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Transmission positron images using imaging plates

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ABSTRACT

As an image recording medium for transmission positron microscopes, imaging plates are quite useful and powerful. Imaging plates are also quite sensitive and the photon-stimulated luminescence (PSL) is linearly proportional to the positron intensity in six digits (10^6). No bulky or expensive equipment is necessary to accommodate in vacuum. Imaging plates can be set under bright lights, this is different from the photographic films. Darkness is only required during exposure and transfer to a reader. Slow Positron Facility at KEK, Japan was used to study the effect of "mono-chromatic" positron beam. Specimens were set just in front of an imaging plate. After a certain time of exposure, the imaging plates were processed by a reader. Used imaging plates can be used repeatedly after erased by ultra-violet lights. Images through samples can be obtained. Similar experiments using non-monochromatic (white) positrons and electrons have been performed at Teikyo University of Science and Technology (TUST) and Research Reactor Institute, Kyoto Univ. (RRI). Sealed ^{22}Na positron source can be conveniently used for non-destructive tests.

1. Introduction

We have been trying to construct a microscope using positrons instead of using electrons for electron microscopes [1]. Different from a transmission electron microscope, a transmission positron microscope has been constructed reforming an old scrapped transmission electron microscope. A positron is the anti-particle of an electron, so by inverting the sign of the acceleration voltage of a transmission electron microscope and by supplying a positron beam instead of an electron source, a transmission positron microscope should be able to be built. In this way, the techniques of electron microscopes highly developed by industries for many years can be utilized. It is not easy to obtain strong intensity positron beams instead of electron beams; accelerators or atomic reactors are required to obtain strong beams of positrons. We have remolded the transmission electron source chamber of an old transmission microscope Type JEM100SX manufactured by JEOL and transported to KEK (High Energy Accelerator Organization) in Tsukuba, Japan. When we supply a positive voltage to the positron emitter, the electron microscope can be converted to a positron microscope. We had been waited for a positron beam to come to the microscope.

At KEK, a strong positron pulsed beam of 10^8 e^+/s has been supplied to a time of flight (TOF) facility which has been open to Cooperative Research for several years. We have been performed positron experiments with given energies below 35 keV. We needed a separate branch of a positron beam for a positron microscope by a changeover switches. The construction of the positron beam branch requires a lot of funds. It took us a long time. A new proposal headed by Professor Fujinami "Transmission Positron Microscopes" has been accepted by the Japan Science and Technology Promotion Agency (JST) from 2005 fiscal year [2]. This project partially supported a branch out the positron beam from TOF to a new transmission positron microscope. A brand-new transmission positron microscope based on our long experience has been set at KEK removing our old positron microscope. The positron beam is expected to reach the new microscope in a few months.

While we have been waiting the new positron beam branch, we have investigated the method of recording positron images using imaging plates.

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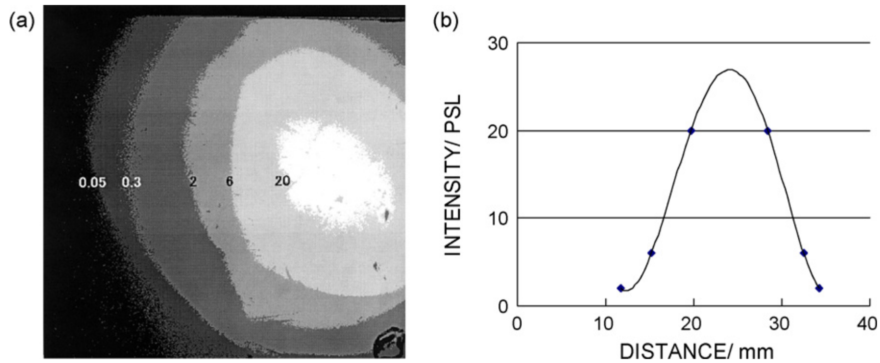

Fig. 1. Intensity distribution of TOF at KEK. The positron speed is 30 keV: (a) positron intensity image and (b) positron intensity curve along a line passing through the center of the beam.

2. Methods obtaining positron images

There are many ways of obtaining positrons images. Photographic films are one of common methods. However, the sensitivity (optical density/fluence) is not constant with the fluence although the positional resolution is excellent. A multichannel plate requires a high voltage supply and an electron detector. CCD (charge coupled device image sensor) also has to be inserted in vacuum.

