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# Optical study of the features of the streamer images in RPC

K. Abe[a], Y. Hoshi[a,*], K. Kumagai[a], T. Nagamine[b], K. Neichi[c], K. Onodera[a], N. Takahashi[a], T. Takahashi[a], A. Yamaguchi[b], H. Yuta[d]

[a] *Department of Applied Physics, Tohoku-Gakuin University, Tagajo 985-8537, Japan*
[b] *Department of Physics, Tohoku University, Sendai 980-8578, Japan*
[c] *Department of Commerce Tohoku-Gakuin University, Sendai 980-8511, Japan*
[d] *Department of Engineering, Aomori University, Aomori 030-0943, Japan*

**Abstract**

Optical images of the streamer from a Resistive Plate Chamber (RPC) are observed using a transparent high-voltage electrode in the operation of streamer mode. The optical images are measured using CCD camera system in mixture $Ar/C_4H_{10}$ with and without $C_2H_2F_4$. Area of typical streamer image is approximately 12 $mm^2$ in both gas mixtures with its surrounding halo of 2–4 mm in diameter. We also observed the quenching effect of $C_4H_{10}$ and $C_2H_2F_4$ on the optical image in the chamber.


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*Keywords:* RPC; CCD camera; Streamer; $C_2H_2F_4$

## 1. Introduction

Resistive Plate Chamber (RPC), first made by Santonico and Cardarelli in early 1980s [1], is a particle detector with two parallel plate electrodes and it has many attractive features for high-energy experiments, because of high efficiency, good time resolution, tracking capability and low cost. These features have naturally led the BELLE collaboration to choose a large size of the glass RPC for the detection of $K_L^0$ and muon in the B meson decay product in the BELLE experiment at KEK [2–4].

The previous works for RPC gas mixture are primarily based on Ar together with $C_4H_{10}$ and $CF_3Br$ as photon and electron quenchers [5,6]. Recently, for environmental reasons, $CF_3Br$ has been replaced by tetrafluoroethane ($C_2H_2F_4$), giving the satisfactory results for the particle detectors [5]. $C_2H_2F_4$ is characterized by sufficiently high electron affinity and negligible ozone depletion power. However, its Global Warming Potential (GWP) is 1300 times higher than carbon dioxide ($CO_2$); thus, use of freon gas would possibly be prohibited in the near future. From this point of view, we started our investigation to test the gas mixture of $Ar/C_4H_{10}$ with and without $C_2H_2F_4$ as a function of Ar fraction.

A study of streamer images can give information on the spatial distribution of charge on the

*Corresponding author. Tel.: +81-22-368-7549; fax: +81-22-368-7070.
*E-mail address:* hoshi@tjcc.tohoku-gakuin.ac.jp (Y. Hoshi).

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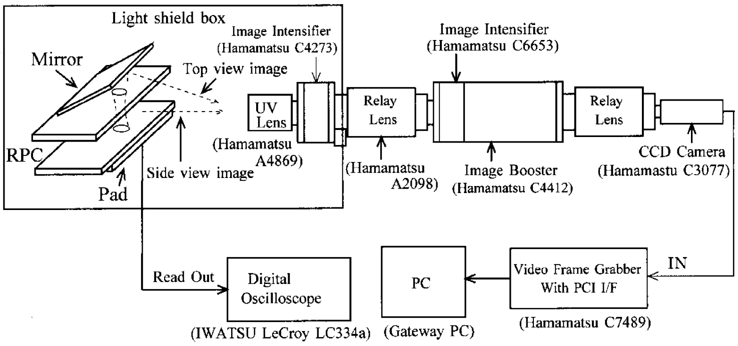


Fig. 1. CCD Camera System.

electrode, which is useful to design the reading pad width of RPCs for an experiment. In order to obtain information on streamer size, we have made a RPC with two transparent high voltage glass electrodes using transparent conductive paint. We have observed the images of the streamers in the gap between the two glass electrodes using a CCD camera with an image intensifier. We have also measured electrically induced signal from a pickup pad placed on one side of the glass RPC.

In this paper, we will report the results of the study of the properties of the optical images in mixture $Ar/C_4H_{10}$ with and without $C_2H_2F_4$ in the glass RPC.

## 2. RPC and CCD camera system

The RPC electrodes were made of 2 mm thick float glass plates commercially produced as window glass. Their surface and volume resistivites are $\sim 10^{12}\ \Omega/\square$ and $5 \times 10^{12}\ \Omega$ cm, respectively. The outer surfaces of the glass plate electrodes are coated by a brush with the transparent conductive paint, ET-680(Oshar Coat) [7]. ET-680 is made of acrylic resin with metal chelating which makes it conductive. Its surface resistivity is $10^7$–$10^9\ \Omega/\square$, after it is dried. The surface resistivity of the paint was measured to be (2–3) $\times 10^8\ \Omega/\square$. The frame of the RPC is made of PVC. The gas gap is 2 mm. The RPC is $11 \times 3$ cm, attached with the copper pickup pad of the same size. A mass flow controller is used to regulate the gas mixture. The total gas flow rate was set to about 10 $cm^3$/min. Fig. 1 shows a block diagram of the setup for three-dimensional (3D) streamer image measurement. The RPC is housed with mirror in a light shielded box. The mirror is used for recording of 3D images between the two electrodes. In order to obtain individual images of streamer, we used two different types of image intensifier, Hamamatsu high speed image intensifier Model-C4273 and Hamamatsu Model-C6653 with a Hamamatsu 50 mm F3.5 UV lens, optically connected with each other in tandem. The images are stored at a phosphor plate built in the second stage image intensifier, Model-C6653, of which high voltage is always applied for measurement. The images on the phosphor plate are continuously taken by a CCD camera Hamamatsu C3077, which consists of $768 \times 493$ matrix elements (pixels) with area of $11.0 \times 13.0$ μm. The images from the CCD camera were sent to a Video Frame Grabber, Hamamatsu C7489, to analyze the streamer image properties.

