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IDENTIFICATION OF THE ENERGETIC CHARGED PARTICLES IN GAS–LOADING EXPERIMENT OF "COLD FUSION" USING CR–39 PLASTIC TRACK DETECTOR

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I Introduction

Since observation of ″cold fusion″ was claimed in 1989, a great number of experiments have been done for verifying these claims [1–4]. Most of laboratories were not able to reproduce the observations and among the results of experiments there are obvious inconsistencies. It has been realized that even if the ″cold fusion″ happened, its signals would be quite weak. Thus for sake of confirming the presence of ″cold fusion″, it is desirable to use detection techniques which have high collecting power, low background and can stably work for long time. CR–39 plastic track detector is able to work in passive and time–integrated modes and has a number of unique merits in comparison with electronic detectors. In gas–loading experiment, if a piece of CR–39 film is clamped on the surface of a metal foil of Pd or Ti, charged particles emitted by deuterated metal can be collected by the CR–39 foil with 2π solid angle. The information on charge, energy, location and direction of the emitted particles can be determined from track parameters.

In the present work, CR–39 plastic films (Track Analysis Systems Inc. Bristol, United Kingdom) have been used for searching for charged particles from deuterized Pd and Ti foils. The effects of high pressure D_2 gas and low temperature on response of CR–39 have been studied and background levels of charged particles from several sources have been estimated. A procedure for identification of nuclear charge of particles has been developed and preliminary result of charge identification was given.

Ⅱ The response of CR–39 to light charged–particles

The nuclear charge and incident kinetic energy can be determined for particles which come to rest in CR–39 by measuring two parameters, range and sensitivity (S). To identify a charged particle, one needs relating the two parameters to the charge Z and energy E of the particle. We define $S = V_t / V_g$, where V_t is etch rate along the track. V_g is general etch rate. By means of calibration with α particles at known energies, the relation between S and dE / dx for a given CR–39 film and etching conditions can be obtained. A ^{252}Cf source and an ^{241}Am source were used for the calibration, α particles from the sources were slowed by Al foils to following energies: 6.1, 5.5, 4.5, 3.5, 3.0 and 2.0 MeV. CR–39 films were irradiated in 10^{-2} torr. vacuum and 25℃ with the α particles. Then CR–39 films were etched in 6.8N NaOH solution at 70℃ for 5 hours. The diameters of α tracks and fission fragment tracks from a ^{252}Cf source were measured at magnification of 1500x. The sensitivity S for α particle registration is given by:

$$S = \frac{1 + (D_\alpha / D_F)^2}{1 - (D_\alpha / D_F)^2} \times \frac{1}{\cos\phi} \qquad (1)$$

where

ϕ is the incident zenith angle of α particles.

D_α is minor mouth diameter of the surface ellipse of α track.

D_F is the diameter of etch pit of vertically incident ^{252}Cf fission fragment.

The range of α particles in CR–39 were calculated by the range–energy relation, given by Benton and Henke [5] . The result of a calibration of CR–39 film under condition of room temperature and 10^{-2} torr vacuum was shown in Fig.1

In D_2 gas loading experiment CR–39 detector is put in a cell filled with high pressure D_2 gas and then subjected to temperature cycles from 25℃ to −196℃. The response of CR–39 detector may change with the environment. To mimic experimental condition as closely as possible, CR–39 films were also calibrated in following environmental condition. D_2 gas was filled into the high pressure cell to a pressure of 15 bar and immersed the cell in liquid nitrogen for 1 hour to allow sufficient time to cool the cell, and then removed it from the liquid nitrogen to allow it to warm up to room temperature in several hours. The cooling and warming cycle was repeated twice a day for 4 days.

CR–39 films were divided into two groups: one group was irradiated with α particles first, then was subjected to loading D_2 gas and temperature cycle. The another group was at first subjected to loading D_2 gas and temperature cycle, then irradiated with α particles. The relationship between S–1 and R for these two groups are given in Fig.1.

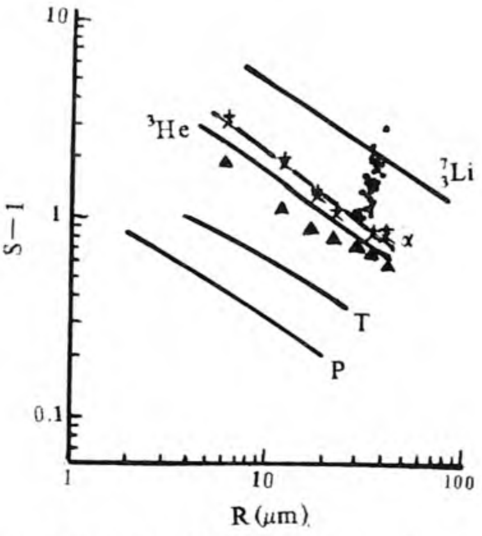

Fig.1 Response curves of CR−39 to α particles under three environmental conditions as well as the data of two runs of gas−loading experiment. The curves labelled "P", "T", "^{3}He" and "$^7_3$Li" were scaled from α particle curve.

