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SHORT NOTE

Significance of Ionization-Track Contribution to Self-Quenching Streamer (SQS) Formation Induced by Alpha-Rays

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The mechanism of the self-quenching streamer (SQS) formation has been discussed for understanding of the new gas counter operation mode, *i.e.* the SQS mode[(1)~(5)]. Previously proposed mechanisms concentrated to explain the SQS formation induced by X-rays in rare-gas based mixtures, such as $Ar+CH_4$. In this short note, we describe direct evidence of a different mechanism for the SQS formation induced by α-rays.

Photographing of the SQS discharge performed by Alekseev *et al.*[(1)(6)] and Atac *et al.*[(2)(3)] has shown obvious evidence of its formation, and gave important information to consider the mechanism for the X-ray induced SQS. The mechanism provided by Atac *et al.*[(2)(3)] is based on the photo-ionization process by energetic photons which are emitted from molecular excited states of Ar. On the other hand, Zhang[(4)] proposed another mechanism, where accumulated Ar metastable states are important in the SQS formation. Problems in the proposed mechanisms for the X-ray induced SQS were recently discussed on the basis of measurements for other rare-gas mixtures by Koori *et al.*[(5)]

The first study on properties of the SQS formation induced by α-rays has been performed by Koori *et al.*[(7)(8)] They observed clear SQS transition in some sorts of sole quenching gas filling such as CH_4, while there was no obvious evidence of SQS transition in the gas filling by the X-ray irradiation. These results could not be explained by the mechanisms described above; they argued a strong contribution of dense ionization tracks formed by α-rays[(5)].

In order to confirm the contribution, we observed optical images of the α-ray induced SQS discharge in a single-wire gas counter. This observation provided important information for us to understand the SQS mechanism that is different from that of the X-ray induced SQS. On the basis of the result, we discuss the significance of ionization-track contribution to the SQS formation when α-rays irradiated.

The single-wire gas counter used is made of a 150 mm long rectangular brass pipe, whose inner cross section is $19.5\times19.5\,mm^2$; a gold plated tungsten wire of 50 μm in diameter is stretched along the axis as an anode. The effective length of the counter is 104 mm. A transparent quartz-window is arranged to obtain a counter-inside view from the axial direction. The counter was irradiated by collimated α-rays (^{210}Po) through a 7 μm thick aluminized mylar window. The gas mixture was $Ne(70)+CH_4(30)$, $Ar(70)+CH_4(30)$ or $CH_4(100)$; the gas flowed in the counter at atmospheric pressure. We used an image intensifier (Night Viewer: HAMAMATSU MODEL-C2100) to obtain clear images of photons emitted from the discharge.

Figure 1 shows photographs of the SQS discharge obtained in a $Ne(70)+CH_4(30)$ mixture. The α-ray source was put at different distances d from the mylar window of the counter and a fixed incident position $h=6$ mm

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for the counter. About 60 streamers were exposed on each photograph. As shown in Fig. 1, streamers develop only in the direction of α-ray incident side for $d=14$ mm (a), and show a tendency to develop in both directions of the α-ray incident side and the opposite side for $d \leq 9$ mm (b, c). We also observed similar bi-directional discharges in an $Ar(70)+CH_4(30)$ mixture for $d \leq 4$ mm. This bi-directional discharge for an incident α-ray was also confirmed from an image taken with a video camera. According to simple estimation of the range in the $Ne(70)+CH_4(30)$ mixture, α-rays reach a distance of 9 mm from the mylar window for $d=14$, 16 mm for $d=9$ and 23 mm for $d=4$ mm (α-rays reach the opposite side cathode for $d=4$ mm); the bi-directional discharges were observed when α-rays reach over the anode wire position.

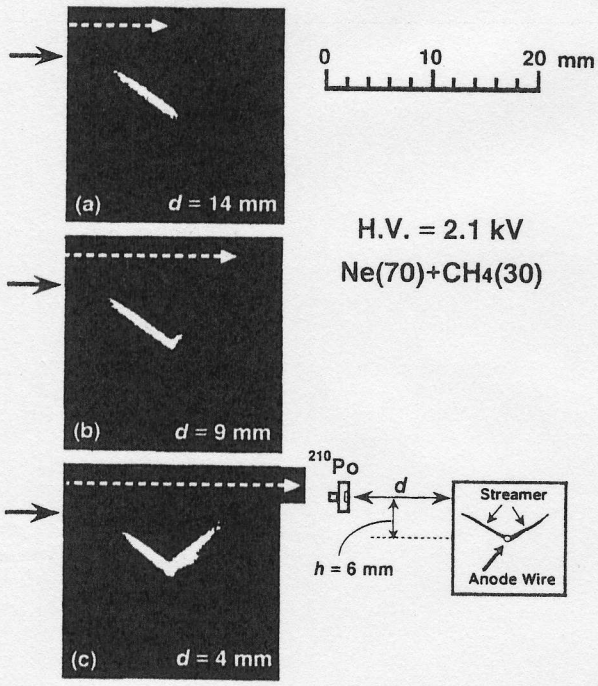

Fig. 1 Photographs of self-quenching streamers in $Ne(70)+CH_4(30)$ mixture at different distances of the α-ray source: (a) $d=14$ mm, (b) $d=9$ mm, (c) $d=4$ mm. Left-side arrows indicate the incident direction of α-rays. The ranges of α-rays are shown by the white-dot lines

