

A new image-plate reader for various sizes and shapes

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A new image-plate reader which can read image plates (IPs) having various sizes and shapes has been developed. The machine consists of a rotating laser head to induce luminescence photons from IPs and a porous cylindrical holder made of a composite of cast iron and porous ceramic – so-called 'breathnite'. Image plates can be fixed onto the inner surface of the cylindrical holder by evacuating the outer surface through a vacuum chamber with a mechanical pump. Image plates having various shapes and sizes up to 400 × 400 mm can be fixed without covering the open surface on the cylinder. In spite of such flexibility to various applications, the reader produces competitive performances compared with other commercial readers.

Keywords: image plates; readers; breathnite.

1. Introduction

Since Sonoda *et al.* (1983) invented image plates (IPs) as a radiological tool, they have become indispensable tools for various experimental techniques as highly sensitive two-dimensional radiation detectors. As various applications using IPs have been developed, IPs having various sizes and shapes have become commonly used. However, most IP readers can only read IPs

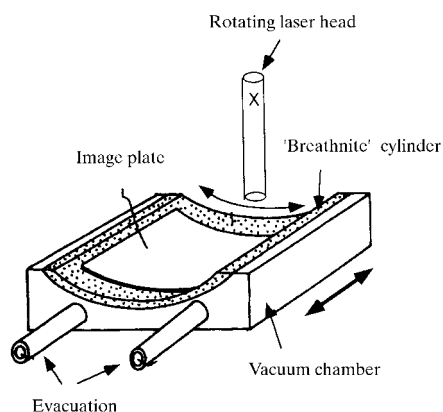


Figure 1

The main parts of the machine, SHIN-MAC ONE (MAC Science Co. Ltd, Yokohama, Japan). The reader consists of a rotating laser (He–Ne, 10 mW) head and a porous cylindrical holder made of a composite of cast iron and porous ceramic materials, called breathnite (Nabeya Corporation Ltd, Gifu, Japan) (New Materials Technology Update, 1987).

having fixed sizes and rectangular shapes, such as 40 × 20 cm or 20 × 25 cm. Although some IP readers can read variable-size IPs, special attachments and settings depending on the sizes and shapes of the IPs are necessary to read them properly.

A new IP reader which can read IPs having various sizes and shapes without requiring any attachments was developed to alleviate such inconveniences.

2. Mechanism of the IP reader

As shown in Fig. 1, the main parts of the machine, SHIN-MAC ONE (made at MAC Science Co. Ltd, Yokohama, Japan), consists of a rotating laser [He–Ne ($\lambda = 633$ nm), 10 mW] head and a porous cylindrical holder made of a composite of cast iron and porous ceramic materials, called 'breathnite' (Nabeya Corporation Ltd, Gifu, Japan) (Horie, 1988, 1989; New Materials Technology Update, 1987).

The IP is vacuum-sucked onto the inner surface of the cylinder by evacuating the outer surface through a vacuum chamber with a mechanical pump. The laser beam induces luminescence photons from the IP. By rotating the laser head (382 r.p.m.) and displacing the cylinder towards the vertical direction of the laser rotation, the entire surface of the IP can be scanned. A side view of the reader is shown in Fig. 2. The luminescence photons are detected by two parallel photomultipliers having different gains (250:1) to switch with each other, depending on the photon intensities, and send the data to a workstation (NSSUN SPARC STATION IPX) through ADC (16 bits). The mechanism ensures a wide dynamic range and linearity, as shown in Fig. 3.

Image plates having various shapes and sizes (smaller than 400 × 400 mm) can be read without any attachments covering the open surface of the cylinder, since the air conductance of the breathnite, having controlled pore sizes (~ 0.1 mm diameter) and ratios (~ 60 – 90 vol.%), is large enough to evacuate the vacuum

