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Generation of SQS in Quenching Gas (CH_4) of Proportional Counter and Related Problems

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Abstract

Two topics on the SQS phenomena in proportional counters are reported.

One is the observation of the SQS transition in pure methane gas under irradiation of 4.5 keV X-rays. The effect of a small amount of argon on the SQS transition was investigated with gas mixtures (CH_4:Ar) having the mixing ratios such as 100:0, 99.8:0.2, 99.7:0.3, 99.5:0.5 99:1, 98:2, 95.5:0.5 and 90:10. The SQS transition was not observed in pure methane gas, although it was observed still in the gas mixture of 99.8:0.2.

The other is the measurement of electron drift characteristics with a single-wire gas counter operated in the SQS transition regions. The counter gas used was a mixture of argon and methane (70:30) in which ethanol vapor was added. From comparison with the proportional mode, the use of the SQS mode is recommended to obtain a better time resolution in the application of drift counter.

I. INTRODUCTION

Characteristics of the self-quenching streamer(SQS) mode in gas counters have been investigated by many groups. In a large number of experiment on the SQS transition of the self-quenching streamer in a gas counter, two research groups have reported investigations on the transition in pure quenching gases. According to the experiment by Koori et al.[1], the transition was not observed in pure quenching gases of a cylindrical single-wire proportional counter with an anode wire of 50 μm in diameter under irradiation of 5.9 keV X-rays. On the other hand, You et al.[2] reported that a weak but clear transition was observed with 5.9 keV X-rays when pure methane gas or pure carbon dioxide gas was used in a multi-wire proportional counter with anode wires of 76 μm in diameter. This problem is very important in understanding the mechanism of the SQS transition in gas counters.

In nuclear reaction studies, position sensitive single wire proportional counters are used frequently as focal plane detectors. By measuring the drift time of primary electrons, this type of counter can be used as a vertical beam position monitor [3]. Since the counter is able to apply only one anode wire, the electron drift velocity in a wide range of electric field strengths is very important. It can be achieved by measuring the drift time in a single-wire gas counter operated in the SQS mode.

II. EXPERIMENTS AND RESULTS

A. *Generation of SQS in a Proportional Counter with a Quenching Gas(CH_4)*

We have performed re-experiments to check whether the SQS transition occurs or not in pure quenching gases. In the present experiment, a cylindrical single-wire proportional counter of simple structure has been used. It is considered that the electric field near the anode wire in the cylindrical gas counter where the avalanche generates is almost the same as in the multi-wire counter used by You et al.[2]. The cylindrical gas counter used is made of a stainless steel pipe of 24 mm inner diameter with a nichrome anode wire of 80 μm in diameter.

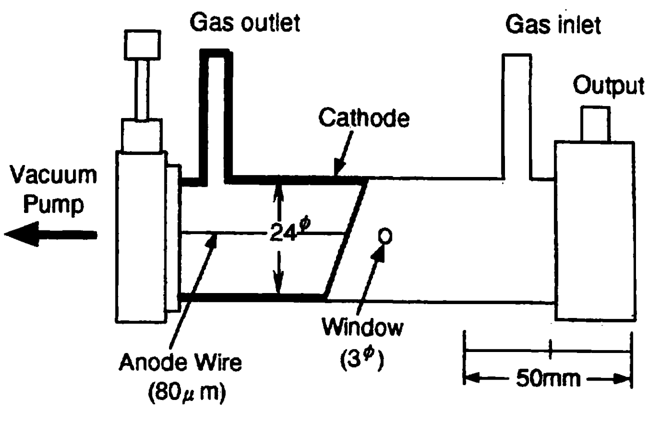

Fig.1 Schematic view of the single-wire proportional counter.

