FUJIFILM

Science Imaging Systems

What is Imaging Plate ?

Fujifilm's Proprietary Imaging Plate

The "Imaging Plate" is a new film-like radiation image sensor comprised of specifically designed phosphors that trap and store the radiation energy. The stored energy is stable until scanned with a laser beam, which releases the energy as luminescence. This phosphor technology, launched in its first application to the medical X-ray diagnostic field, portends great promise in a wide range of newer scientific and technological applications.

Table of Contents

FUJIFILM

Science Imaging Systems

What is Imaging Plate ?

Photo-stimulable Phosphor

A special phosphor was designed for the Imaging Plate. A certain substance has been known to emit light when irradiated with radiation, UV rays or an electron beam, or when heated, or mechanically hit or stimulated by chemical reaction in some cases. Materials of this kind are generally called fluorescent substances. In particular, the substances which are powders with practical applicabilities are often called phosphors.

A phosphor emits light when stimulated by, for example, radiation. The light disappears instantaneously when the stimulation ceases. This phenomenon is called "fluorescence." Some of the phosphors, however, continue emitting lights for a while after the stimulation stops, which is called "phosphorescence." "Luminescence" incorporates both of these light emission phenomena. The luminescence characteristics, specifically those of fluorescence and phosphorescence, should be taken into account when developing phosphors for practical usage. And depending on the application, these characteristics are accurately adjusted by varying the phosphor composition or manufacturing conditions.

The phosphor used for the Imaging Plate has special properties differing from those previously known, but which have not yet been put to practical use. It utilizes the "photostimulated luminescence" (PSL) phenomenon which is neither "fluorescent" nor "phosphorescent."

The PSL phenomenon is said to have been discovered by the world-famous Becquerel of France in the mid-19th century. This phenomenon involves a substance that emits light again upon the second stimulation by light having a longer wavelength than the luminescence wavelength of the first stimulation by, for example, radiation.

The PSL phenomenon, however, did not attract much interest until recently. In Japan, it was studied by military researchers until the end of World War II to develop an infrared -ray detection system. In the U.S., research was carried out in 1947 in which PSL was taken using photo-film for detecting the radiation image. No other studies were reported for some time afterwards.

This PSL phenomenon satisfies our basic concept of the Imaging Plate as an X-ray image sensor, which stores the first radiation information and releases that information as light.

Top of Imaging Plate Technology

Original source: http://home.fujifilm.com/products/science/ip/principle.html

FUJIFILM

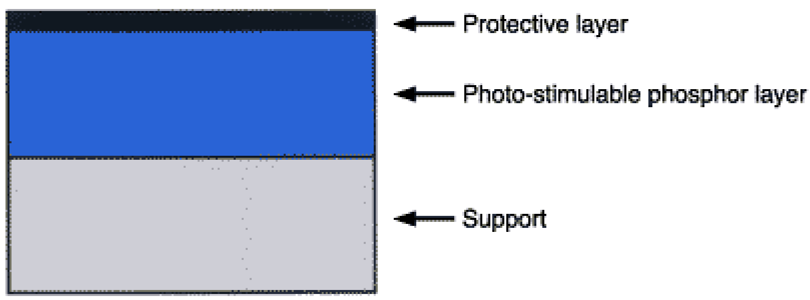
Science Imaging Systems

What is Imaging Plate ?

Principle of Imaging Plate Methodology

The Imaging Plate is a flexible image sensor in which bunches of very small crystals (grain size: about 5 µm) of photo-stimulable phosphor of barium fluorobromide containing a trace amount of bivalent europium as a luminescence center, formulated as BaFBr: Eu^{2+}, are uniformly coated on a polyester support film. The composite structure of the Imaging Plate is shown in Figure 1.

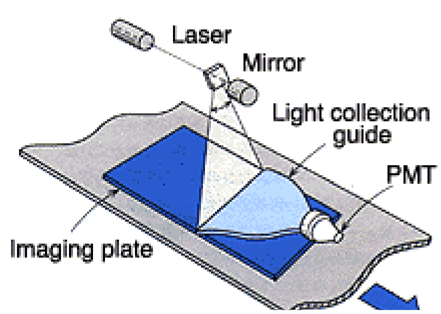
Figure 1: Composite structure of the Imaging Plate



Exposure of samples to the Imaging Plate is performed in a manner similar to that of photo-film. The exposed Imaging Plate is scanned with a laser beam of red light while the plate is being conveyed with high accuracy in a phosphor reader as shown in Figure 2.

Figure 2: Principle of reading the radiation image from the Imaging Plate.

The exposed Imaging Plate, while being conveyed, is scanned with a focused laser beam. The PSL released upon the laser is collected into the photomultiplier tube (PMT) through the light collection guide and is converted to electric signals.

