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Note: Development of target changeable palm-top pyroelectric x-ray tube

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A target changeable palm-top size x-ray tube was realized using pyroelectric crystal and detachable vacuum flanges. The target metals can be exchanged easily by attaching them on the brass stage with carbon tape. When silver and titanium palates (area: 10 mm^2) were used as targets, silver Lα and titanium K lines were clearly observed by bombarding electrons on the targets for 90 s. The intensities were the same or higher than those of previously reported pyroelectric x-ray tubes. Chromium, iron, nickel, copper, and zinc K lines in the x-ray tube (stainless steel and brass) disappeared by replacing the brass stage and the stainless steel vacuum flange with a carbon stage and a glass tube, respectively.
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Recently, we have developed an electron probe micro-analyzer (EPMA) with a palm-top size chamber including the electron source and the sample stage using a pyroelectric crystal ($LiTaO_3$) as the electron source.[1,2] One of the notable features of the palm-top EPMA was the ease of exchanging samples because detachable vacuum joints were used for the sample chamber and samples were attached with carbon tape. Applying this feature, in the present study, we present a novel palm-top pyroelectric x-ray tube whose target is easy to exchange.

Brownridge[3] first invented a pyroelectric x-ray generator using cesium nitrate ($CsNO_3$) single crystal and gold foil as a target. Kawai *et al.*[4] investigated the phenomena of x-ray emission due to a charged-up using insulator materials, and found that x-rays were effectively emitted at the pressure of about 1 Pa. Brownridge *et al.*[5] reported that intensities of x-rays obtained with a pyroelectric x-ray generator depended on the pressure and that about 1 Pa was the suitable pressure for generating x-rays. After that, Brownridge *et al.*[6] enhanced the performance of the pyroelectric x-ray generator and obtained characteristic x-rays of up to 87 keV (Pb Kα). They also tried to develop a portable x-ray tube using the pyroelectric crystal. Currently, Amptek Inc.[7] commercialized the portable x-ray generator. Geuther *et al.*[8] fabricated a pyroelectric x-ray generator using a paired-crystal of $LiTaO_3$. Their pyroelectric x-ray generator emitted continuous x-rays with the end point energy of 215 keV. Hiro *et al.*[9] also fabricated a portable pyroelectric x-ray tube using a paired-crystal of $LiTaO_3$ and obtained Kα lines of copper and zinc with high intensities by pasting brass plate on one $LaTiO_3$ crystal. These pyroelectric x-ray generators and tubes did not require a high-voltage power supply because a high voltage can be obtained by heating or cooling a pyroelectric crystal with a heating resistor or Peltier device. The pyroelectric x-ray tubes emitted x-rays with a battery for operating the Peltier device. It was difficult to exchange targets in the pyroelectric x-ray tubes previously reported because the targets were fixed in the x-ray tubes. In our pyroelectric x-ray tube, the target metals are easy to exchange.

Photo and schematic view of the pyroelectric x-ray tube in this study are shown in Figs. 1(a) and 1(b), respectively. The pyroelectric x-ray tube was developed by modifying the fabrication procedure of the palm-top EPMA.[1] In this section, the modified points are summarized. A stainless steel vacuum flange with a T shape was used for the chamber of the pyroelectric x-ray tube. The wires of the Peltier device were passed through a hole drilled in the blank vacuum flange and the hole was closed with resin. A vacuum pump was directly connected to the vacuum flange with a T shape through the vacuum hose. The brass rods supporting the brass stage for target metals and the $LiTaO_3$ crystal were attached to the blank vacuum flanges with carbon tape. The center of the vacuum flange with a T shape had a hole with a diameter of 10 mm. Polyimide tape (Kapton tape) was placed over the hole. A silicon PIN detector (X-123; Amptek Inc.) was set towards the hole as shown in Fig. 1(c). The Peltier device was connected to 3 V batteries and the $LiTaO_3$ crystal was heated for 2 min. Then, the $LiTaO_3$ crystal was cooled by applying power to the Peltier device and x-ray spectra were measured for 90 s. Titanium (99.5%) and silver (99.98%) plates were used as target metals. The targets were 2 mm in length and 5 mm in width.