Imaging plates are a card coated with barium fluorohalides phosphors which shows photo-stimulated luminescence (PSL). Darkness is not required before exposure but darkness is only required during exposure and the time of transfer the card to an analyzer. We use Fuji Imaging Analyzer BA2500. When the exposed plate is transferred to an analyzer, darkness is required so that the plate was put in a black paper envelope through which light does not penetrate. The envelope was taken to an analyzer, and the plate was taken out in darkness and was set in the analyzer in dim light. If an analyzer is far, we can carry the envelope. Photo-stimulated luminescence is linearly proportional to fluence in six digits. We have succeeded to obtain positron images using imaging plates, the first in the world [3].

Fuji Imaging Plates BAS-TR2025 [4] for bio imaging analyzer BAS2500 were used. The imaging plates were cut into 30 mm × 30 mm, and these imaging plates do not have protective layers to respond slow positron or electron beams. Fuji Imaging Analyzer BAS2500's at the photon Factory, KEK, at Teikyo University of Science and Technology and at Kyoto University Reactor Research Institute were used to analyze positron and electron images recorded on imaging plates.

A positron excites an electron of barium fluorohalides phosphors to a metastable state and the metastable electron decays very slowly. In an analyzer, by irradiating with scanning red laser (633 nm), blue light (400 nm, short life-time of 0.8 μs) is emitted. This blue light is detected by photo-electron conversion element, after digital imaging process, an image is obtained.

Photo-stimulated luminescence usually has very wide dynamic ranges. Logarithm of the detected number of photo-stimulated luminescence is taken to shrink imaging data to narrower ranges and then quantized, which means the figure was rounded to an integer. This value is called QL (quantum level) by Fuji Film Co., Japan [4]. The "IPReader" (commercial name of an imaging plate analyzer by Fuji Film Co.) output is kept as QL. The grade of the number of positrons entered to one pixel can be recorded as 8 bits (Grad 256), 10 bits (Grad 1024), or 16 bits (Grad 65536). 16 bits was selected in this experiment. Photo-stimulated luminescence value PSL is proportional to the photo-stimulated luminescence. The photo-stimulated luminescence per area, I, can be represented as PSL/mm^2. The relation between PSL and QL is defined as

$$\mathrm{PSL} = \left(\frac{\text{pixel size}}{100}\right)^2 \times \left(\frac{4000}{\text{sensitivity}}\right) \times 10\left(\text{latitude} - \left(\frac{\mathrm{QL}}{\text{grad} - 0.5}\right)\right)$$

according to Fuji Film Co. [4], PSL = 0, when QL = 0 where Grad = 2 bit.

For the same kind of particles, IP, reading densities are the same, therefore the comparison between different exposures is possible. We have used sensitivity = 4000, latitude = 5, and Grad = 1024.

The PSL is proportional in the range one to one million of the fluence of positrons [3]. This is much more sensitive than films and

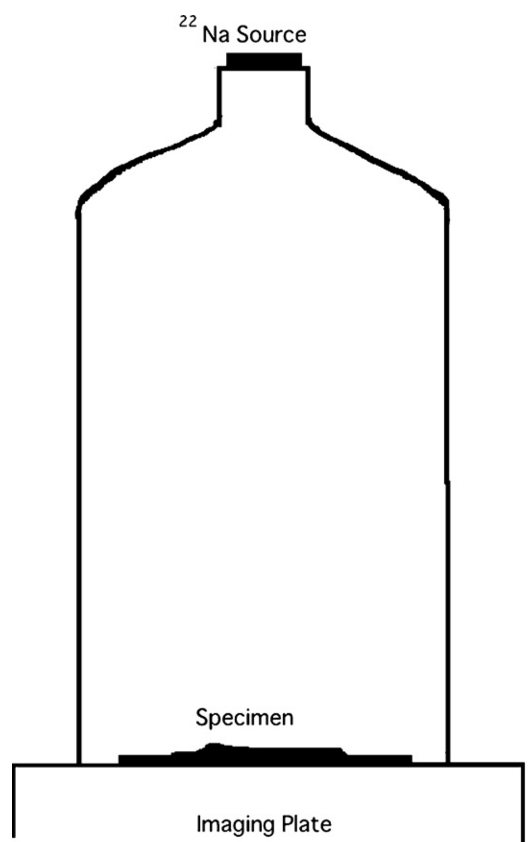

Fig. 2. A specimen was put on an imaging plate, and the set was irradiated by positrons from a ^{22}Na sealed source.