▲ D_2 gas−loading and temperature cycle first, then α irradiation
× α irradiation first, then D_2 gas−loading and temperature cycle
\+ α irradiation in 25 ° and 10^{-2} torr vacuum.
• charged particles detected by CR−39 film on the surface of Pd or Ti foil.

The results show that for post−irradiation group the environmental condition of D_2 gas loading experiment has little effect on response of CR−39; in contrast, for pre−irradiation group, the environmental condition makes the S of CR−39 decreasing. Fortunately, the decrease of S is so small that identification of nuclear charge is still possible.

The restricted energy−loss model of track formation has been successfully used to describe etching behavior of charged particles in plastic track detectors. We used the expression in ref.6 to compute restricted energy loss (REL) for α particles used in this experiment. The relationship between S−1 and REL obtained with least−squares fit is

$$S - 1 = 1.36\ \mathrm{REL}^{1.27} \tag{2}$$

Equation (2) can then be used to interpolate response for energies and for other light particles not specifically determined from our calibration. The predicted relations between S−1 and R for P, α, ^{3}He and $^7_3$Li were given in Fig.1. The results show that the calibration curves for Z = 1, 2 and 3 are wide apart separated. Thus it is possible to identify charge Z of light particles by measuring S and R in CR−39. The charge resolution depends on the error of measuring range R and sensitivity S.

III Estimation of background from several sources

Since signals of charged particles from deuterized Pd and Ti foil are very weak, it is important to know charged particle background. There are three types of charged particle backgrounds in CR–39, which are relevant to the present experiment. 1) α particle tracks emitted by nuclides such as ^{238}U and ^{232}Th series, present as impurities in CR–39 and Pd or Ti foils; 2) cosmic–ray spoliation tracks; 3) α–decay tracks due to airborne radon.

CR–39 film itself has accumulated background tracks from above–mentioned sources between the time it was made and the time it is used. A CR–39 film was etched in 6.8N NaOH solution at 70℃ for 8 hours. All tracks were counted. The density of tracks was found to be 114 tracks / cm^2. These kinds of background tracks can be reduced by preetching the CR–39 for 1 hour in 6.8N NaoH solution at 98℃ and by protecting the CR–39 film from airborne radon during the experiment.

Table1 Charged particle background measured by preetched CR–39 film

Place or material	The rate of production of background tracks(track / cm^2.day)
high pressure cell	5
open air in lab	6
Pd foil (30μm)	2
Pd foil (25μm)	1
Ti foil	1

By using preached CR–39 films, we have estimated the background levels in metal materials, high–pressure cell and laboratory environment. The results are given at Table 1. It is shown from Table 1 that, the background level from all possible sources should be less than about 20 tracks / cm^2day.

IV Identification of charged particle tracks from deuterized Pd and Ti foils

Pd or Ti foils and CR–39 film were stacked together in a sandwich–like structure and put in a stainless–steel cell attached to a source of D_2 gas. The cell was subjected to the same temperature cycle as above mentioned. Then, we etched the CR–39 films in 70℃ 6.8N NaOH solution in an interrupted way. After each etching process, we scanned CR–39 films at magnification of 150x to search for charged particle tracks and measured the track parameters at magnification of 1500x. For a track etched to the end of its range as in Fig.2, the quantities D_1, D_2 and R (and a knowledge of G) provide a pair of S and R (7) .

Etch pits of about 10^3 tracks / cm^2 density were found in 2 runs of 4 runs.

They are from a Pd foil and a Ti foil made in U.S.A. After etching for 8 hours we measured track parameters of 40 tracks. Their data of S and R are drawn in Fig.1. The data points locate between curves of Z = 2 and Z = 3.

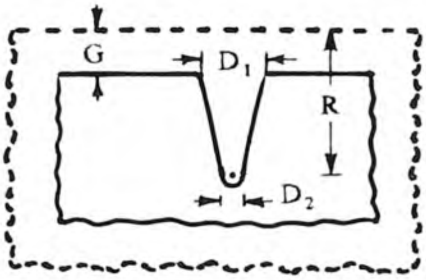

Fig.2 Etch pit of a normally incident particle of range R after removing a layer of thickness G. After a certain etch time, from the measurement of D_1 and D_2 and depth we calculate S and R.

V Discussion

The calibration using pre and past irradiation treatments of gas–loading experiments mimics the actual experimental condition only in some extents. In fact, the effect of environment takes place just during irradiation. So in order to identify charge Z more accurately, the response of CR–39 should be calibrated using α particle irradiation under the condition of high–pressure D_2 gas and temperature cycle.

Since a contamination of α particles occurs not very seldom, more experiments are under way to obtain more reliable results.

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