# Gamma ray sensitivity of R-12 superheated emulsion detector at higher pressure using $^{241}$Am and $^{137}$Cs gamma sources

R. Sarkar[1,*] P. K. Mondal[2], and B. K. Chatterjee[1]
[1]Department of Physics, Bose Institute, 93/1, A P C Road, Kolkata-700009, INDIA
[2]Astroparticle Physics & Cosmology Division, Saha Institute of Nuclear Physics, Kolkata-700064, INDIA
* email: sarkar_rupa2003@yahoo.com

## Introduction

Since its discovery in 1979 [1] the Superheated Emulsion Detector (SED) is being used for the detection of energetic radiations e.g. gamma rays, neutrons and other charged particles. In SED a large number of micron size superheated liquid droplets are dispersed in a viscoelastic gel matrix. When a SED is exposed to energetic radiations the droplets may evaporate explosively into bubbles if an energetic particle deposits sufficient amount of energy inside a droplet. In SED the detection of energetic radiation is based on the detection of the acoustic pulse produced during the vaporisation of a superheated liquid droplet.

The superheated liquid comprises of a large number of voids which are constantly being created, whence they grow to a maximum size and finally collapse back and vanish [2]. Whenever a void gets enough energy to overcome the barrier $W$ [$W = 16\pi\gamma^3 / 3(P_V - P)^2$ where, $\gamma$ is the liquid-vapour interfacial surface tension, $P_V$ is the saturation vapour pressure and $P$ is the ambient pressure], the bubble nucleation takes place [2]. The threshold energy ($W$) for nucleation can be controlled by controlling the temperature and/or pressure. The nucleation threshold energy increases with increase in pressure and the detector becomes sensitive to energetic radiations at higher temperature [3]. It was reported earlier that the R-12 SED is insensitive to gamma rays at room temperature and it becomes gamma ray sensitive at about 38.5$^{o}$C (for $^{241}$Am gamma source) at atmospheric pressure [4]. In the present work we have studied the threshold temperature ($T_o$) for the gamma ray induced nucleation in R-12 SED at higher pressure. In this work we have used $^{241}$Am (0.5 Ci, 59.54 keV gamma rays) and $^{137}$Cs (19.8 mCi, 662 keV gamma rays) gamma sources.

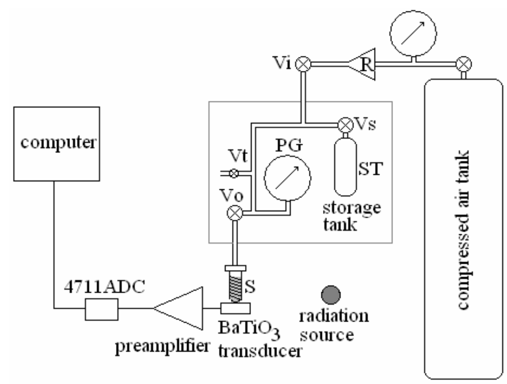


**Fig. 1** Schematic representation of the experimental setup.

## Experiments

The experiments were performed using a high pressure manifold, the schematic diagram of which is depicted in Fig. 1. The system is capable of providing a stable pressure over the duration of the experiment which usually lasts for a few hours [3]. In the present work R-12 SED was used to study the threshold temperature for 59.54 keV and 662 keV gamma rays at four different pressures (2, 3, 4 and 5 kg.cm$^{-2}$).

A glass vial containing superheated sample R-12 was placed on the top of a piezoelectric transducer and was wrapped with a heating coil. Initially the pressure over the superheated sample was raised to a desire value and then a gamma source was placed at a measured distance from the vial to maintain a constant flux during the experiment. The temperature of the sample was increased gradually from the room temperature. The acoustic pulses produced due to the droplet vaporizations were detected by a transducer which converts them into electrical signals. The signals were converted to TTL pulses, which were then counted by using a ADC card (Advantech USB 4711) supported by LabVIEW 8.6 software in MCS mode. This provides the number of counts accumulated in a dwell-time of 30 seconds and records it as a function of time. The counts were then normalized by the gamma ray flux ($\psi$) and surviving number of droplets ($S$) in every successive channels. The observed data for $^{241}$Am and $^{137}$Cs are given in Fig. 2 and Fig. 3 respectively with their smoothed curves.

