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Charge and energy discrimination of ions in CR39 track detectors by diameter-depth correlations

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In track detectors as CR39 and other polycarbonate compounds the path of an ionizing particle is revealed by the chemical etching of the damaged trail, by conical pitches which depend on the properties, etching time and conditions of the solution and on travelling ion characteristics. Many experimental studied have been done on calibrations, to correlate the track patterns to the charge and energy of ions. However no much has been done to discriminate effectively the species and, when possible, the energy of ions. In this contribution we investigate the possibility to solve the problem of discrimination by using the correlations between diameter and depth of conical pitch of the tracks and by an accurate control of etching time depending on charge and energy of ions.

1. Introduction

In solid state track detectors as CR39 and other polycarbonate compounds, the path of an ionizing particle along the damaged trail is revealed by a conical pitch which is visible to microscopic analysis after a chemical etching. The pitch characteristics (mainly diameter and length) depend on properties of the etching solution (chemical composition, concentration, temperature and time interval) and on travelling ion so to allow determination of ion properties.

Many investigations have been done in the past from experimental point of view, concerning the track characteristics determination in function of ion species (H_1,H_2, He, C, O, Li, B, etc) and energies and of etching time, ref. [1-4], ref.[5,6]. Detailed calibration curves have been determined also for different etching conditions. An other approach of the problem has been to determine experimentally the pit characteristics in terms of track etching rate V_T in function of physical parameters as restricted energy loss, residual energy range, etc (ref.[5], ref.[6]). In this case, if the V_T has been determined for various ion and kinetic energy conditions, it could be possible to relate the V_T behaviour to physical parameter of travelling ion, to predict the pit characteristics of a specific case and finally to infer charge and energy values.

Despite of the important and well documented work, only in few cases CR39 has been used to actually identify ion species and energy ref.[7]. Therefore we thought interesting to investigate on the expected pitch features facing to experimental conditions so to have a guide-line in choosing etching process features and, in particular, the time interval. Moreover, because two parameters, i.e. the diameter and the length pitch ,were related to ion properties, we examined the possible advantage of using both correlated in ion species and energy discrimination .

2. Track formation along the ion path

Under the hypothesis that the etching rate of bulk V_B (which depends on chemical composition of the etching solution, concentration and temperature) is maintained constant, and the etching rate of track $V_{T,}$ could be assumed constant too, in the case of motion of ion normal to the bulk, it can be shown, two equations can be derived [8] :

$$D = 2V_B t\sqrt{\frac{(V_T - V_B)}{(V_T + V_B)}} \qquad (1)$$

$$L = (V_T - V_B)t \qquad (2)$$

Because V_T ($>V_B$) is produced by the damage, which in turns is increasing with the specific energy loss (dE/dx), the measurement of diameter (or of the length *L*) could allow the charge ion discrimination. V_T will change generally with the depth penetration. In a generic case, equations *1* and *2* are valid only locally because of variation of V_T along the ion path. Modelling of conical shape of pit track is produced by the V_T changing inside the CR39 sample. The track rate V_T is strongly depending (roughly proportionally) on the amount of the restricted specific energy loss $(dE/dx)_r$. It in turn is varying with the crossed region in dependence of its residual energy E_{res} at a given depth x. Finally the track etched rate V_T can be assumed function of residual energy E_{res} ,(or of residual range) each value of it defining the associate $(dE/dx)_r$. In addition to the above cited values V_T and V_B ($V_T > V_B$), the important parameters governing the track profile formation are: the etching time ($t_{etching}$) and the total time needed to reach the range depth (t_{track}).

3. Simulation of pitch profiles

Calculations of pitch profiles need some basic parameter knowledge: the bulk rate V_B and the V_T evolution from entrance position of travelling ion to its range along the track path. In our experimental conditions it was V_B =2.2 μ/h. From diameter measurements and eq.1 ,a value V_T = 3.5 μ/h has been deduced, for ^{4}He at 5.48 MeV . In our simple model, the V_T behaviour has been assumed proportional to the total stopping power (calculated by the SRIM3 code) and the normalization factor has been assumed as :

f_{vt} = $(dE/dx)_{Z,A,E}/(dE/dx)^4{}_{He,5.48\ MeV}$ Figures 1 and 2 show results for ^{4}He in the energy range 1-10 MeV for diameter and length profiles, respectively for several etching time of CR39 samples in a 6.25 moles of NaOH solution, kept at a temperature of 70.5 ± 0.5 °C

