Bull. Inst. Chem. Res., Kyoto Univ., Vol.69, No.5-6, 1991

Application of Carbon Fibers to the Resistive Wire Anode of Position-Sensitive Proportional Counters for Soft X-Rays (100 - 1000 eV)

Yasuhito ISOZUMI*, Yonghe CHEN* and Rintaro KATANO*

Received November 15, 1991

Fine carbon fibers can be used as resistive wire anodes of position-sensitive proportional counters (PSPC), since their electric resistance (e.g., ~4 kΩ/cm for a 7-μm diameter fiber) is suited for position-encoding based on the charge-division method. In the present work, the fibers have been applied to a PSPC designed for soft X rays (100 - 1000 eV). Performances of the PSPC, such as linearity, gas gain and position resolution, are described briefly.

KEY WORDS: Position-sensitive/ Proportional counter/ Carbon fiber/ Soft X ray/ Charge-division method/

1. INTRODUCTION

Position-sensitive proportional counters (PSPC) of many types are used to determine the position of X rays diffracted in the crystal X-ray spectrometer. Resistive wire anodes of carbon-coated quartz or alloy metal are often used for one-dimensional position-encording, in which the position is deduced from the ratio between the electric charges at two ends of the anode (charge-division method).[1,2] The charge-division method by resistive wire anodes makes the structure of PSPC much simpler than the other methods, in which it is necessary to use cathode plates with paticular patterns printed on, e.g., *backgammon* for the division of electric charges induced on the cathode[3] or *strip* for building in delay-line elements.[4]

Electric resistance of carbon-coated quartz wires, commercially available, is 1 - 10 kΩ /cm; this value is sufficiently high for the charge-division method. However, the life span of such anodes is shortened through the exfoliation of carbon film on the quartz wire, which is easily caused by electric discharges in the PSPC. Alloy metal wires are stronger than carbon-coated quartz wires. A shortage of alloy metal wires is their comparatively low resistance: for example, 0.17 kΩ/cm for 10-μm diameter Karma (70%Ni, 20%Cr, 7%Al+Fe) and 0.12 kΩ/cm for 10-μm diameter nichrome (80%Ni, 20%Cr). Lower resistance of the anode wire results in higher noise level of signals, which directly makes worse the position resolution of the PSPC.

The resistance of fine carbon fibers is as high as that of carbon-coated quartz wires, while the carbon fibers are more fragile to be handled than quartz or metal alloy wires.

* 五十棲泰人, 陳　永和, 片野林太郎 : Laboratory of Nuclear Radiation, Institute for Chemical Research, Kyoto University, Uji 611.

Multi-wire proportional counters consisting of carbon fiber anodes were developed by previous works.[5,6] The performance of carbon fibers as the resistive anodes of PSPC was examined in detail by Mori et al.[7]

We have been searching for position-encoding methods available for soft X-rays (100 – 1000 eV).[8] One of possible ways is to use the carbon fibers with high electric resistances. We report here our recent development on the PSPC for soft X-rays, in which the fine carbon fiber is used as a resistive anode for position-encoding by the charge-division method.

2. PSPC WITH CARBON FIBER ANODE

Except the anode wire, the structure of the present PSPC is the same as that used in our previous work.[8] The sensitive thickness of the PSPC is 10 mm; its frame is made of a brass plate with the same thickness. The material of entrance window is a Mylar film of 2.5 μm thickness, through which about 30% carbon X-rays (277 eV) can penetrate inside the PSPC. The window area is so large, i.e., 20 mm $\times$ 100 mm, that it is necessary to support the window film by two meshes of 80-μm thick stainless steel. The counter gas is isobutane with a pressure of 200 Torr. Other pure organic molecular gases such as methane, ethane, propane and pentane are also available to achieve high gas gains of more than 10^6 for soft X rays. As shown in our previous work,[8] isobutane results in the most stable operation of the PSPC.

The carbon fibers used in the present work were manufactured by Toyou Rayon, which have a circular cross section of 7 μm diameter; the resistivity of carbon is about 1.5×10^3 Ω cm. The resistance of the 10-cm long carbon fiber anode mounted in the present PSPC was measured to be 40 kΩ.

The carbon fiber has been mounted in the PSPC in the following way:

1) A boundle consisting of several hundreds of carbon filaments is cut into 30 cm lengths. After fraying one of them into a fringe, one of the filaments is carefully dragged out by a bar (0.5-mm diameter stainless steel) with a bonding material on its tip, e.g., a small piece of both-side adhesive tape.

2) Using a spontaneous adhesive agent such as Aron Alpha (Thoa Kagaku Co. Ltd.), one end of the filament is attached to the tip of a 0.2-mm copper wire, of which the other tip is previously run through holes of two harmetic seals of the PSPC.