Figure 2(a) shows an energy dispersive x-ray (EDX) spectrum without placing target metals on the brass sample stage. Chromium, iron, nickel, copper, and zinc K lines were observed. Chromium, iron, and nickel came from the stainless steel vacuum flange with a T shape. Copper and zinc Kα lines originated from the brass rods and the brass stage. Figure 2(b) shows an EDX spectrum with the silver and titanium plates on the brass sample stage. Silver Lα and titanium K lines were clearly detected in addition to chromium, iron, nickel, copper, and zinc K lines with 90-s measurement. The intensities of x-rays emitted from the targets in the x-ray tube were the same or higher than those in previously reported x-ray tubes.[3,5–9] This result indicates that metal plates with areas of 10 mm^2 can be used as targets of the pyroelectric x-ray tube we presented. The target metals were also easy to exchange because of the target changeable stage and the

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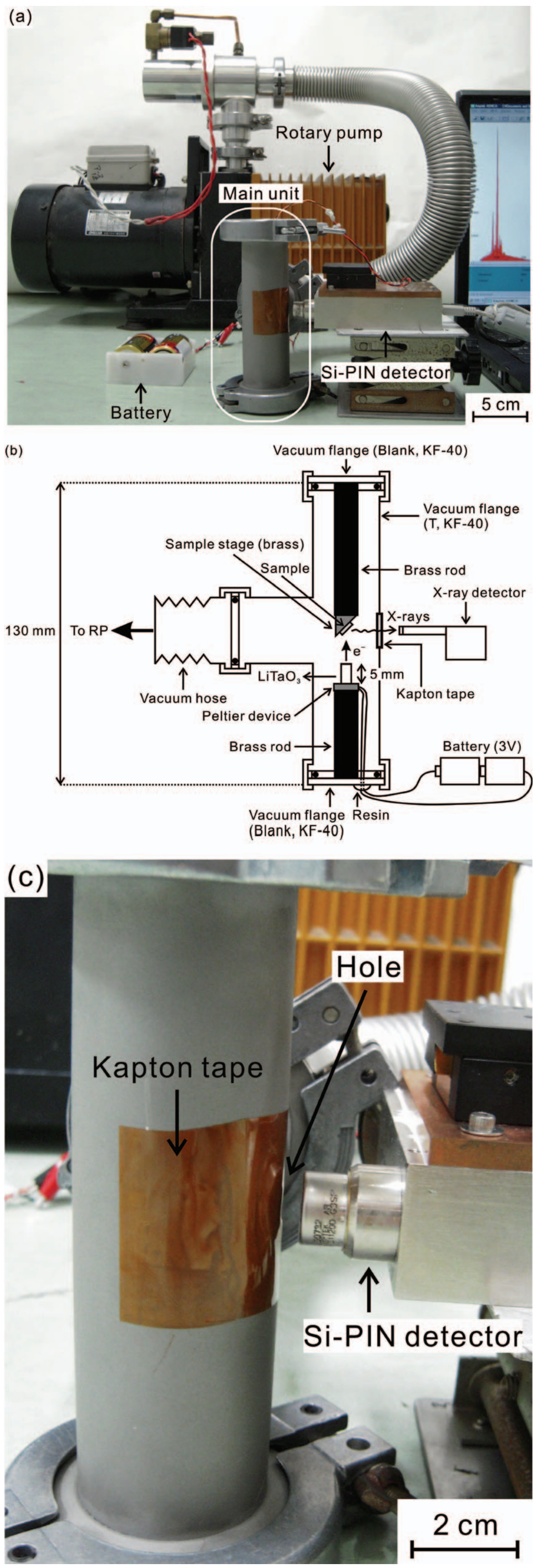

FIG. 1. (Color online) (a) Photo and (b) schematic view of the proposed pyroelectric x-ray tube. (c) Photo of the chamber (ISO Quick release couplings) including the electron source and target with the silicon PIN detector.