## 3. Results and discussion

Since we used cosmic rays for the counting system of this small size RPC, we could not have enough coincidence rate to find the operating high voltage for the RPC. Thus, we measure the single (non-coincidence) counts and set the high voltages for 12 sets of the gas mixtures using the relation of the coincidence and single count rates obtained from the previous report [8]. Table 1 lists the

Table 1
Parameter for the gas mixtures used in this experiment

| $Ar/C_4H_{10}/C_2H_2F_4$ (%) | Op. HV (kV) | $Ar/C_4H_{10}$ (%) | Op. HV (kV) |
|---|---|---|---|
| 81.8/10/8.2 | 5.0 | 80/20 | 5.6 |
| 75/10/15 | 6.0 | 75/25 | 6.4 |
| 60/10/30 | 7.0 | 66.6/33.3 | 7.0 |
| 45/10/45 | 7.8 | 50/50 | 8.4 |
| 30/10/60 | 8.8 | 33.3/66.6 | 9.8 |
| 18/10/72 | 9.2 | 25/75 | 10.4 |

Op. ; Operating high voltage in this experiment.

operating voltages and the Ar gas fractions for the 12 gas mixtures.

To identify the image and the signal pulse from the same streamer, we used the times of the built-in clocks in the digital oscilloscope and the PC and made correspondence among the images and signal pulses. Fig. 2 shows the typical examples of streamer images (left) and the oscilloscope views of the corresponding pulses (right), operated with $Ar/C_4H_{10}$ and $Ar/C_4H_{10}/C_2H_2F_4$ gas mixtures. The top and side views are taken in a single view as indicated in Fig. 2. Each top view shows the round shape spot corresponding to the streamer image, together with scattered small spots all over the view. The scattered spots could possibly come from electric noises, because no after-pulse is observed in the oscilloscope view.

The image in the side view is the direct view of the streamer through the 2 mm gap in the RPC limited to the gap size. The image in the top view is a round shape observed through the float glass electrode with approximately 4 mm diameter. The diameter of the visible streamer images was measured by Hamamatsu Video Frame Grabber. Fig. 3 shows the effective diameters of the images in the top and side views which stay constant within measurement error. The streamer diameter from top view is measured to be an average of major and minor axes of the round images.

Fig. 4 shows the brightness of the top and side view images, which was recorded in the Video Frame Grabber. The brightness of the top view is very weak compared with the side view brightness, because the float glass absorbs strongly UV photons from the Ar photoionization emission in