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The schematic view of of this counter is shown in Fig.1. The counter is designed to be able to be evacuated before experiment. The counter was filled with gas mixtures of methane and argon, and the SQS transition was investigated under experimental conditions where the fraction of argon in the gas mixture was changed from 0 to 10%. The purities of gases were better than 99.999% for argon and 99.95% for methane. Mixing ratios of the gases (CH_4:Ar) were changed by 100:0, 99.8:0.2, 99.7:0.3, 99.5:0.5, 99:1, 98:2, 95:5 and 90:10. X-rays used were 4.5 keV Ti K X- rays from X-ray generator [4] and ^{55}Fe X-rays. Figure 2 shows variation of pulse height spectra with the applied anode voltage of 4.3kV to 4.6kV for (a) pure methane and (b) mixture of the methane

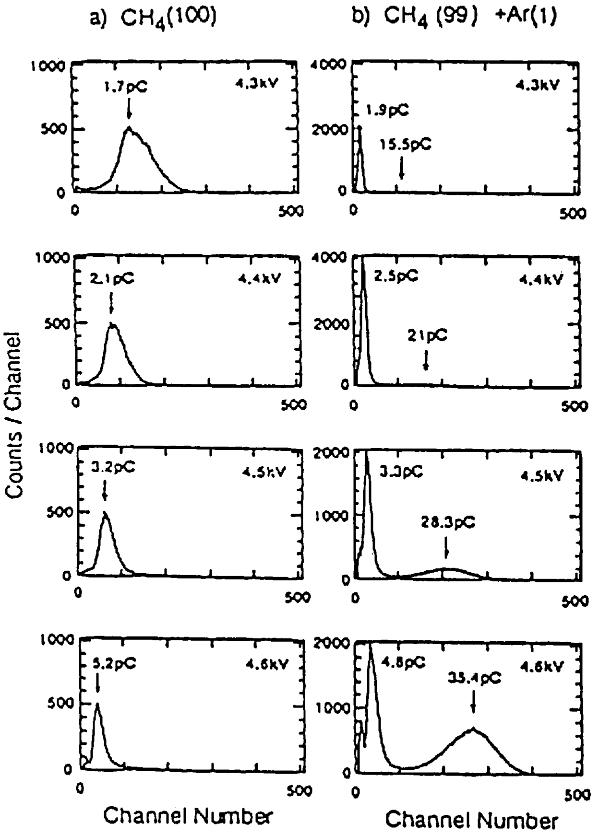

Fig. 2 Variation of pulse height spectra obtained with proportional counter for(a) pure methane gas and (b) mixtures of the methane and argon gas (99:1).

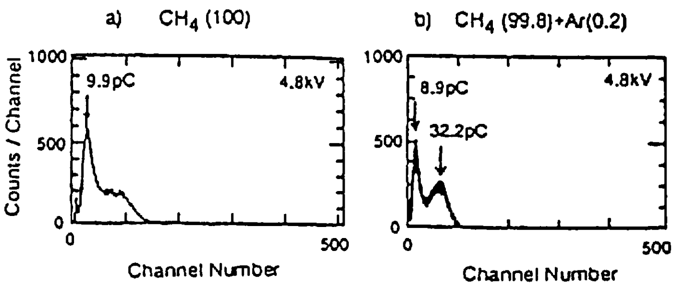

Fig. 3 Pulse height spectra obtained with proportional counter for (a) pure methane gas and (b) mixture of the methane and argon gas (99.8:0.2).

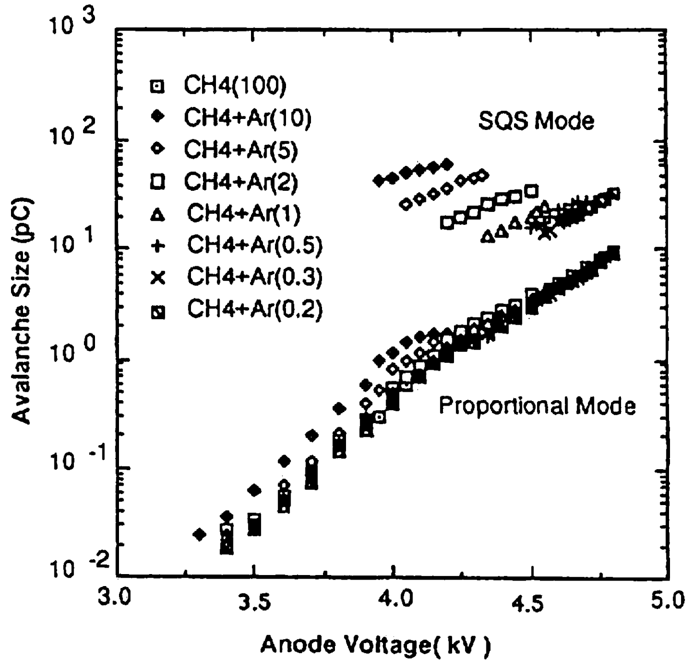

Fig. 4 Avalanche size as a function of the applied anode voltage for the different mixtures of CH_4:Ar.