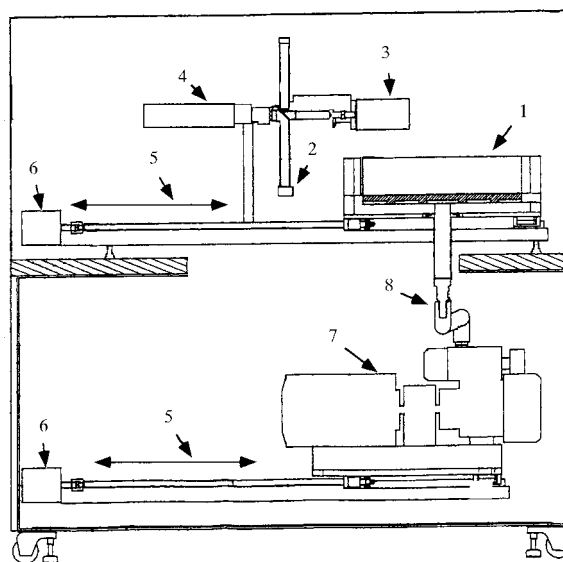


Figure 2

Side view of SHIN-MAC ONE. (1) cylindrical breathnite IP holder; (2) rotating laser head; (3) pulse motor and encoder for the rotating laser head; (4) He–Ne laser; (5) synchronized displacement system of the IP holder and the vacuum pump; (6) pulse motor for the displacement system; (7) vacuum pump; (8) vacuum connection between the IP holder vacuum chamber and the vacuum pump.

chamber and small enough to maintain a pressure difference between the inner and the outer surface of the cylinder holder to vacuum-suck IPs without covering the open surface. To ensure spatial homogeneity of reading, the accuracy of the radius of the cylinder (200 mm diameter) was controlled carefully to less than 20 μm, which is the depth of the focus of the laser beam. The structure of breathnite is schematically described in Fig. 4.

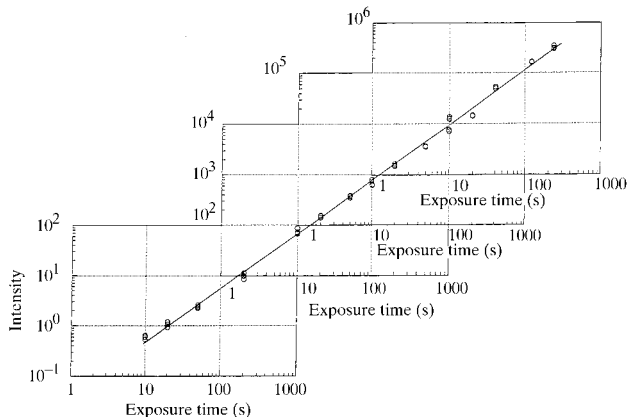


Figure 3
Plots of exposure times *versus* photon intensities read by the IP reader. Data consist of four different source intensity regions by using Al foil attenuators.

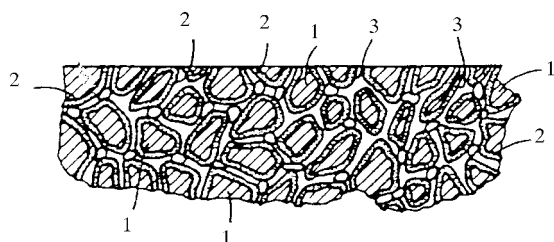


Figure 4
Schematic drawing of the breathnite structure. (1) cast iron; (2) porous ceramics; (3) pore (Horie, 1988, 1989).

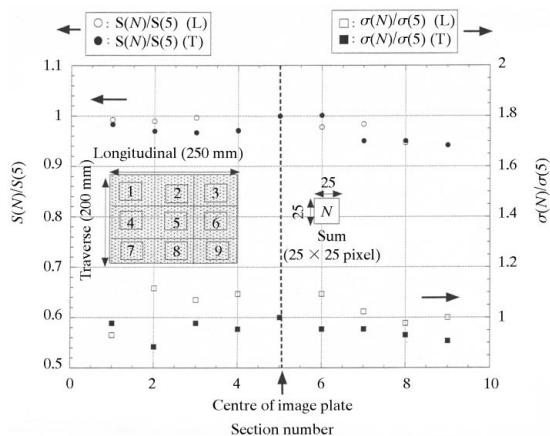


Figure 5
Plots of summations of readout intensities of the central 25 × 25 pixels of each section, numbered 1–9, on the exposed IP and the standard deviations of the intensity in the sections, against section number. Symbols in the figure are designated as follows: *S*(*N*), summation of the readout intensity at the *N*th section; σ (*N*), standard deviation of the intensity at the *N*th section; *L*, laser scan towards the longitudinal direction of the IP; *T*, laser scan towards the transverse direction of the IP.

Table 1

Main specifications of the image-plate reader, SHIN-MAC ONE.