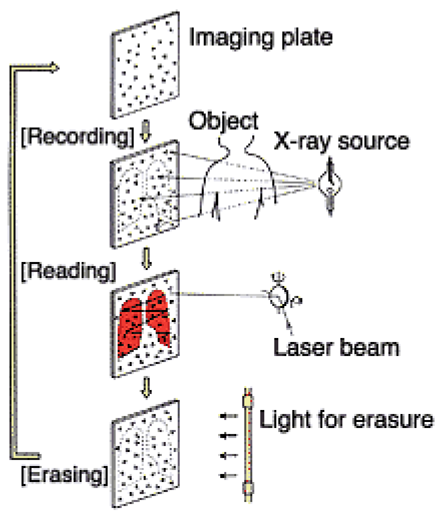


Depending on the purpose, the reading density may be selected from 5 to 40 pixels/mm. The reading sensitivity and sensitivity range can also be selected according to the purpose. A bluish purple (400 nm) PSL, released upon laser excitation, is collected through the light collection guide to the photo-multiplier tube (PMT), and converted there to analog electric signals in chronological order. Subsequently, these are converted to digital signals of 8 to 16 bits, again depending on the intended purpose.

Image analysis and data processing are done on the CRT screen. The processed image, if necessary, is printed either as a color or grayscale hard copy. The image or data processings include those of image density/gradation, spatial frequency, operational reduction or addition between multiple numbers of images, and measurements of radiation dose, length or area. Application calculation processing then becomes possible based on these data. It is a particularly great advantage to quantify the image on the CRT as accurately as the scintillation counter method. The Imaging Plate is reusable after erasing the residual latent image with uniformly irradiated visible light as shown in Figure 3.

Figure3: Process of recording, reading, erasing and reusing the radiation image by the Imaging Plate method.

The exposed Imaging Plate is reusable after erasing the residual latent image with uniformly irradiated visible light.

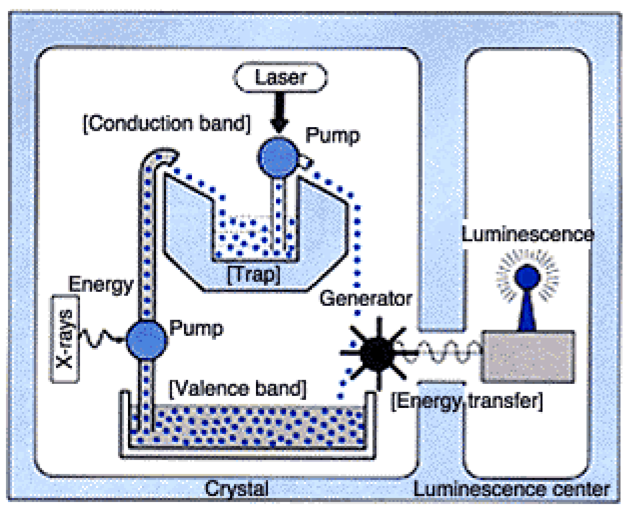


The BaFX: Eu^{2+} (X = Cl, Br or I) crystal is an ionic crystal having a tetragonal structure, and Ba is replaced with the Eu^{2+} ion to create a solid solution. This crystal, when irradiated by radiation, for example, produces mainly two types of color centers in the crystal where an electron is trapped in an empty lattice of the F or X ion. The color center actually produced mainly depends on the discrepancy between the stoichiometric composition of F and X. The type of color center can be determined by comparing the theoretical value with the measured value from the electron spin resonance (ESR) spectrum by assuming an empty lattice for each anion. Experiments carried out for the composition of X = Br reveal that the spectra of the PSL excitation process produced by visible rays after sufficient X-ray irradiation coincide well with the peak of the optical density, light current, ESR intensity and PSL intensity at the color center. The relative change between the intensity of blue luminescence with the Eu^{2+} ion and that of red luminescence with the Eu^{3+} ion detected in a trace amount is also observed before and after the PSL excitation process.

From these data, the luminescence mechanism of the BaFBr: Eu^{2+} photo-stimulable phosphor is interpreted as follows. Part of the Eu^{2+} ions become Eu^{3+} ions through the primary excitation by X-rays, for example, with electrons being released into the conduction band. These electrons are trapped into the Br ion empty lattices of the lattice defects, which are inherently present in the crystal, and color centers of the metastable state are formed. When the PSL excitation light to be absorbed by the color center is irradiated, the trapped electrons are liberated again into the conduction band, or Eu^{3+} ions, becoming an excitation state of the Eu^{2+} ion, to release PSL. The luminescence mechanism is schematically shown in Figure 4.

Figure 4: Imaging plate luminescence mechanism.