3) After the filament is passed through two harmetic seals by drawing the copper wire, one end of the filament is attached to the tip of one of harmetic seals. The filament is pulled horizontally through the copper wire, on which a weight of 0.5 – 1 g is loaded to add a tension to the filament. The filament is attached to the tip of the other harmetic seal; Aron Alpha is again useful for the attachment between the filament and the tip of harmetic seal. The nominal tensile strength of the filament is strong enough to keep it straight in the length of 10 – 20 cm: 440 kg/mm^2 or 22 g/filament. However, the filament is very weak for bending. We must be careful not to bend the filament at the edge of the hole of harmetic seals, specially in adding the tension to filament.

4) To get good electric contact between the filament and the tip of the harmetic seal, the hole of the harmetic seal is filled with an adhesive material with good electric conductivity, e.g., Arzertie VL-10 (Tamura Kaken Co. Ltd.).

3. PERFORMANCE

3.1 Gas Gain

In Fig. 1, gas gains measured for three different wires are given as a function of anode voltage: carbon fiber of 7-μm diameter and gold-coated tungsten wires of 30 and 50 μm diameters. Absolute values of gas gains may not be precise enough. Those were determined from the heights of output pulses from the preamplifier (Canberra 2003T), using the ratio of voltage per collected charge 0.45 V/pC for the preamplifier. Moreover, it was assumed that the W value is 27.3 eV for the present counter gas, i.e., isobutane.

As seen in Fig. 1, higher gas gains can be obtained with a thinner wire when the anode voltage is fixed.

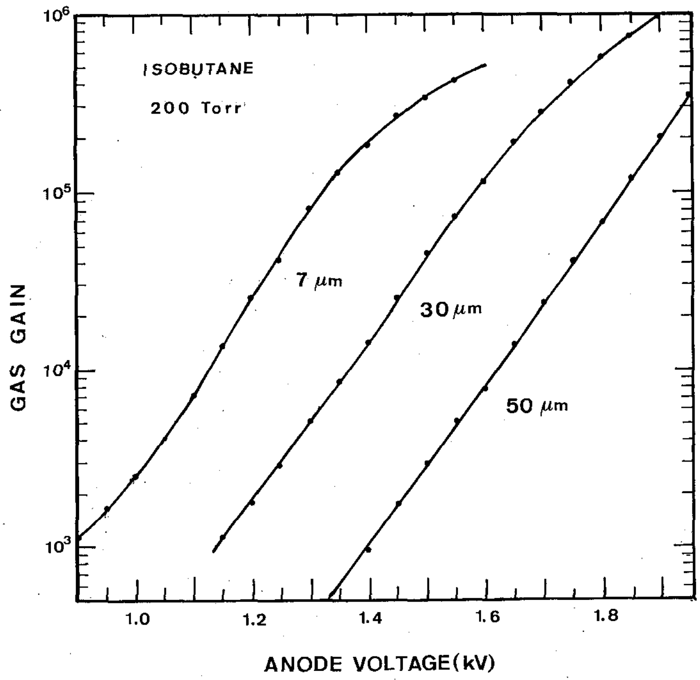

Fig. 1. Gas gains of the PSPC with wire anodes of various diameters, i.e., 7, 30 and 50 μm. Values for gas gains have been estimated with the preamplifier output for 7.2-keV K conversion electrons from ^{57}Co. The counter gas is isobutane with a pressure of 200 Torr.

3.2 Energy Linearity

Energy spectra of electrons obtained with the carbon fiber are given in Fig. 2; the anode voltage was changing from 1200 V to 1600 V. The electron source, i.e., an electroplated ^{57}Co (~500 Bq), was mounted inside the PSPC, which detected efficiently 5.6-keV KLL Auger electrons, 7.2-keV K conversion electrons and 17.2-keV L conversion electrons. In the spectrum (A), the linearity in the region below 20 keV is kept well. The spectrum was obtained with an anode voltage 1200 V, which corresponds to the gas gain of 2.5×10^4, as seen in Fig. 1. The linearity apparently becomes worse in increasing the anode voltage. When the wire of 30 μm diameter is used, the linearity is kept below 1650 V, which corresponds to the gas gain of 2×10^5. Thus, for thinner wires, the distortion in linearity appears at lower gas gains. This is a shortage of thinner wire anodes.