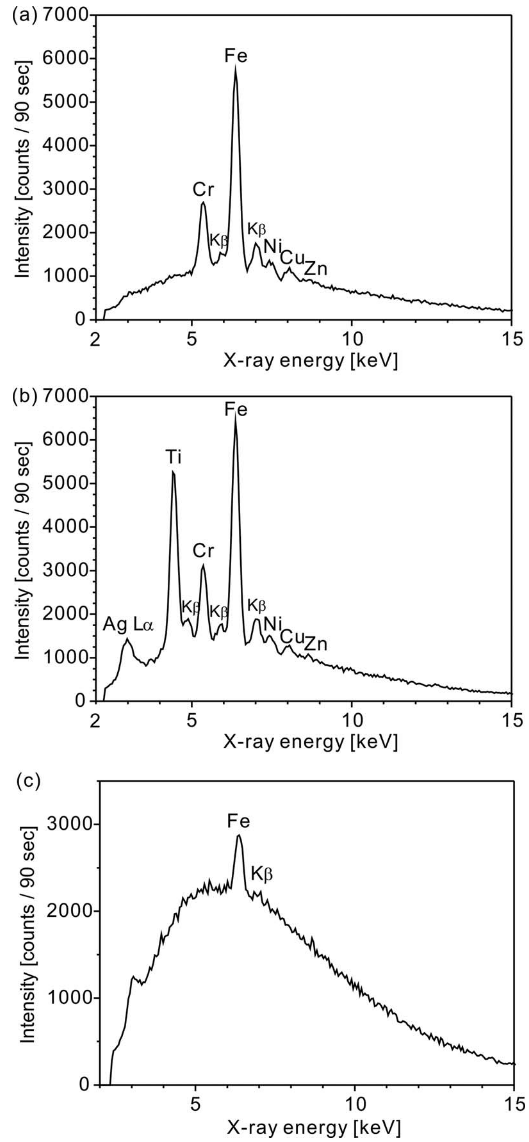

FIG. 2. (a) EDX spectrum without placing target metals on the brass stage. (b) EDX spectrum of titanium and silver plates placed on the brass stage. (c) EDX spectrum of an iron wire whose diameter and length were 0.1 and 5.0 mm, respectively. The brass stage and the stainless steel vacuum flange in the pyroelectric x-ray tube were replaced with a carbon stage and a glass tube.

detachable vacuum flanges in the pyroelectric x-ray tube. Thus, the pyroelectric x-ray tube proposed in the present study works as a target changeable x-ray tube. When the brass stage and the stainless steel vacuum flange in the pyroelectric x-ray tube were replaced with a carbon stage and a glass tube, characteristic x-rays from the target metal was only obtained as shown in Fig. 2(c). Thus, it is possible to obtain characteristic x-rays solely from the target metals using the carbon stage and the glass tube. It should be also added that the pyroelectric x-ray tube will become easier to carry if a valve is inserted between the vacuum hose and the vacuum flange with a T shape and then the vacuum hose is detached after the pressure enough to generate x-rays ($\sim$1 Pa) was obtained.

In conclusion, applying the features of the palm-top EPMA we previously reported in which samples could be exchanged easily, a target changeable palm-top size x-ray tube was realized using pyroelectric crystal. The pyroelectric x-ray tube mainly consisted of a $LiTaO_3$ crystal, the brass stage for target metals, detachable stainless steel vacuum flanges, and a vacuum pump. The target metals can be exchanged easily by attaching them to the brass stage with carbon tape. In addition to the advantage of its ease of exchanging the targets, the pyroelectric x-ray tube works with 3 V batteries. When electrons were bombarded on silver and titanium palates with an area of 10 mm^2, silver Lα and titanium K lines were clearly observed. The intensities were the same or higher than those of previously reported x-ray tubes. We confirmed that the pyroelectric x-ray tube proposed in the present study worked as a target changeable x-ray tube when metal plates with an area of 10 mm^2 were used as target metals. Chromium, iron, nickel, copper, and zinc K lines were additionally detected, having come from metals in the x-ray tube (stainless steel and brass). These characteristic x-rays could be removed by replacing the brass stage and the stainless steel vacuum flange with a carbon stage and a glass tube, respectively.

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[1] S. Imashuku, A. Imanishi, and J. Kawai, Anal. Chem. **83**, 8363 (2011).
[2] S. Imashuku, A. Imanishi, and J. Kawai, "Palmtop EPMA by Electric Battery," *AIP Conf. Proc.* (submitted).
[3] J. D. Brownridge, Nature (London) **358**, 287 (1992).
[4] J. Kawai, N. Inada, and K. Maeda, Adv. X-Ray Chem. Anal., Jpn (in Japanese) **29**, 203 (1997).
[5] J. D. Brownridge and S. J. Reboy, Appl. Phys. **86**, 640 (1999).
[6] J. D. Brownridge, Appl. Phys. Lett. **85**, 1298 (2004).
[7] See http://www.amptek.com/ for the information on the portable pyroelectric x-ray generator.
[8] J. A. Geuther and Y. Danon, J. Appl. Phys. **97**, 104916 (2005).
[9] E. Hiro, E. T. Yamamoto, and J. Kawai, Adv. X-Ray Chem. Anal., Jpn. (in Japanese) **41**, 195 (2010).