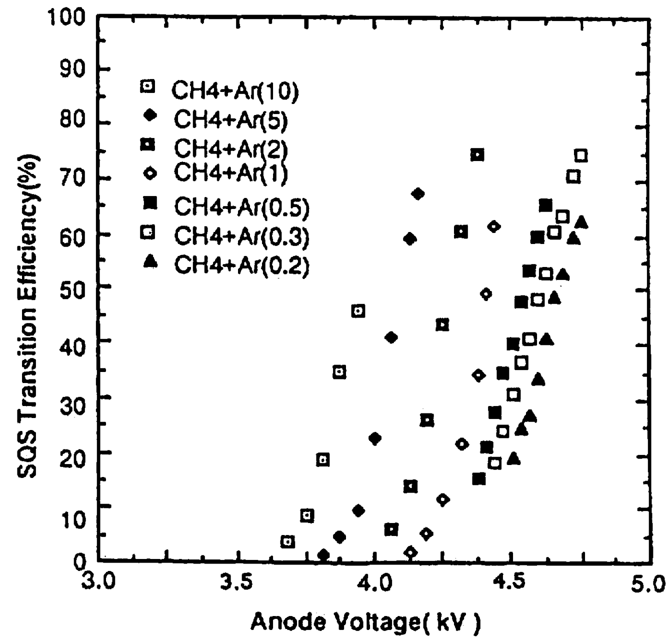

Fig. 5 SQS transition efficiency as a function of the applied anode voltage for the change of argon concentration.

and argon gases(99:1),respectively. The avalanche size for each peak is indicated in units of pC in the figure. In pure methane gas, no peaks corresponding to the SQS were observed. In the case of mixture gas, however, they were observed clearly for higher anode voltages. Figure 3 shows comparison of pulse height spectra for pure methane gas and mixture of the methane and argon gas (99.8:0.2) at higher anode voltage of 4.8 kV. Although a peak of SQS was clearly observed in Fig.3 b) as in Fig.2 b), such a peak structure was not observed clearly in Fig.3 a) and a shoulder portion was exhibited. The shoulder may be due to the effect of residual gas in the pure methane because the purity was 99.95%.

Electron avalanche sizes obtained from the measured pulse height spectra are plotted against applied voltages in Fig.4. Figure 5 shows curves of the transition efficiency from the proportional to SQS mode as a function of the applied anode voltages in the (CH_4+Ar) gas mixtures. The data were checked with commercially available standard gas mixtures (CH_4(90):Ar(10) and CH_4(99):Ar(1)). The results show that addition of a small amount (in the present case, 0.2%) of argon in methane gas results in drastic change in observed pulse height spectra. This observation supports the experimental result by Koori et al.[1]. The data suggests that the existence of argon plays an important role in the generation of the SQS. The values of avalanche sizes from the proportional to the SQS transition are considered to be about twice of the experimental results of You et al.[2] relating with argon concentration. It is considered that the amount of impurity in their experiment corresponds to addition of about 0.1% equivalent argon. It was concluded that no jump phenomena caused by the SQS transition occur in the cylindrical gas counter with pure methane gas irradiated by 4.5 keV X-rays[5]. These results may suggest that mixtures consist of more than two kinds of gases which have different ionization potentials generate the SQS strongly. It may be also possible to check the existence of impurities in the gas through observation of SQS transition.

