Stability measurement of R-134a superheated emulsion detector to be used in dark matter search experiment

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1. Introduction

The superheated emulsion detector (SED) is based on the dispersion of superheated liquid droplets in an impurities-free gel base matrix. The SED performs well as a neutron detector in a mixed radiation field as it is sensitive to heavy ionizing particles at a specific temperature and pressure combination of the superheated liquid, but insensitive to low ionizing particles in the same thermodynamic regime [1, 2]. This property of SED allows it to be used in dark matter (DM) direct search experiments with a better rejection of backgrounds, which is a challenging field these days [3, 4]. DM is an unseen, non-luminous type of matter that makes up around 85% of universe's total gravitating mass and 27% of its entire mass-energy budget. The SED should be run for a long time to detect the dark matter candidates as the cross-section of the interaction is extremely small, on the scale of 10^{-41} cm^2 [5].

To perform the SED for an extended period of time in the DM search experiment, one must know the superheated droplet stability feature. Superheated state is generally short lived in nature due to the presence of heterogeneous nucleation sites such as trapped air bubbles in gel base matrix, roughness of container, dissolved gas pockets etc. and which can initiate spontaneous nucleation to reach at stable vapour state. By removing such potential heterogeneous nucleation sites, the stability of the superheated state can be improved significantly. Another factor is that during SED fabrication process, stress is induced in the SED, which also promotes spontaneous nucleation so it requires curing for some days to be used in the experiment.

In the present work, for distinct ranges of superheated droplet sizes, the stability of R-134a ($C_2H_2F_4$, b.p. -26.3 ºC) SEDs have been investigated and which is discussed in the following sections.

2. Present Work

The stability of R-134a SED has been measured as a function of curing time for the SEDs of different sizes of the droplets. Here the curing time refers to the day from the SED fabrication. The gel matrix utilised in R-134a SED fabrication was properly degassed by vacuum pump to remove the trapped impurities. For an efficient degassing, the gel matrix was heated at a controlled temperature during degassing. The gel matrix was prepared by combining glycerol with ultrasound gel in an appropriate proportion to keep the droplets suspended. The gel medium provides a smooth surface, reducing the risk of heterogeneous nucleation. The SED was fabricated at a constant temperature by gradually lowering the pressure of the superheated liquid to achieve its superheated state. By adjusting the stirrer rotation speed, different sized R-134a SEDs were created. 900 rpm (rotation per minute) and 1400 rpm of the stirrer generate SEDs were used in the measurement.

Fig. 1 depicts the distribution of radii for the 900 rpm and 1400 rpm SEDs. The sharp peak of the droplet radius distribution in the case of 900 rpm SED is at 60 µm bin, which accounts for 13.42% of the total distribution and is expanded up to 172 µm bin. The droplet radius distribution has sharp peak around 4 µm bin in case of 1400 rpm, which constitutes about 48.22% of the total contribution and is expanded up to 140 µm bin. It is observed that 1400 rpm produces small sizes droplets as compared to 900 rpm. Both smaller and larger sized SEDs have been investigated to study the droplet stability.

To better understand the stability of superheated droplets, the rate of bubble nucleating events from the SEDs were investigated in the presence of a ^{241}Am-Be neutron source (10 mCi) and with varying curing times.

Both SEDs were irradiated with ^{241}Am-Be (10 mCi) neutron source at 34 ºC operating temperature. The temperature of the SED was controlled by the temperature controller with a precision of ± 1 ºC.

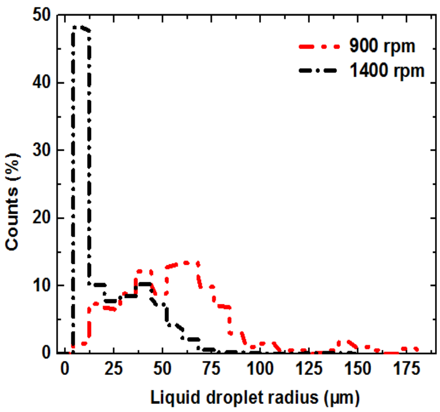

Fig.1. Distribution of radius of R-134a superheated droplets generated with 900 rpm and 1400 rpm.

Both SEDs were irradiated four times with the neutron source, resulting in an around eight months of curing time. Fig. 2 illustrates the neutron induced bubble nucleation event count rate as a function of curing time for the 900 rpm SED and 1400 rpm SED. Both SEDs are stable throughout five months of curing period, as the event rate steadily decreases over the five months of SED curing time, as seen in Fig. 2. Superheated droplets that have been cured for a longer period of time, such as 7.7 months, become more fragile, can be observed by the high nucleation event rates (see Fig. 2).

3. Conclusion

From the above measurements, it has been observed that stirring at 1400 rpm creates smaller and more uniform droplets than stirring at 900 rpm. The rate of bubble nucleation events in presence of ^{241}Am-Be neutron source shows that both 900 rpm SED and 1400 rpm SED are stable up to five months of curing time.

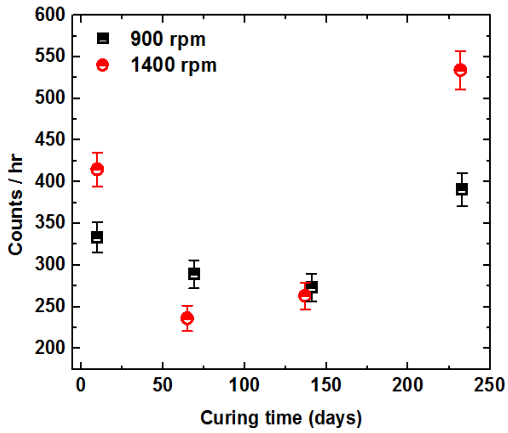

Fig.2. Bubble nucleating event count rate as a function of curing time for 900 rpm SED and 1400 rpm SED, irradiated with ^{241}Am-Be neutron source at 34 ºC SED operating temperature.

References

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