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# Measurement of the energy spectrum of $^{252}\text{Cf}$ fission fragments using nuclear track detectors and digital image processing

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The energy spectrum of  $^{252}\text{Cf}$  fission fragments was measured using Nuclear Tracks Detectors (NTD's) and Digital Image Analysis System (DIAS). The detection material was fused silica glass. The detectors were chemically etched in an 8% HF solution. After experimenting with various etching time, it was found that the best resolution of the track diameter distribution was obtained after 30 minutes of etching. Both Gaussian and Lorentzian curves were fit to the track diameter distribution histograms and used to determine the basic parameters of the distribution of the light ( $N_L$ ) and heavy ( $N_H$ ) formed peaks and the minimum of the central valley ( $N_V$ ). Advantages of the method presented here include the fully-automated analysis process, the low cost of the NTDs and the simplicity of the nuclear track method (NTM). The distribution resolution obtained by this method is comparable with the resolution obtained by electronic analysis devices. The descriptive variables calculated were very close to those obtained by other methods based on the use of semiconductor detectors.

**Keywords:** Nuclear track detectors; fission fragments; californium-252.

El espectro de energías de los fragmentos de fisión del  $^{252}\text{Cf}$  fue determinado usando detectores por trazas en sólidos y un sistema de análisis por digitalización de imágenes. El material de detección usado fue “vidrio de silicio fundido”. Los detectores fueron químicamente grabados en una solución al 8% de HF (ácido fluorhídrico). Después de haber experimentado con diferentes tiempos de grabado, se encontró que la mejor resolución de la distribución de diámetros de las trazas formadas, se obtenía a los 30 minutos de ataque químico. Curvas tanto Gaussianas como Lorentzianas se ajustaron al histograma de la distribución de los diámetros de las trazas y fueron usadas para determinar los parámetros básicos de dicha distribución, para los fragmentos ligeros ( $N_L$ ) los pesados ( $N_H$ ) y de los mínimos en el valle central ( $N_V$ ). Las ventajas del método presentado en este trabajo incluyen el proceso totalmente automatizado de análisis, el bajo costo de los detectores por trazas, respecto a otros métodos, y la simplicidad de la metodología de trazas nucleares. La resolución de la distribución de los fragmentos de fisión obtenida por este método, es comparable con la resolución de dispositivos electrónicos de análisis y los valores obtenidos de las variables ( $N_L$ ,  $N_H$  y  $N_V$ ) son muy cercanos al método basado en el uso de detectores semiconductores.

**Descriptores:** Trazas nucleares en sólidos; fragmentos de fisión; californio-252.

PACS: 25.85.CA; 29.40.Wk; 29.30.Ep; 87.66.Pm

## 1. Introduction

Fast moving charged particles produce trails of atomic disorder (usually referred to as nuclear tracks) in an immense variety of dielectric solids, including crystals, glasses, high-polymers, intermetallics, oxide conductors and superconductors [1]. The measurement of these nuclear tracks has many applications in several areas of science, including hole engineering and track membrane technology, radiobiological dosimetry, radon dosimetry, and other areas of the earth sciences [2]. One specific application is the design of track-etch templates for micro- and nanofabrication. Although the optical microscope was the main tool for track observation for many years, there has been relatively little investigation of

the optical characteristics of the etched tracks or the energy response of the detectors [3].

Recent literature documents several applications of  $^{252}\text{Cf}$  sources in particular, including the production of the carrier-free short-lived fission products widely employed in many different fields of modern nuclear chemistry [4], and the study of the differences between spontaneous fission neutrons and the cosmic ray background [5].  $^{252}\text{Cf}$  sources have recently proven useful in the detection of fast neutrons in radiation with a high neutron/gamma ratio and in locating the source of cosmic-ray-produced neutrons, with a relatively high signal-to-noise ratio in this context [6]. Fission fragment tracks from  $^{252}\text{Cf}$  have been observed in 150  $\mu\text{m}$ -diameter  $\text{SiO}_2$  optical fibers by an atomic force microscope [7,8].

TABLE I. Comparison of the values obtained in this study with those obtained by Schmitt and Pleasonton (1966) and Kahn and Durrani (1973).

