible (less than 1% by one scan). One measurement scan over the range of 440-750 nm of stimulation lights took 310 seconds at the rate of 1 sec/ 1 nm. All measurements and irradiations were carried out at room temperature; 3] irradiations: The used proton beam was prepared by a dynamitron of FNL (Fast Neutron Laboratory), the alpha beam by a cyclotron of CYRIC (Cyclotron and Radioisotope Center) and the electron beam by JEM-2000EXII transmission electron microscope of High Voltage Electron Microscope Laboratory, which facilities are all in our university. The proton irradiations were done perpendicularly on the pieces of the imaging plate covered with 8.2 μm thick aluminium foil in a vacuum scattering chamber through Rutherford scattering method that was useful to defocussing and spreading the protons on the imaging plates and to easy beam handling and background rejection. A scatterer of 0.2 μm thick gold foil was set at the center of the chamber at a right angle to the proton beam. The imaging plates were put at 153 mm away from the scatterer with the scattering angle of 5.5° and the number of incident protons was measured through a silicon solid state detector, located 98 mm far from the gold foil, with an angle of 165°. The number of incident protons on the imaging plates were 2.2×10^9 - 2.8×10^9 protons/cm^2 and the irradiation times were 1-17 minutes for proton energies of 3.2-1.5 MeV. The alpha measurement was done in air with the imaging plates covered with 10 μm thick aluminium foil at the course 1 of CYRIC and the electron one in vacuum chamber without wrapping. The imaging plates had been left in dark for initial 18 hours after each irradiation in order to avoid afterglow following the erasing and/or the irradiation, short time thermal fading, possible energy-dependent fading and the effect of difference of the energy-dependent irradiation times.

Figure 1 shows a PSL stimulation spectra made of the proton measurements and preliminary measurements of alpha and electron irradiations, normalized at 500 nm in order to show the clear relative variations around 600 nm. Figure 2 shows the ratios of PSL intensities of 600 nm to those of 500 nm versus the incident proton energies. A direct relationship between the PSL ratio and the energy is evident. The deviations from the straight line in the figure were within a few percent. The reason why the imaging plate can offer the particle energy determination in itself is not clear, even if the path length of the particle and/or the sharp rise of Bragg curve at the particle ending may be relevant to the evidence. Taking into account that the spatial resolution of the imaging plate is, at most, 50-25 μm and the path length of 3.2 MeV protons is about 80 μm after passing both the wrapping aluminium foil and the surface protection cover, the accuracy of 'a few percent deviation' appears unreasonably good. From the figures the particle energy determination with the imaging plate may be expected to be valid for alphas and electrons as well.

An alpha measurement of a wide range of energy was started by the cooperation with Prof. A. Yamaya and his crew.

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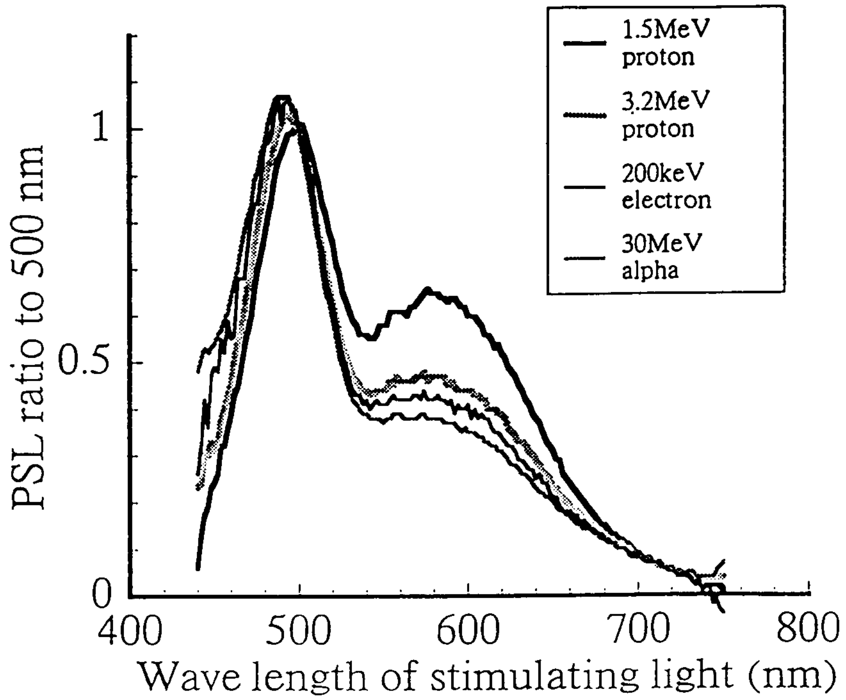

Fig. 1. PSL stimulation spectra for the images of 1.5 and 3.2 MeV protons, 30 MeV alpha particles and 200 keV electrons, normalized at 500 nm.

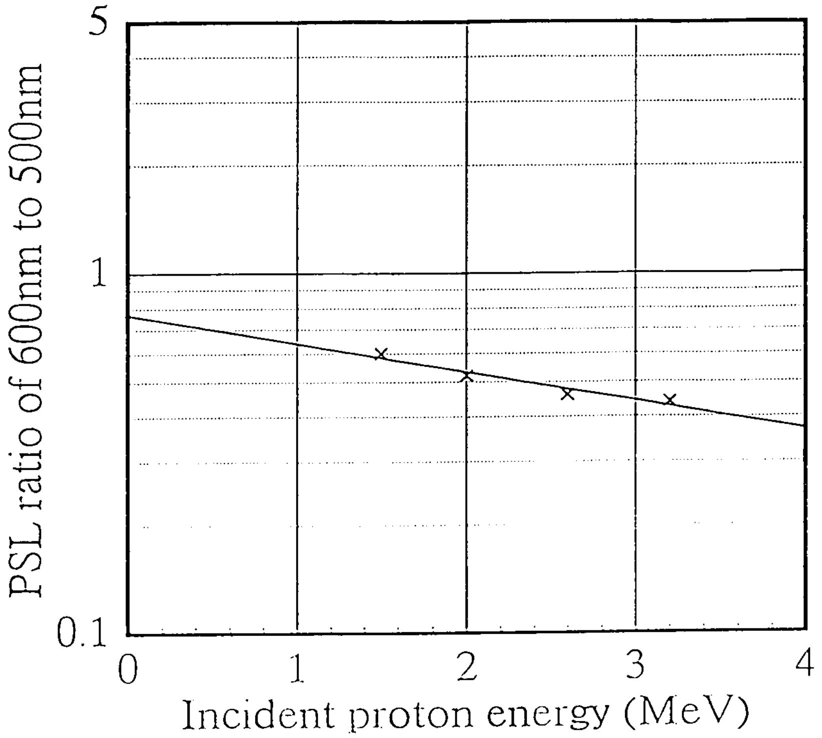

Fig. 2. Energy dependence of PSL ratios of 600 nm to 500 nm for protons.