R114 & C_4F_{10} as sensitive liquid in superheated drop detector for neutron detection

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Introduction

Superheated drop detector (SDD) consisting of drops of superheated liquid is one of the demanding detectors for neutrons and WIMPs dark matter search experiment. Since its discovery in 1979, SDD is mainly used in neutron dosimetry.

For superheated drop neutron detector, the type of the detector liquid used is the refrigerant liquid of low boiling point such as R12 (CCl_2F_2 ; b.p. -29.8°C), R114 ($C_2Cl_2F_4$; b.p. 3.7°C), R134a ($C_2H_2F_4$; b.p. -26°C) etc.

C_4F_{10} is the liquid used for WIMPs dark matter search experiment by PICASSO (Project In CAnada to Search for Supersymmetric Objects) collaboration at SNO Lab, Canada [1]. WIMP induced nuclear recoils are similar to neutron induced nuclear recoils and therefore have identical technique of detection.

In the present work, a comparative study has been done among R114 and C_4F_{10} with respect to neutron detection in a mixed neutron – gamma radiation field.

Present work

For neutrons, the recoil nuclei are produced due to interaction of neutrons with the detector liquid, and these recoil nuclei deposit their energy in the liquid according to their LET in the medium. The energy deposition in the sensitive liquid was calculated using SRIM code for the carbon, fluorine ion in C_4F_{10} and carbon, chlorine, fluorine ion in R114 for the neutron of maximum energy 6 MeV. The relation between the energy of the neutron and the operating temperature of the liquid can be obtained from the expression given below [2].

$$\frac{W}{k\,r_c}(T,P) = \frac{dE}{dx}(E_n) \qquad (1)$$

Where W is the critical energy for bubble formation, r_c is the critical bubble radius and k is the nucleation parameter which has been found earlier to be equal to 0.11 for neutron induced nucleation upto around 10 MeV for R114. For C_4F_{10}, k has been calculated at 25°C using the above expression and found to be equal to 0.15. In the calculation, the threshold neutron energy has been considered as 371 keV at 25°C obtained from experiment [3].

The present experiment was performed both with R114 and C_4F_{10} in presence of ^{252}Cf fission neutron source at the neutron sensitive temperatures, 55°C for R114 and at 35°C for C_4F_{10}. The experiment has also been done at both the neutron and gamma sensitive temperatures, 70°C for R114 and 55°C for C_4F_{10}. Trace of each pulse has been recorded in dizitised storage oscilloscope and PC based Labview and power (P) has been calculated from the amplitudes of the pulses [4].

Results

The calculated values of critical radius and critical energy for bubble formation for both the liquids are shown in **Table.1** below

Liquids	Critical radius at 25°C (r_c) (μm)	Critical energy at 25°C (W) (keV)
C_4F_{10}	0.133	4.91
R114	0.194	10.81

The power distributions at three different temperatures are shown in Fig.1 in presence of ^{252}Cf source.

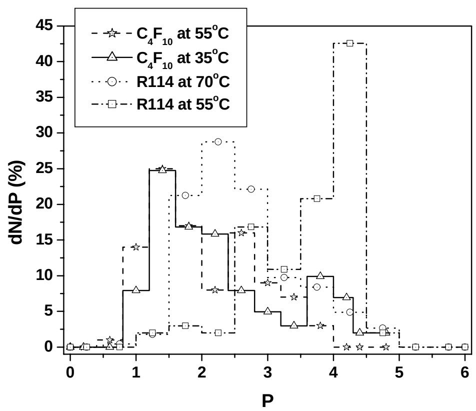

Fig.1. The differential power distributions at different temperatures for both the liquids.

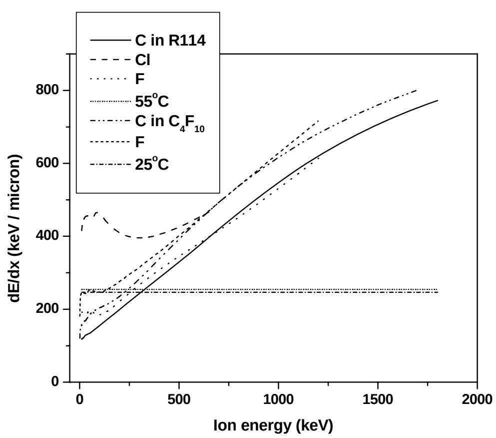

Fig.2. $\frac{dE}{dx}$ of C, Cl, F in R114 and C, F in C_4F_{10}.

The $\frac{dE}{dx}$ of different constituting nuclei in R114 and C_4F_{10} is shown in Fig.2. The dotted lines in Fig.2 are the critical LETs for bubble nucleation in C_4F_{10} and in R114, calculated using equation (1).

Discussions & Conclusions

It is observed from table.1 that the critical energy for bubble formation is less in C_4F_{10} than that of R114 therefore it is expected that less neutron energy to be needed to trigger the nucleation. This is also found from the experiments [2, 3]. For lower energy neutron detection, C_4F_{10} and for higher energy neutron detection, R114 would be the good candidate as sensitive liquids in superheated drop detector. For a wide range of energy detection, both the liquids can be utilized in the specific temperature range. But it is found from Fig.2 that $\frac{dE}{dx}$ of chlorine is much higher in the lower energy region than the other recoil nuclei, C, F in both the liquids. The low energy ions are effective for the peak neutron energy of about 2 MeV from ^{252}Cf. Therefore, due to the high LET of chlorine, at a given temperature, the energy deposition in the effective length required for bubble formation is larger in R114. This large energy deposition is reflected when the power spectrum is measured which is related to the energy deposition in the medium. For the case of R114, large amplitude pulses are observed which gives higher values of *P*. The discrimination of events caused by nuclear recoils and by electrons is more prominent in R114 than in C_4F_{10} which is an important property for neutron detection. Fig.1 shows that for R114, neutron – gamma discrimination events are well separated while for C_4F_{10} it is not so clearly visible. It is to be noted that fabrication with purified detector ingredients in a clean room environment will improve the discrimination effects. Further work in this direction is going on.

References

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