PROPERTIES OF SELF-QUENCHING STREAMER (SQS) TUBES

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1. INTRODUCTION

Since the self-quenching streamer (SQS) mode of gas counters was systematically investigated by Alekseev et al.[1] and Atac et al.[2], this mode has been applied to gas counters measuring high energy particles; for example, limited streamer tubes are operated in this mode.[3] The SQS mode has the following advantages for radiation detection: high gas multiplication, fast rise time of signals, localization of streamers, and so on. Because of these advantages, counters operated in the SQS mode, which are to be called SQS tubes, would be widely used as monitoring devices for a high counting rate condition instead of GM tubes.

Basic properties of the SQS mode have been revealed through investigations for understanding the mechanism of this mode and for applying it to instruments in high energy physics. In our previous works[4], we have studied the characteristics of SQS mode in a gas counter filled with Ar-mixtures at one atmospheric pressure by means of α-, β-, and X-rays. Furthermore, we have very recently found that all the rare gas (He, Ne, Ar, Kr, and Xe) mixtures with quenching gas of CH_4, C_2H_6, C_3H_8, isoC_4H_{10}, or CO_2 can be used as gas mixtures for the SQS mode except Ne- and He-mixtures with CH_4 or CO_2.[5] Further studies on the properties of this mode are needed in order to apply it to monitoring devices. In this article, we will describe the properties of an SQS tube from this point of view.

2. EXPERIMENTAL PROCEDURE

The experimental setup used is illustrated in Fig.1. A single-wire gas counter was made of a stainless steel pipe whose inner diameter was 14 mm; a gold plated tungsten wire of 50 μm in diameter was stretched along the axis as an anode. The effective length of the counter was 105 mm. The counter was filled with Ar-isoC_4H_{10} (75:25) mixture, and was irradiated by ^{55}Fe X-rays or ^{90}Sr β-rays through a 10 μm thick mylar window. Gas multiplication properties, pulse shape of current signals, and dead zone were measured at several gas pressures equal to and less than one atmospheric pressure.

The pulse height, which was measured with a charge sensitive preamplifier, was converted to the avalanche size corresponding to the number of electrons or ions produced in an avalanche.

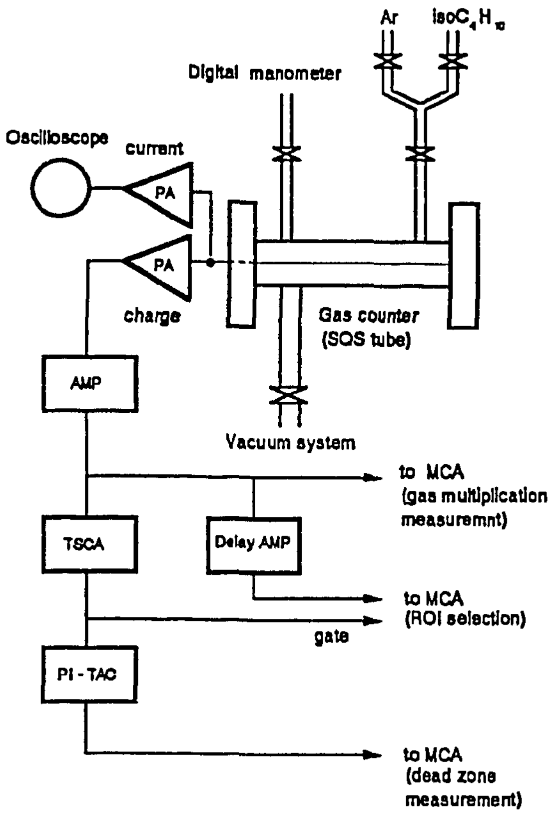

Fig.1. Schematic block diagram for the measurement.

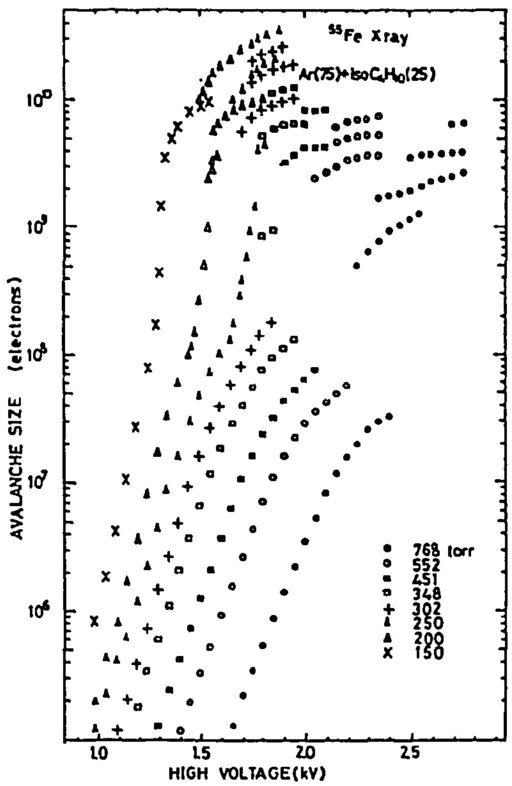

Fig.2. Avalanche size curves for several gas pressures.