Method	Schmitt and Pleasonton		Khan and Durrani		This Work (Fused silica glass)	
	Surface Barrier (Electronic system)		Nuclear Tracks in Solids (Manual counting)		Nuclear Tracks in Solids (Automatic counting)	
	Reasonable limit	Expected value	Phosphate Glass	Soda-Lime Glass	Gaussian fit	<b>Lorentzian fit</b>
$N_L / N_V$	$> 2.85$	$\sim 2.9$	2.04	1.45	2.64	<b>2.74</b>
$N_H / N_V$	$\sim 2.2$	$\sim 2.2$	1.57	1.24	2.26	<b>2.07</b>
$N_L / N_H$	–	$\sim 1.30$	1.27	1.16	1.17	<b>1.32</b>
$\Delta L / (L-H)$	$< 0.38$	$\sim 0.36$	-	-	0.30	<b>0.41</b>
$\Delta H / (L-H)$	$< 0.45$	$< 0.44$	-	-	0.41	<b>0.44</b>
$(H-HS) / (L-H)$	$< 0.70$	$< 0.69$	-	-	0.84	<b>0.56</b>
$(LS-L) / (L-H)$	$< 0.49$	$< 0.48$	-	-	0.80	<b>0.56</b>
$(LS-HS) / (L-H)$	$< 2.18$	$\sim 2.17$	-	-	2.63	<b>2.15</b>

Current applications of  $^{252}\text{Cf}$  sources require knowledge of the fission fragment emission spectrum in the presence of gamma radiation, neutrons and light isotopes such as alpha particles. One important development was the evaluation of the parameters of the  $^{252}\text{Cf}$  fission fragments energy distribution using silicon semiconductor detectors [9]. These authors defined the resolution factors of the distribution curves and calculated their basic ratios. In the '70s, Khan and Durrani [10] demonstrated the advantages of using nuclear track detectors (NTD's) to record the energy spectrum of fission fragments in the presence of mixed radiation fields. However the main problem with the use of NTD's, as mentioned by these authors, is the relatively poor resolution of the spectra compared with the resolution obtained by active detectors.

The present study aims to determine the energy spectrum of fission fragments from a  $^{252}\text{Cf}$  source using fused silica glass detectors, and to improve the resolution of the detectors by using a digital image analysis system (DIAS) to obtain the track diameter distribution.

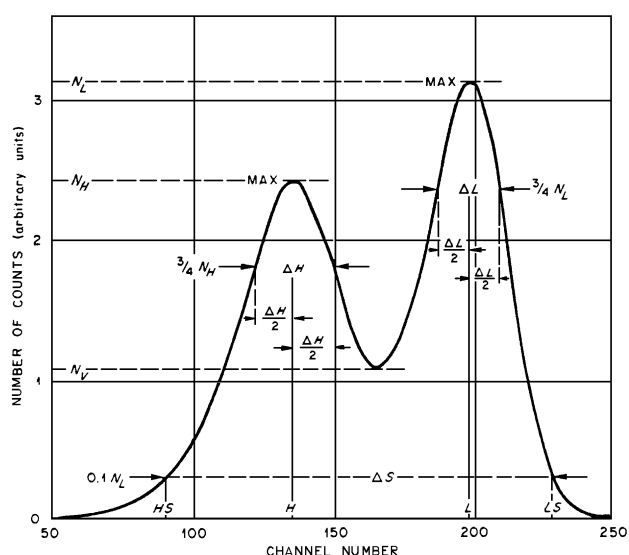
## 2. Experimental procedure

Track formation in NTDs is based on the energy transfer between the incident particle and the detector material. Fission fragment energies may be calculated by measuring the diameters of the etched tracks [11]. In the present paper the fission fragment energy spectrum was studied by combining nuclear track methodology (NTM) with digital image processing techniques and appropriate statistical models.

The method is based on the relation between the energy transferred to the material by the spontaneous fission fragments of  $^{252}\text{Cf}$  (79.4 and 103.8 MeV) and the track size distribution developed in the material by the chemical etching process [9,10,12]. Of the several available nuclear track detectors, fused silica glass was chosen due to its appropriate energy response, the fact that it is produced commer-

cially, and the high level of homogeneity exhibited across different groups of detectors [13]. The irradiation was performed in air, with the source separated from the target by a 10-micron thick aluminum foil with collimating holes of approximately 100 microns in diameter. Consequently only the fission fragments with normal or close to normal incidence were recorded by the detectors.