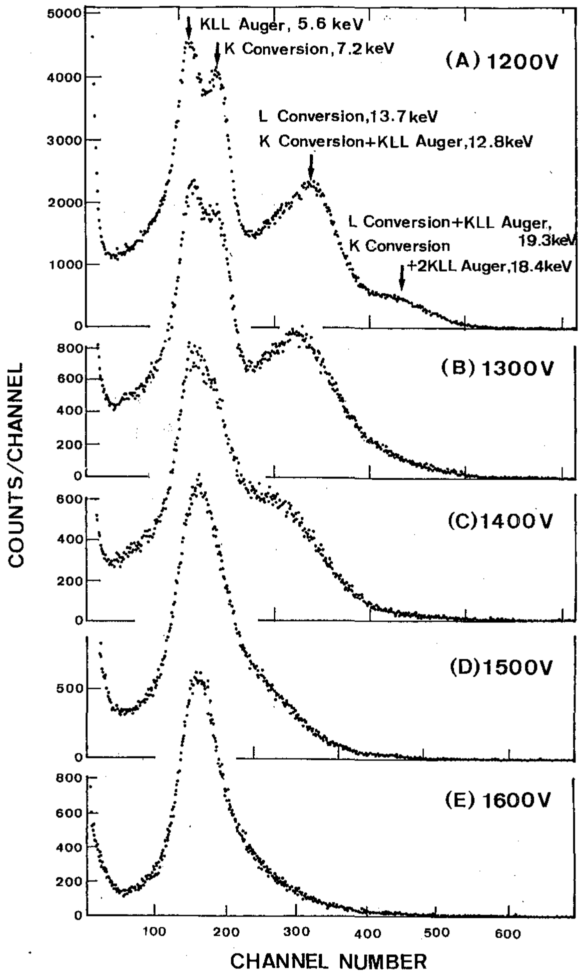

Fig. 2. Energy spectra of electrons from ^{57}Co measured by the present PSPC with the carbon fiber anode of 7-μm diameter.

3.3 Energy Resolution

In Fig. 3 are shown energy spectra of carbon K X rays measured with various anode voltages: (A), with the 7-μm diameter wire; (B), with the 30-μm diameter wire. The best resolution obtained with the 7-μm diameter wire is 68% at 1200 V, while that with the 30-μm diameter wire is 50% at 1600 V. The reason why the thinner wire results in the worse energy resolution is not clear.

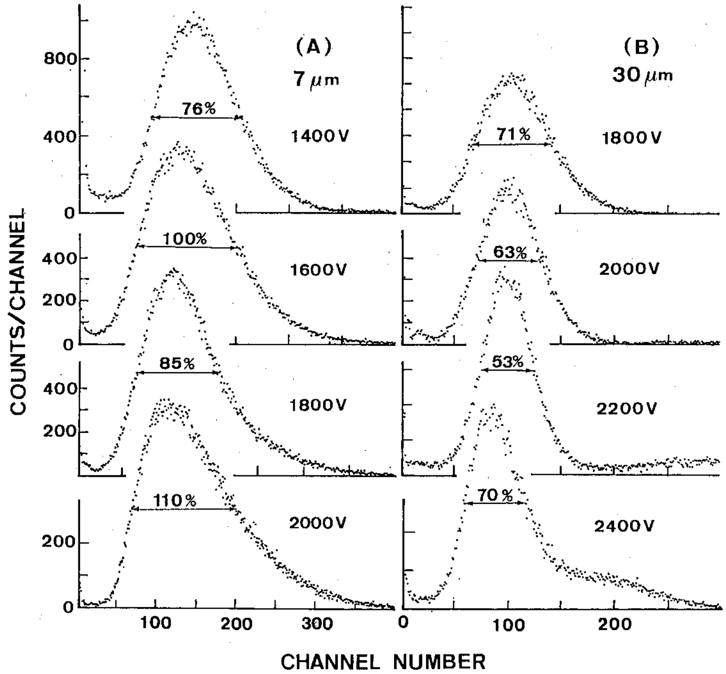

Fig. 3. Energy spectra of carbon K X rays measured by the PSPC with (A) the 7-μm diameter carbon fiber anode and (B) the 30-μm diameter gold-coated tungsten wire anode.

3.4 Position Resolution

Three position spectra obtained with carbon K X rays are given in Fig. 4; spectra (A) and (B) were obtained by the resistive anodes, i.e., the 7-μm diameter carbon fiber (40 kΩ /10 cm) and the 10-μm diameter Karma wire (2 kΩ/10 cm), respectively, while the spectrum (C) was obtained by the *backgammon* method in our previous work.[8)] In the measurements for position resolution, a 80-μm thick stainless steel plate with ten slits of 100-μm width at 5-mm intervals is mounted at the entrance window of the PSPC.