Pulse shapes of signal current flowing through a 200 Ω resister were recorded on photographs. The dead zones were evaluated by measuring counting losses at different time intervals between signals by means of a time interval to amplitude converter (PI-TAC).

3. RESULTS AND DISCUSSION

(1) Gas Multiplication Properties.

Figure 2 shows avalanche sizes measured as a function of applied voltage at several gas pressures. The SQS transition, which is indicated by a leap in the avalanche size curve, is clearly shown for the pressures of 760-300 Torr. At the pressures of 350 and 300 Torr, the mode may be identified as the SQS mode from this observation, but as described later this pressure region is placed between the SQS and GM modes. The SQS transition dose not appear for pressures less than 250 Torr: The avalanche size increases continuously with increase in the applied voltage. This feature is attributed to the GM mode. It should be noted that either the SQS or GM mode can be alternatively obtained by changing the pressure of the counting gas mixture.

(2) **Pulse Shapes.**

In the SQS mode, an electron avalanche initiated by radiation develops to an SQS formed normal to the anode wire. On the other hand, the development of an electron avalanche spreads over the entire anode wire in the GM mode (the GM discharge). This difference in the avalanche development, therefore, may appear in the pulse shape of signals, especially of current signals induced by electrons. Ion induced current is very small in comparison with electron induced one, because of very slow drift velocity of ions. Figure 3 shows the pulse shape of the electron induced current signals at the pressures of 760, 300, and 150 Torr, where the SQS, intermediate, and GM modes are obtained, respectively. The difference in the avalanche development is evident.

In the SQS mode (obtained at 760 Torr), the signals rise very fast and decay exponentially. Furthermore the signals are doubled with a delay of about 0.4 μs at higher voltages; the doubled signals correspond to the double SQS. The width of the SQS signals is about 0.2 μs fwhm.

The GM signals observed at 150 Torr rise more slowly than the SQS signals and form and approximately flat top shape having about 0.5 μs fwhm. This pulse width corresponds to a time for that an avalanche, initially formed at the half way of the anode wire in this case, develops and reaches to the ends of the wire.

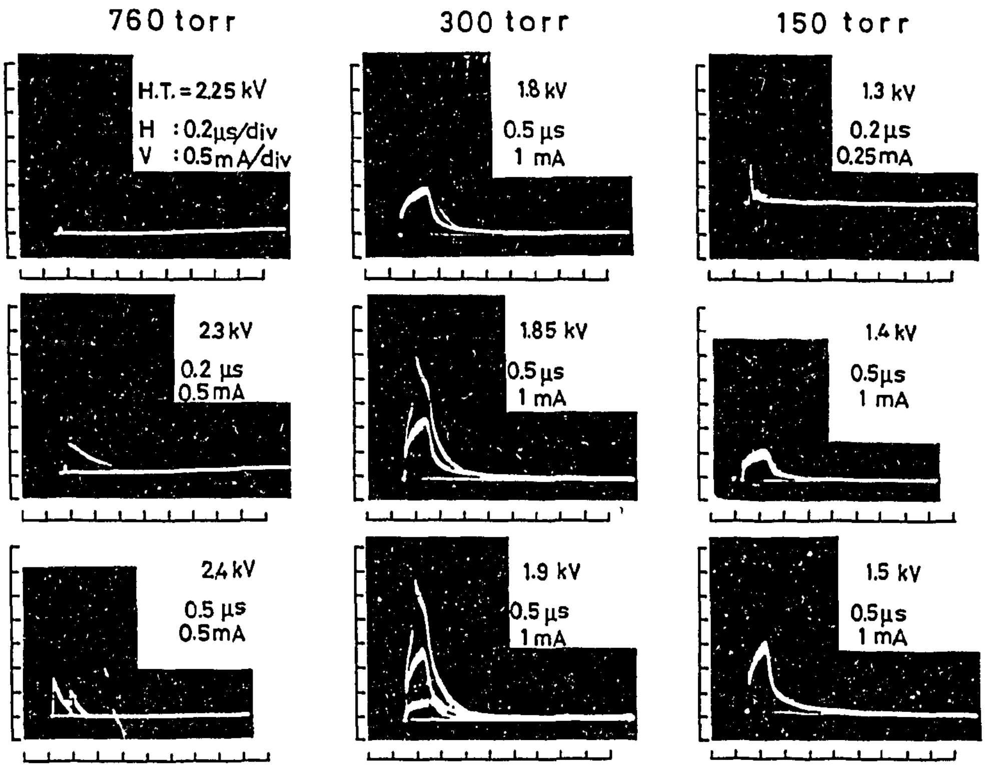

Fig.3. Pulse shapes of current signals observed at 760, 300,150 Torr, where the SQS, intermediate, and GM modes are obtained, respectively.

In the intermediate mode at 300 Torr, both GM-like signals and SQS-like signals added on GM-like ones are seen in the photograph. Although simple SQS-like signals are not observed in the photographs, SQS's are formed simultaneously with a GM discharge in this gas pressure region. The evidence like this has been observed by Alekseev et al.[1] without any interpretation. The fact explains a leap observed in the gas multiplication curve for 300 Torr (see Fig.2).