The fused silica detectors were etched in an 8% HF solution at a temperature of  $20^\circ\text{C} \pm 1^\circ\text{C}$  for five minutes. The detectors were then washed in distilled water, air-dried and analyzed in the digital image analysis system (DIAS) to obtain the track diameter distribution [14]. The 5-minute etching and analysis procedure was repeated until the detectors had each been subjected to total of 60 minutes of chemical etching. In this manner it was possible to observe to

FIGURE 1. Energy spectrum of  $^{252}\text{Cf}$  spontaneous fission fragments. (Schmitt and Pleasonton, 1966).

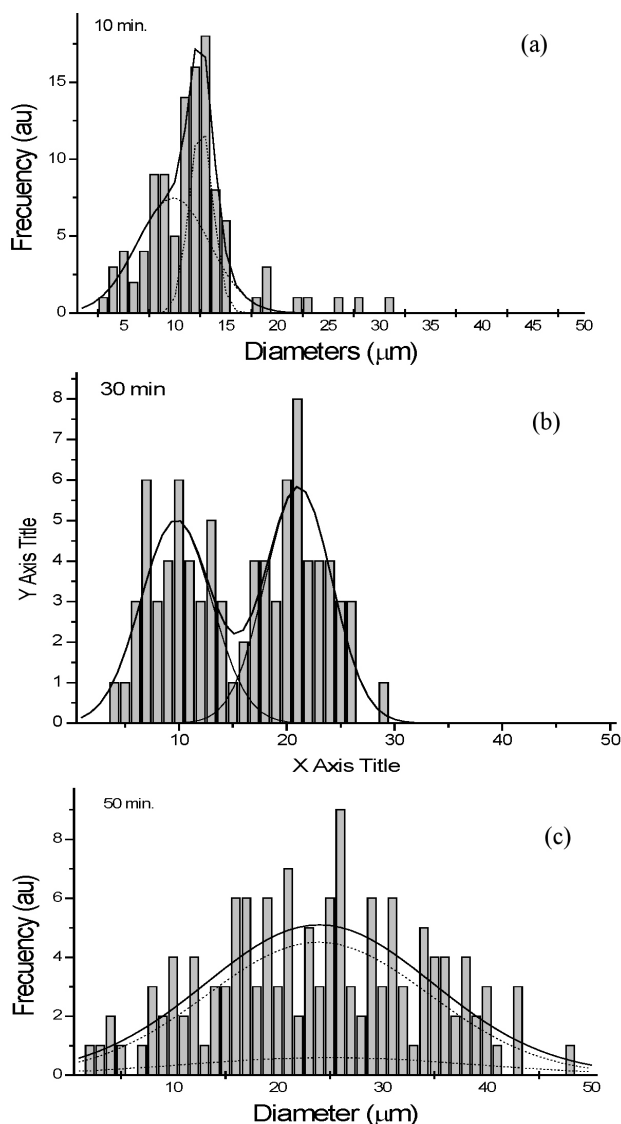


FIGURE 2. Distribution of the nuclear track diameters with etching times of a) 15 minutes, b) 30 minutes and c) 50 minutes.

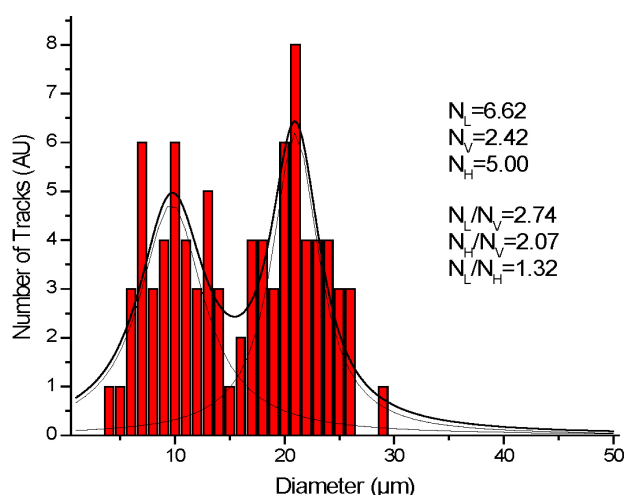


FIGURE 3. Lorentzian fit to the data obtained after 30 minutes etching.

evolution of the traces in the material and to define the etching time after which the track diameter distribution had the highest resolution, that is, the time after which the track distributions of the heavy and light fragment groups were most separated. Only tracks where the ratio ( $d/D$ ) of the smaller diameter ( $d$ ) to the larger diameter ( $D$ ) was between 0.9 and 1.0 were counted [15], and only  $D$  was used for the analysis. It was found that the best resolution was achieved after 30 minutes of etching.