Selective pixel size (μm)	100 × 100, 200 × 200 or 400 × 400
Readable image-plate size (mm)	Any (plural) image plates smaller than 400 × 400
Dwelling time per pixel of laser [μs pixel (100 μm) ⁻¹]	12.5
Laser head rotation speed (r.p.m.)	382
Laser beam depth of focus (μm)	~20
Radius of rotating laser head and breathnite image-plate holder (mm)	200 ± 0.015
Readout time for 400 × 400 image plate	
Pixel size 100 × 100 μm	10.5 min
Pixel size 200 × 200 μm	5.3 min
Pixel size 400 × 400 μm	2.7 min
Sensitivity (minimum readable photon density) (X-ray photons pixel ⁻¹)	1
Dynamic range (photons pixel ⁻¹)	1–10 ⁶
Effective readable digits (linearity)	5
Laser beam spot size at image plate (μm)	<30 (diameter)

3. Main specifications and machine performances

The main specifications of the reader are summarized in Table 1.

The readout linearity was checked using an RI source (⁵⁵Fe, 3 μCi) with changing exposure times. The source intensity was changed using Al foil attenuators. The results are plotted in Fig. 3. The readable intensity range of the luminescence photon is from 1 to 10⁶ photons pixel⁻¹, and five-digit linearity is ensured; the performance matches that of other commercial readers (see, for example, Miyahara *et al.*, 1986).

To examine the readout uniformity, a 200 × 250 mm image plate was set parallel to the direct-beam direction inside the entrance door of the experimental hutch of PF-BL15C, and exposed for 8 s to an air-scattered white beam. The exposed plate was scanned by the laser beam towards either the longitudinal or traverse direction of the IP to check the effect of the reading direction on readout uniformity. The results are shown in Fig. 5. In the analysis of the data, the IP area was divided into nine sections

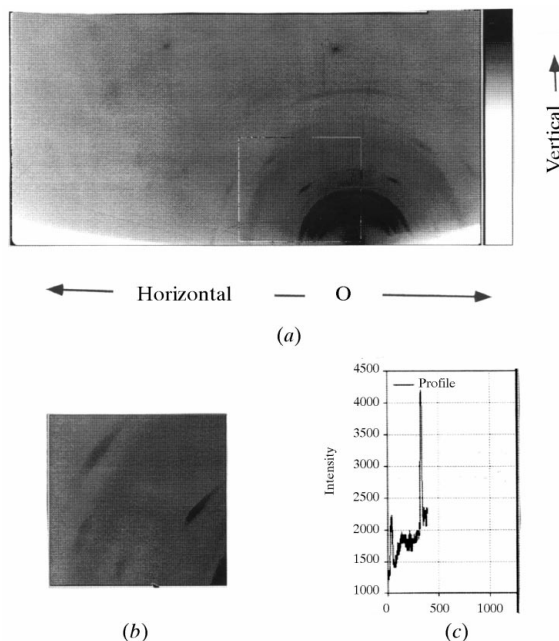


Figure 6
An IP diffraction image from a sputter-deposited α-Fe₂O₃ thin film analysed by SHIN-MAC ONE: (a) original (40 × 20 mm); (b) magnified; (c) cross section.

having equivalent area, and 25×25 pixels were chosen from the centre part of each section for analysis of the total intensity and its standard deviation in the area. No systematic deviation from the centre of the IP, both in the sum and the standard deviation of the total intensities, was observed in both the longitudinal and traverse scans. The homogeneity is as good as -0.05 in the summation, and ± 0.1 in the standard deviation. The values are close to those of typical commercial readers (Amemiya *et al.*, 1988).

4. Examples for application

A 100 nm-thick sputter-deposited α -Fe₂O₃ thin film was used for a test sample. The sample was prepared on an Si (111) wafer at 773 K by the magnetron sputtering deposition method with an oxide target having the same composition as the deposited film. A highly focused and high-flux synchrotron radiation beam was used as an incident beam with an incident angle of 0.5° under a total reflection condition at PF-BL3A. The IP was mounted on the spherical-type goniometer (Takagi *et al.*, 1995) and set for the G-GIXD geometry (Takagi & Kimura, 1998). In Fig. 6 an IP image read by SHIN-MAC ONE is shown as an example. Both strong diffraction arcs from α -Fe₂O₃, indicating a preferred orientation of the film, and some weak spots from the single-crystal Si wafer are clearly shown in the image.

5. Conclusions

As was shown in the above sections, SHIN-MAC ONE, the first IP reader developed to read IPs having various sizes and shapes without any attachments, by using breathnrite as the IP holder,

showed competitive performances compared with other commercially available IP readers in spite of its flexibility for various applications. Although applications for various experiments must be investigated further in the future, we believe that the reader will become a powerful tool which may be applicable to various experiments in which special settings of IPs having various sizes and shapes are required.

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