An excited electron is trapped into the halogen ion empty lattice in the crystal, makes a color center having a metastable state, and emits the radiation energy. Irradiation by the laser beam to be absorbed by the color center excites the electron again, and the recombination energy with the hole is transferred to the Eu ion, the luminescence center, resulting in luminescence.



Although the PSL mechanism is unclear in some respects, research in the future shall well elucidate the mechanism.

Original source: http://home.fujifilm.com/products/science/ip/feature.html

FUJIFILM

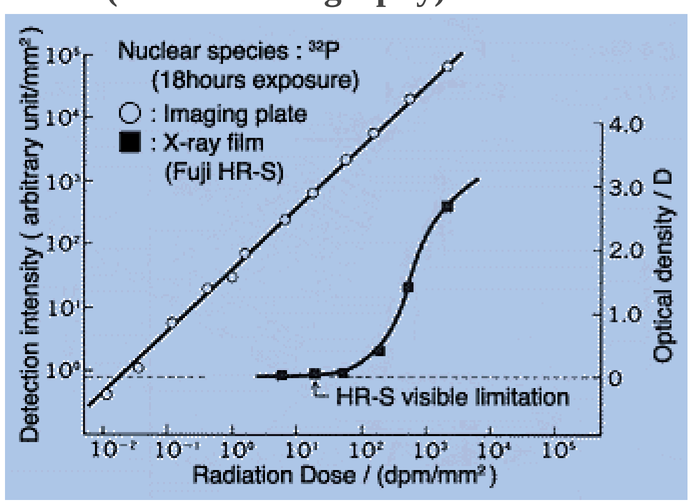
Science Imaging Systems

What is Imaging Plate ?

Features of Imaging Plate Methodology

Several techniques have been developed for detecting radiation: the ionization chamber; scintillation counter, and proportional counter tube. However, very few have been established for detecting a radiation image two-dimensionally: photo-film, the two-dimensional proportional counter tube, X-ray image intensifier and X-ray TV. Among these, the means most widely used in various fields is photo-film. The differences between the Imaging Plate and photo-film are clearly illustrated characteristically in Figure 5, depicting the detection of beta rays from radioactive isotope ^{32}P.

Figure 5: Comparison of characteristics between Imaging Plate and photographic methods (for autoradiography).



The abscissa is radiation of a standard sample of ^{32}P (beta rays 1.7 MeV) used for exposure, measured by liquid scintillation counter. The left ordinate is the amount of luminescence from the imaging plate. The right ordinate is the blackened density of photo-film. The visible limitation is the limit necessary to distinguish between the "presence and absence" of an image, and is generally about 1/10 of the determination limit.

Similar characteristics are obtained with other beta rays of different energies, electron rays, X-rays, and gamma-rays.

The features of the Imaging Plate method become clear when compared with other radiation image sensors.

1. Ultrahigh sensitivity. Several ten times more sensitive than film, and several thousand times depending on the sample.

2. Wider dynamic range. A wider range of 10^4 to 10^5 over the 10^2 range of the photographic method.

3. Superior linearity. The fluorescence emission is proportional to the dose in the entire range.

4. Higher spatial resolution. When compared with other electronic systems, a higher pixel density can be designed to meet the system purpose though less freely than film.

5. Digital electric signals are directly available from the reader. Computer processing or combination with other electronic systems is easy.

6. Due to an integral-type detector, the IP method produces less detection counting errors even at a high flux density, which often happen with pulse-type detectors such as the proportional counter tube and scintillation counter.

7. The accumulated background can be erased before use.

The Imaging Plate method, replacing the conventional radiation image sensors, not only visualizes the latent radiation image with a high sensitivity through the digital process of conventional radiation image sensors, but also makes it possible to quantify the position and intensity of the radiation image.

Top of Imaging Plate Technology

Science Imaging Systems

What is Imaging Plate ?

A Host of Imaging Plate Applications

---| *Nature* has reported that the "Imaging Plate illuminates many fields." Applications of the Imaging Plate are being widely tried to dramatically improve conventional methods in the medical X-ray diagnostic field as well as in scientific and technological fields requiring radiation image processing. The latter includes X-ray crystallography, microstructure analyses by electron microscope, and analyses by autoradiography. |---

Top of Imaging Plate Technology

FUJIFILM

Science Imaging Systems

What is Imaging Plate ?

References

Miyahara, *Science and Technology of Japan*, **26**, 28 (1985).
Interpretation on CR.

M. Sonoda, M. Takano, J. Miyahara, H. Kato, *Radiology*, **148**, 833 (1983).
Report on the development of a CR system using an imaging plate.

H. W. Leverenz, *"An Introduction to Luminescence of Solids,"* Dover Publications Inc. (1968).

"Handbook of Phosphor," edited by Phosphor Association, Ohm Co. (1987).

Y. Amemiya, J. Miyahara, *Nature* (London), **336**, 89 (1988).
Applications of imaging plate.