The parameters describing the  $^{252}\text{Cf}$  spontaneous fission fragments energy spectrum, as explained by Schmitt and Pleasonton [9], include the number of counts per channel at the peaks of the heavy ( $N_H$ ) and light ( $N_L$ ) fragment groups and at the central valley minimum ( $N_V$ ), and several ratios based on these and other variables (Fig. 1). Both Gaussian and Lorentzian curves were fitted to the track diameter distribution histogram obtained after 30 minutes of etching and the descriptive variables calculated using Microcalc Origin<sup>®</sup> and Microsoft Excel<sup>®</sup> software.

### 3. Results and discussion

The track diameter distributions for etching times of 15, 30 and 50 minutes are shown in Figs. 2a, 2b and 2c, respectively. It is clear that the greatest separation of the distributions is achieved after 30 minutes of etching. Fitting a Gaussian curve to the data displayed in Fig. 2b yielded the values  $N_H=4.99$ ,  $N_V=2.21$  and  $N_L=5.84$ . Fitting a Lorentzian curve to the same data (Fig. 3) yielded  $N_H=5.00$ ,  $N_V=2.42$  and  $N_L=6.62$ .

A comparison of the descriptive variables of the distribution based on the Gaussian and Lorentzian fits with those obtained by Schmitt and Pleasonton [9] and Kahn and Durrani [10] is shown in Table I. The values based on a Lorentzian fit to the data are closer to the expected values obtained by Schmitt and Pleasonton.

The method used here to obtain the fission fragments energy spectrum, based on the use of NTD's and a digital image analysis system, yields resolutions comparable to those obtained by electronic analysis devices while presenting the advantages of nuclear track methodology. NTD's have low cost compare with the electronic devices, consisting in a simple methodology not affected by the gamma radiation background and available in different shapes and sizes. Different detector materials are sensitive to different ranges of particles and energies. The results presented here may be considered a corollary to the research initiated by Khan and Durrani [10], and provide an alternative method for measuring the energy spectrum of  $^{252}\text{Cf}$  fission fragments with a resolution comparable to that obtained by electronic devices.

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1. D. Nikezic and K.N. Yu, *Mat. Sci. Engineer. R: Reports* **46** (2004) 51.
  2. D. Hermsdorf, M. Hunger, S. Starke, and F. Weickert, *Radiat. Meas.* **42** (2007) 1.
  3. D. Nikezic and K.N. Yu, *Comp. Phys. Com.* **178** (2008) 591.
  4. Ch.E. Dullmann *et al.*, *Nucl. Instrum. Meth. Phys. Res. A* **512** (2003) 595.
  5. L. Forman, *Distinguishing spontaneous fission neutrons from cosmic-ray background*. (SPIE 49th Annual Meeting, Denver, Co. 2004).
  6. L. Forman, P. Vanier, and K. Welsh *Fast neutron source detection at long distances using double scatter spectrometry* 48 SPIE Annual Meeting: (International Symposium on Optical Science and Technology, San Diego, Ca. 2003).
  7. G. Espinosa, *Trazas Nucleares en Solidos* (PUMA-Instituto de Fisica-UNAM, 1994).
  8. G. Espinosa, J.I. Golzarri, C. Vazquez, and R. Fragoso, *Radiat. Meas.* **36** (2003) 175.
  9. H.W. Schmitt and F. Pleasonton, *Nucl. Instrum. Meth.* **40** (1966) 204.
  10. H.A. Khan and S.A. Durrani, *Nucl. Instrum. Meth.* **109** (1973) 341.
  11. C. Amero, J.I. Golzarri, M. Izarrouken, and G. Espinosa, *Radiat. Meas.* **34** (2001) 341.
  12. G. Espinosa and V.M. Castaño, *Radiat. Prot. Dosim.* **34** (1990) 29.
  13. V. Castaño and G. Espinosa, *Material Letters.* **9** (1990) 365.
  14. G. Espinosa, *Prot. Dosim.* **66** (1996) 363.
  15. G. Espinosa, *Radiat. Prot. Dosim.* **59** (1995) 227.