Moreover, we confirmed the SQS formation in a sole quenching gas filling of CH_4 for the α-ray irradiation[8]. As shown in **Fig. 2**, the observed image of discharges is similar to that of SQS formed in the rare-gas based mixtures ($Ne(70)+CH_4(30)$ and $Ar(70)+CH_4(30)$ mixtures).

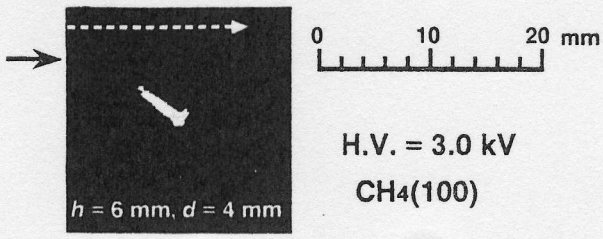

Fig. 2 Photograph of self-quenching streamers in sole quenching gas filling of CH_4 ($d=4$ mm). A left-side arrow indicates the incident direction of α-rays. The range of α-rays is shown by the white-dot line

According to the observed results, dense ionization tracks evidently contribute to the SQS-formation; the mechanism of SQS formation induced by α-rays is quite different from that induced by X-rays. It is necessary, therefore, to discuss another mechanism based on the ionization-track contribution. **Figure 3** shows drifting of electrons formed along an ionization track by α-rays; the drifting was calculated on the basis of the electron drift-velocity measured in an $Ar(70)+CH_4(30)$ mixture[9]. The nearest electron arrives at the anode wire in 133 ns, and is followed by other delayed electrons. So it may be quite natural to think that large amount of free electrons are fed into an initial avalanche from the directions limited by ionization tracks. Such electron-feeding process to the high field tip of positive ion cone[5] must cause the SQS development in the specific directions such as bi-directional discharges shown in Figs. 1 and 2. The direction of SQS development may depend on the electron density along the ionization track.

In summary, the contribution of electrons in the ionization track formed by α-rays plays a significant role for the SQS formation induced by α-rays instead of the photo-ionization process in the case of X-ray irradiation. From this point of view, we will discuss in detail on the mechanism of SQS formation induced by α-rays in the next article.

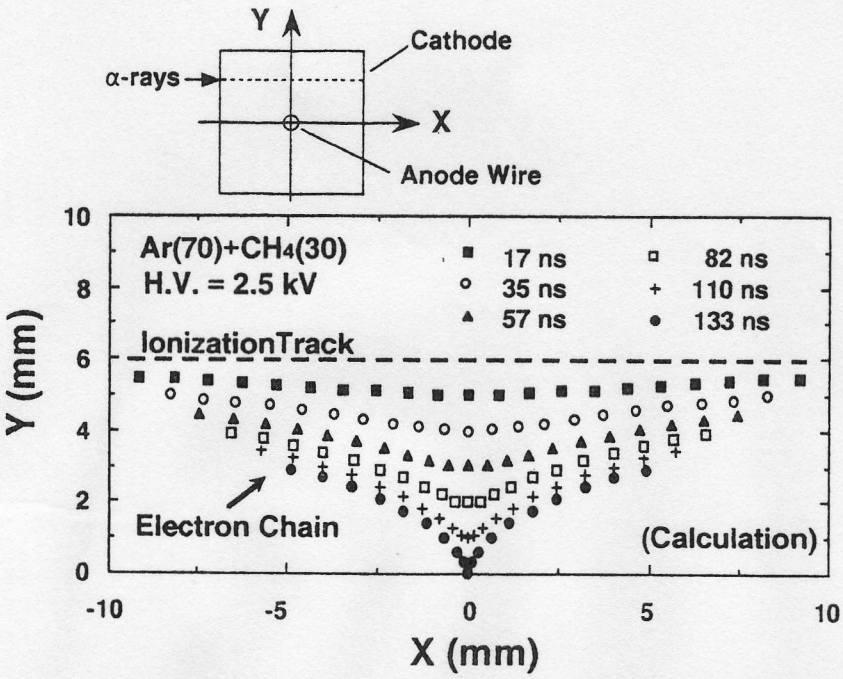

Fig. 3 Calculated electron drifting from an ionization track formed by α-rays to the anode wire. The calculation was done on the basis of electron drift-velocity measured in an $Ar(70)+CH_4(30)$ mixture[9]

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