The position resolution of the 7-μm diameter fiber is considerably better than that of the 10-μm diameter wire. This mainly comes from the difference between electric resistances of two wires. The equivalent noise charge (ENC) for the RC-CR shaping electronics is given by [9)]

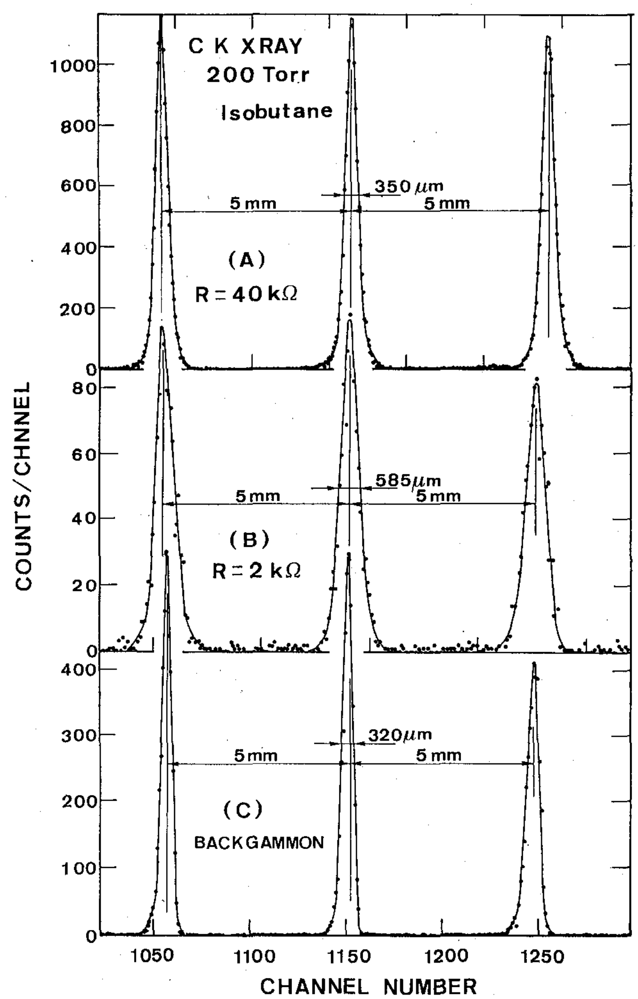

Fig. 4. Position spectra obtained with (A) a the 7-μm diameter carbon fiber (40 kΩ/10 cm), (B) a 10-μm diameter Karma wire (2 kL/10 cm) and (c) the *backgammon* method. The incident radiations are carbon K X rays.

$$\mathrm{ENC} = 2.7 \cdot (\, \kappa \cdot T \cdot \tau / 2R_a + \kappa \cdot T \cdot R_f \cdot C^2/2\tau)^{1/2} \qquad (1)$$

where R_a is the resistance of anode wire, R_f is the noise resistance of input FET channel, C is the input capacitance, τ is the shaping time constant of the circuit, κ is Boltzmann's constant, and T is the temperature. The position resolution is inversely proportional to the ENC given by Eq. (1).

The resolution obtained with the carbon fiber is almost equal to that obtained with the *backgammon* method.

4. CONCLUDING REMARKS

As seen from the position spectra (A) and (C) in Fig. 4, the position resolution obtained by the carbon fiber is as good as that by the *bacgammon* method. The PSPC with the resistive wire anode has a simpler structure than the PSPC with printed cathodes in the *backgammon* or the delay-line method. When it is necessary to eliminate background counts by the anti-coincidence technique as in our previous work,[2] the PSPC with the resistive anode is more useful than the PSPC with printed cathodes.

We are now fabricating a flat crystal soft X-ray spectrometer combining the present PSPC system with thin film multilayers commercially available, e.g., NiC and MoB_4C.

REFERENCES

(1) Y. Fujita, H. Kawakami and M. Hosoda, *Nucl. Instrum. Methods* **196**, 271 (1982).
(2) S. Kishimoto, Y. Isozumi, S. Ito, R. Katano and H. Takekoshi, *Appl. Radiat. Isot.* **40**, 229 (1989).
(3) R. Allenmand and G. Thomas, *Nucl. Instrum. Methods* **137**, 141 (1976).
(4) R.A. Boie, J. Fischer, Y. Inagaki, F.C. Merrite, V. Radeka, L.C. Rogers and D.M. Xi, *Nucl. Instrum. Methods* **201**, 93 (1982).
(5) K. Hasegawa, K. Mochiki, M. Koike, Y. Satow, H. Hashizume and Y. Iitaka, *Nucl. Instrum. Methods* **A252**, 158 (1986).
(6) F. Bird, S. Shapiro, V. Ashford, D. McShurley, R. Reif, D.W.G.S. Leith, S. Williams, *IEEE Trans. Nucl. Sci.* **NS-33**, 261 (1986).
(7) C. Mori, T. Aoyama and T. Watanabe, *J. Nucl. Sci. Technol.* **23**, 214 (1986).
(8) R. Katano, Y. Isozumi, and S. Ito, *Nucl. Instrum. Methods* in press.
(9) C.F.G. Delaney, *Electronics for the Physicists,* P. 261 (Ellis Horwood Limited, Chichester, England 1980).