(3) Dead Zone.

In order to correctly identify the operational mode at 300 Torr, the dead zone, which was defined by Alekseev et al.[1], must be measured. Since the streamer develops normal to the axis of the counter, the spatial dead region along the anode is very small (about 0.2 mm) and the sensitivity of the counter may be kept except for the dead region. On the other hand, the GM tube is completely insensitive during the dead time, because an avalanche spreads over the entire anode wire.

The dead zone is defined as the product of dead region and dead time. As described above, the dead zone can be evaluated by measuring counting losses at different time intervals between signals. The measured characteristics of counting losses are clearly different in the SQS and GM modes, as shown in Fig.4. In the SQS mode obtained at 760 Torr the counting losses are partial, but the counter in the GM mode (150 Torr) is completely insensitive during a dead time. Concerning to the intermediate mode at 300 Torr, whose operation mode could not be determined yet, the mode at this pressure can be now attributed to the GM mode, because counts are completely lost during the dead time as shown in Fig.5.

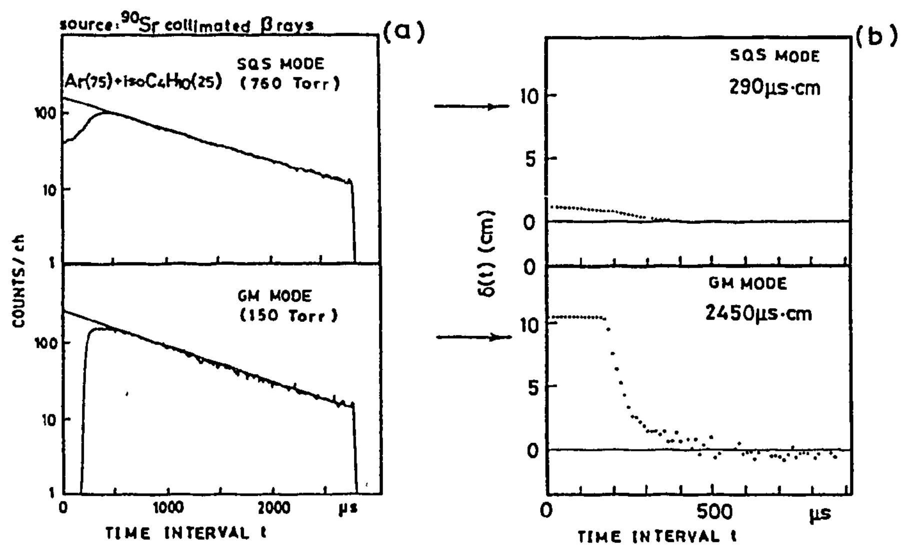

Fig.4. Counting losses (a) and dead region as a function of time intervals for the SQS and GM modes.

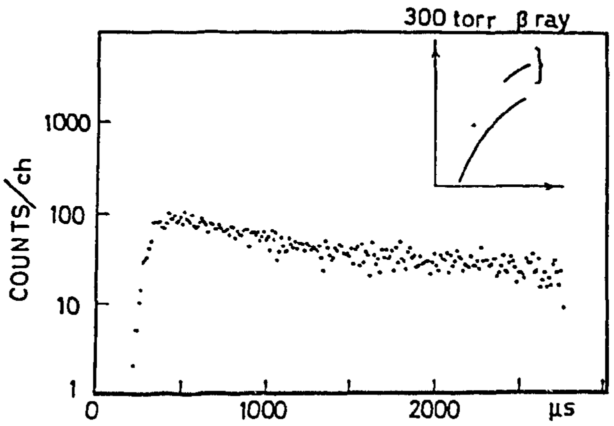

Fig. 5 Counting losses as a function of time intervals measured at 300 Torr. The GM mode is established. at this pressure.

The calculated dead zone is about 290 μs·cm for the SQS mode and about 2450 μs·cm for the GM mode in this counter. The SQS mode, therefore, is superior to the GM mode by about one order of magnitude in the counting rate capability. Similar measurements provide the dead zone of about 3900 μs·cm for a commercially available GM tube.

It should be noted that the avalanche size in the GM mode may be limited by the anode length. In the SQS mode, the avalanche size is determined by the anode and cathode radii. According to the above measurements, the critical pressure for changing the mode is 300-350 Torr for this gas mixture. Alekseev et al. have suggested that the GM mode can be obtained if the mean free path of photons emitted from avalanches is larger than the spread of avalanches, and the SQS mode for an equivalent or smaller mean free path of the photons. The estimated critical mean free path is about 50 μm in the mixture used, if the photons are due to the de-excitation of molecular excited states of Ar.

4. SUMMARY

Either the SQS or GM mode can be obtained by changing the gas pressure with a cylindrical gas counter. The operation mode of the counter may be correctly determined from the dead zone measurement. The measured results show that the SQS and GM modes are exclusive, even though SQS's can be simultaneously formed with a GM discharge. The counting rate capability of the SQS mode is much superior to the GM mode by about one order of magnitude. Hence, SQS tubes are suitable in use of them in high flux radiation fields instead of GM tubes.

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