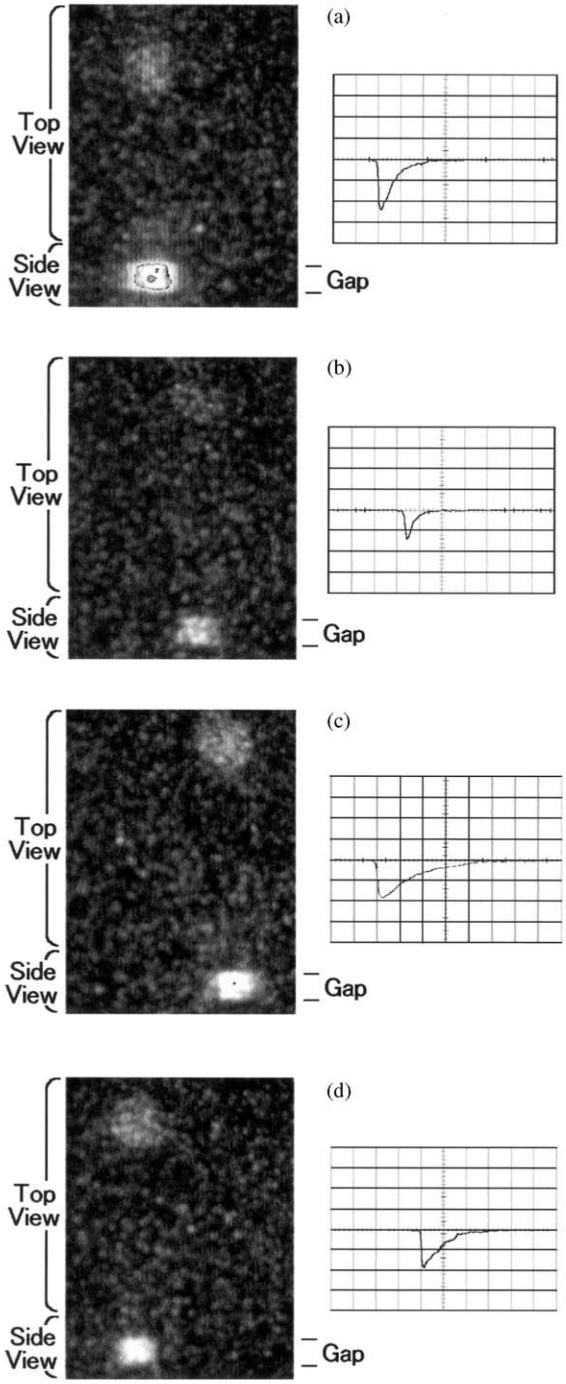


Fig. 2. Typical single streamer image (left) and corresponding pulse (right), The oscilloscope scale is 50 ns/div by 50 mv/div: (a) for $Ar/C_4H_{10}/C_2H_2F_4 = 81.8/10/8.2$, (b) for $Ar/C_4H_{10}/C_2H_2F_4 = 18/10/72$, (c) for $Ar/C_4H_{10} = 80/20$ and (d) $Ar/C_4H_{10} = 25/75$.

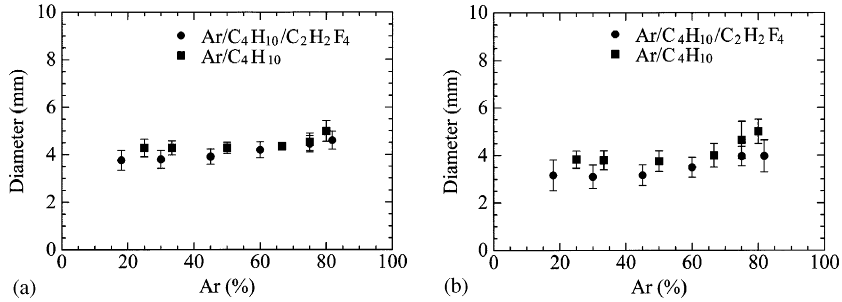


Fig. 3. Effective diameter of streamer image.

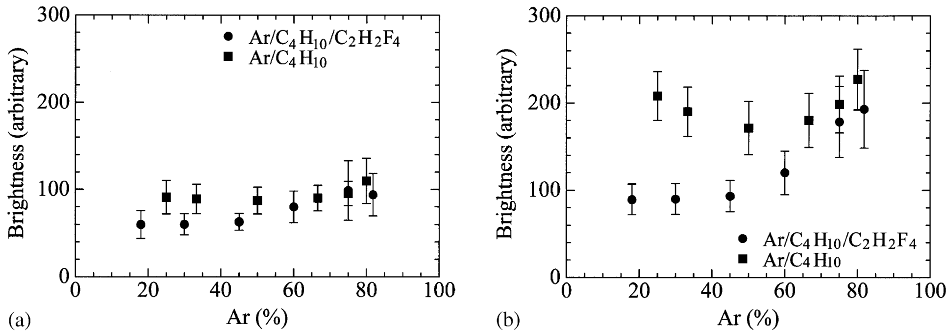


Fig. 4. Brightness of streamer image.

the streamer. The brightness in Fig. 4(b) shows a linear rise for Ar fraction of more than 50% in $C_2H_2F_4$ mixture. This could be due to the reduction of $C_2H_2F_4$ which decreases the quenching effect as the Ar fraction increases.

## 4. Summary

We made a RPC with transparent float glass electrodes, using transparent conductive paint, and observed the optical images of the streamer in mixture $Ar/C_4H_{10}$ with and without $C_2H_2F_4$. Each image has a central spot corresponding to the streamers with small scattered spots all over the view. The effective diameter of the images is approximately 4 mm and show no change even if Ar fraction increases. A typical streamer area of the top and side view images is approximately 12 $mm^2$ with halo for the mixtures of $Ar/C_4H_{10}$ with and without $C_2H_2F_4$. The increase of the streamer brightness observed with $C_2H_2F_4$ gas mixture can be explained by the reduction of the quenching effect as $C_2H_2F_4$ decreases.

## References

[1] R. Santonico, R. Cardarelli, Nucl. Instr. and Meth. A 187 (1981) 377.
[2] BELLE Collaboration, KEK Report 95-1 April 1995.
[3] K. Abe, et al., IEEE Trans. Nucl. Sci. NS-46 (6) (1999) 2017.
[4] K. Abe, et al., IEEE Trans. Nucl. Sci. NS-47 (6) (2000) 1748.
[5] M. Sanpei, et al., IEEE Trans. Nucl. Sci. NS-44 (3) (1997) 752.
[6] S. Narita, et al., IEEE Trans. Nucl. Sci. NS-48 (3) (2001) 893.
[7] Y. Inoue, et al., Nucl. Instr. and Meth. A 394 (1997) 65.
[8] S. Narita, et al., IEEE 2000 Nuclear Science Symposium, 2000, Oct. Lyon France.