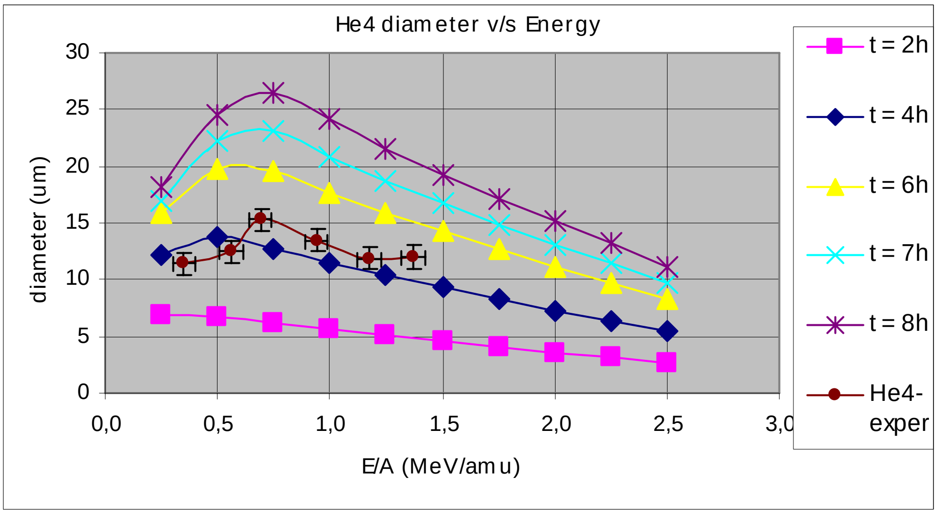

Fig.1

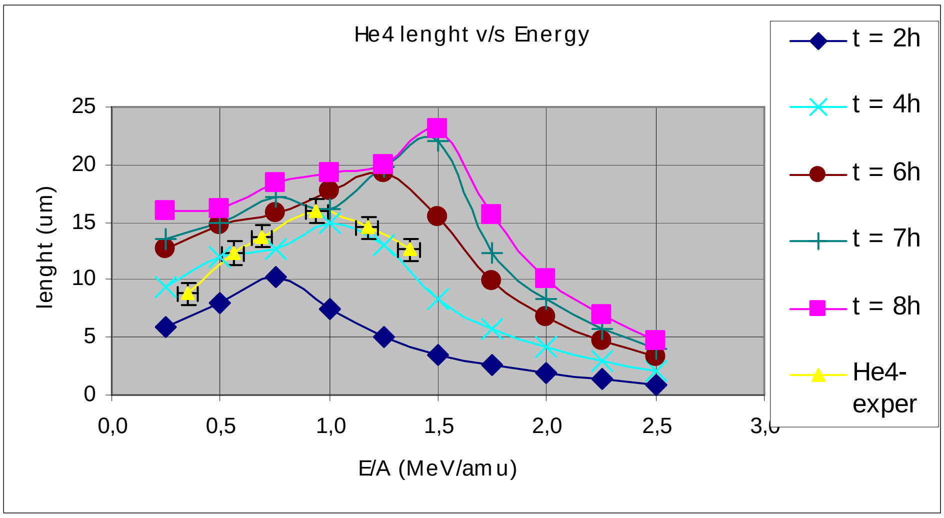

Fig.2

Experimental results relative to ^{241}Am alpha source, with energy degrated by suitable tickness Al foils, are shown for comparison, in the case of etching time of 4h. Lenght and diameter of pitch profiles have been measured by standard optical microscopy after checking by a confocal analysis system.To test our approach we have considered ions of ^{1}H, ^{4}He, ^{7}Li, ^{12}C, ^{16}O,^{19}F and^{28}Si in the range of 0.25 to 2.5 MeV/amu and many etching times.

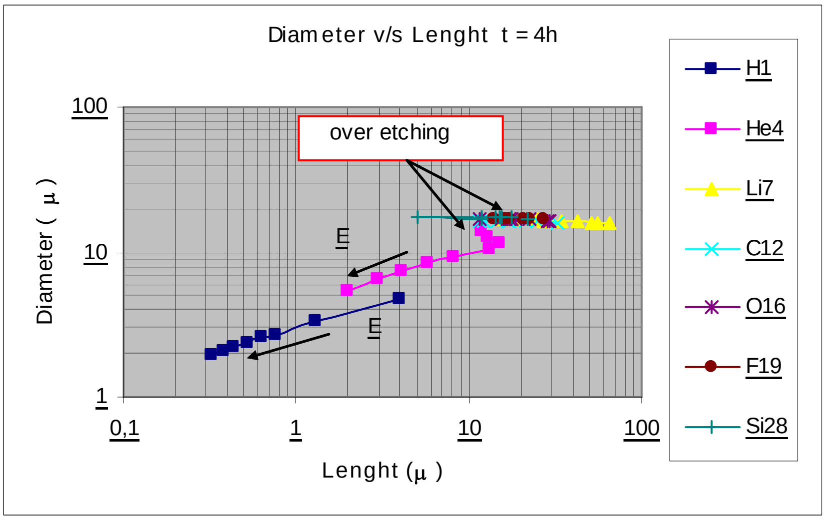

Fig. 3

Figure 3, shows correlation between diameter pitch length versus energy. Altought the choice of must suitable etching time has to be related to the specific case, it seems the present approach, based on this correlation, to be powerful for the ion identification and energy determination. However,more studies are needed to analize the potentiality and limits of the this approach

References

[1] Sadowski, M., Al-Mashhadani, E.M., Szydlowski, A., Czyzewski, T., Glowacka, L., Jaskola, M., and Wielunski, M. *NIMB* 1994, 86, 311.

[2] Szydlowski, A., Sadowski ,M., Czyzewski, T., Jaskóla, M., Korman, A., andFija, I,.*NIMB* 1999, 149, 113.

[3] Szydlowski, A, Banaszak, A., Czyzewski, T., Fija, I. , Jaskóla, M., Korman, A., Sadowski, M,.and Kretschmer,W. *Radiat. Meas*. 2001, 34, 325.

. [4]Szydlowski, A, Banaszak, J., Parys, P., Woloswki, J. ,Woryna, E, Jungwirth, K., Kralikova, B. , Krasa, J., Laska, L., Pfeifer,M. Et al. *Plasma Physics and Control. Fusion* 2003, 45, 1417.

[5] Dorschel, B., Hermsdorf, D, Reichelt, U., and Starke, S. *Radiat. Meas*. 2003, 37, 573.

[6] Nikezic, D., and Yu, K.N. *Radiat. Meas*. 2003, 37, 595.

[7] Giorgini, M., for the MACRO collaboration. *Nucl. Phys. B* [*Proc. Suppl.*]2000, 85, 227.

[8] Somogyi, G. *NIM* 1980, 173, 21.