B. Measurements of Drift Characteristics in SQS Mode

The measurements of drift characteristics with a single wire gas counter has been performed as a part of the continuous studies on the influences of ethanol vapor, added as the second quenching gas on the properties of a gas counter. In the previous works, the effects of small concentrations of ethanol on the properties of SQS discharge in a gas counter filled with argon-based gas mixtures were reported [6]. The ethanol also plays a role in improving the position resolution in the SQS transition region [7]. The counter used in the measurement of the drift characteristics was a small size single-wire gas counter with an anode wire of 50 μm in diameter. The counter was operated in the SQS transition region in the applied voltages of about 0.7 to 4.5 kV. The start pulse signal was taken from a plastic scintillation counter placed behind the gas counter. The radiation source was 1 mm collimated beta-rays from ^{90}Sr. The counter gas used was Ar(70):CH4(30) with additional of ethanol vapor at atmospheric pressure. A typical results is showed in Fig.6. The drift velocity deduced from Fig.6. is showed in Fig.7. It is interesting that in the region of less than 2.5 mm from the anode wire corresponding to the electric field strength of 2 to 4 kV/cm the drift velocity in the SQS transition is lower than that in the proportional mode. This phenomena is still being studied carefully. In the drift counter application, the use of the SQS mode is recommended because of a better resolution in time analysis.

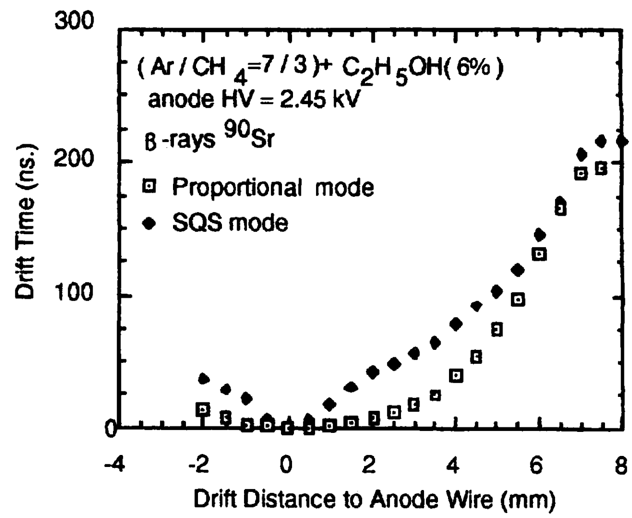

Fig.6 Drift time as a function of drift distance in the transition region from the proportional to the SQS mode.

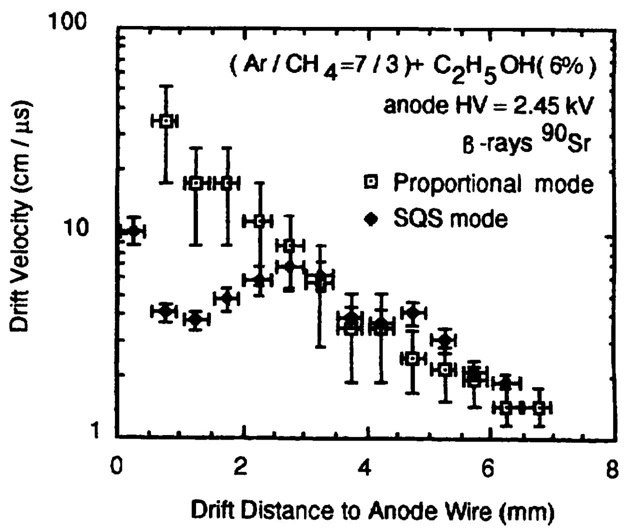

Fig.7 Drift velocity deduced from drift times in Fig.6.

III. CONCLUSIONS

Two topics on the SQS phenomena in proportional counters are described.

Existence of the SQS transition in pure quenching gas for a proportional counter has been investigated with 4.5 keV X-rays. The effect of small argon concentration on the SQS generation is investigated. The mixing ratios of the gases (CH_4:Ar) were changed from 0 to 10%. The SQS transition was not observed in pure methane gas, although it was observed still in gas mixture of 99.8:0.2 (CH_4:Ar).

The results may suggest that gas mixtures consisting of more than two kinds of gases which have different ionization potentials generate the SQS strongly. And there may be two possible paths to reach the SQS or the Geiger discharge in accordance with the length of mean free path of release photons in the avalanche.

Also the measurements of electron drift characteristics with a single wire gas counter operated in the SQS transition regions have been performed. We found a different behavior of electron drift in SQS mode from that proportional mode in the region near the anode wire. In the drift counter application, the use of the SQS mode will have possibility to obtain a better time resolution.

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