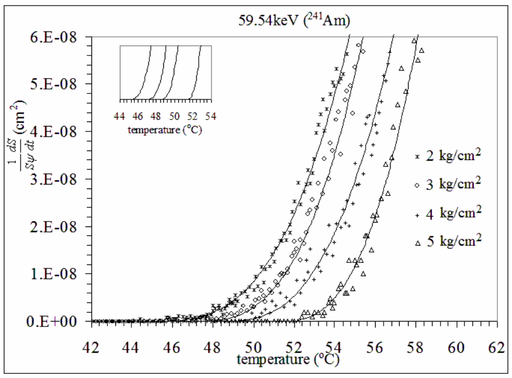


**Fig. 2** Normalised counts with temperature at 2, 3, 4 and 5 kg.cm$^{-2}$ for 59.54 keV gamma rays.

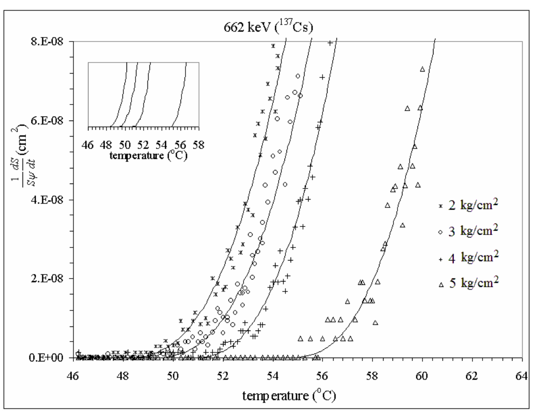


**Fig. 3** Normalised counts with temperature at 2, 3, 4 and 5 kg.cm$^{-2}$ for 662 keV gamma rays.

## Observations

It is observed from Fig. 2 and Fig. 3 that at a constant pressure the normalized counts increase gradually with the detector temperature after a certain temperature. The temperature at which the detector becomes sensitive to the external radiation is the threshold temperature ($T_o$) for nucleation. The observed data were then smoothed to get the threshold temperature for nucleation and are shown in Fig. 2 and Fig. 3 respectively. It is also observed from both the figures that $T_o$ increases with increase in applied pressure as discussed earlier. For $^{241}$Am and $^{137}$Cs sources the obtained values of $T_o$ are given in Table-1.

**Table-1:** Threshold temperature for $^{241}$Am and $^{137}$Cs gamma sources at different pressures.

| Pressure ($P$) (kg.cm$^2$) | Threshold temperature ($T_o$) (°C) | |
|---|---|---|
| | $^{241}$Am | $^{137}$Cs |
| 2 | 45.5 | 48.4 |
| 3 | 47.2 | 49.5 |
| 4 | 48.8 | 51.2 |
| 5 | 51.9 | 54.9 |

## Conclusion

At higher pressures the spontaneous nucleation in SED is greatly reduced and provides a more stable detector. Higher pressure increases the gamma detection threshold temperature, as can be expected. Table-1 shows the gamma detection threshold for R-12 SED by $^{241}$Am and $^{137}$Cs. It shows that the higher energy gamma source has a higher detection threshold than the lower energy gamma source. More work is needed to understand the observed data.

## Acknowledgments

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## References

[1] R. E. Apfel, Nucl. Instrum. and Meth. **162**, 603 (1979).

[2] R. Sarkar, B.K. Chatterjee, B. Roy and S.C. Roy, Radiat. Phys. Chem. **75**, 2186 (2006).

[3] R. Sarkar, M. Datta and B.K. Chatterjee, Nucl. Instrum. and Meth. A **682**, 31 (2012).

[4] B. Roy *et al.*, Radiat. Phys. Chem. **61**, 509 (2001).