Glass fission track analysis by AFM and SEM: Inferring latent track structure through etched tracks

J.C. Hadler[1], I. Alencar[1], P.J. Iunes[1], S. Guedes[2]

[1] Instituto de Física "Gleb Wataghin", Universidade Estadual de Campinas, UNICAMP, 13083-970, Campinas - SP, Brazil.
[2] Departamento de Ciências Exatas e da Terra, Universidade Federal de São Paulo, UNIFESP, Rua Professor Artur Riedel 275, 09972-270 Diadema, SP, Brazil.

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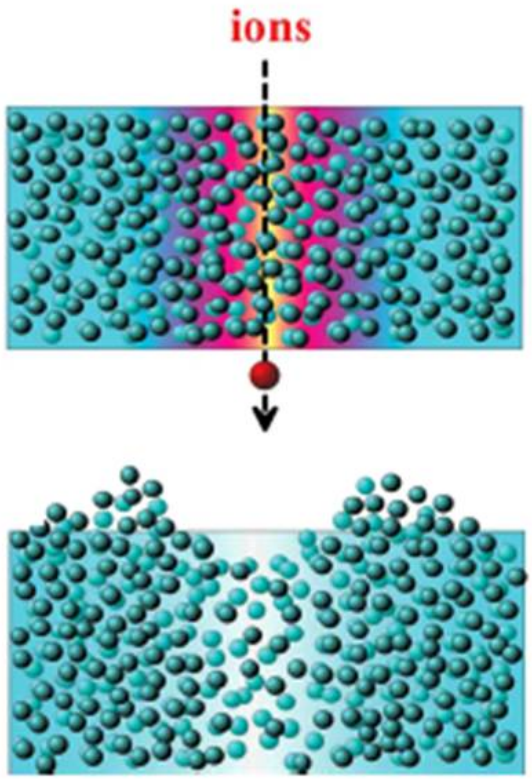
Latent track:

A damage trail (lattice defects) caused by charged particles traversing dieletric materials.



Goals:

- To study the glass latent track structure through etched tracks;
- To observe the glass fission track structure evolution by a chemical etching.

To observe a track, a chemical etching is required to enlarge the damage trail.

Bulk etching rate V_B:

The rate in which the bulk material is dissolved.

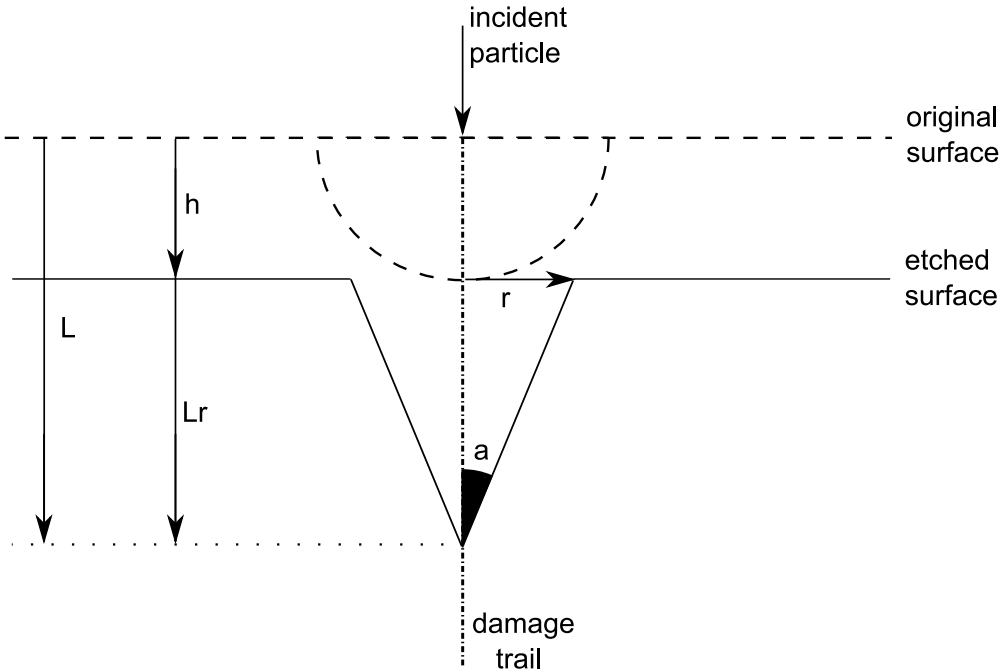
Track etching rate V_T:

The rate in which the damaged region along the track is dissolved.

Response function V:

$$V \equiv \frac{V_T}{V_B}$$

Assumptions: isotropic material and constant V_T.



$$\text{tg } a = \frac{r}{L_r} = \frac{h}{\sqrt{L^2 - h^2}}$$

$$r = h\sqrt{\frac{L-h}{L+h}}$$

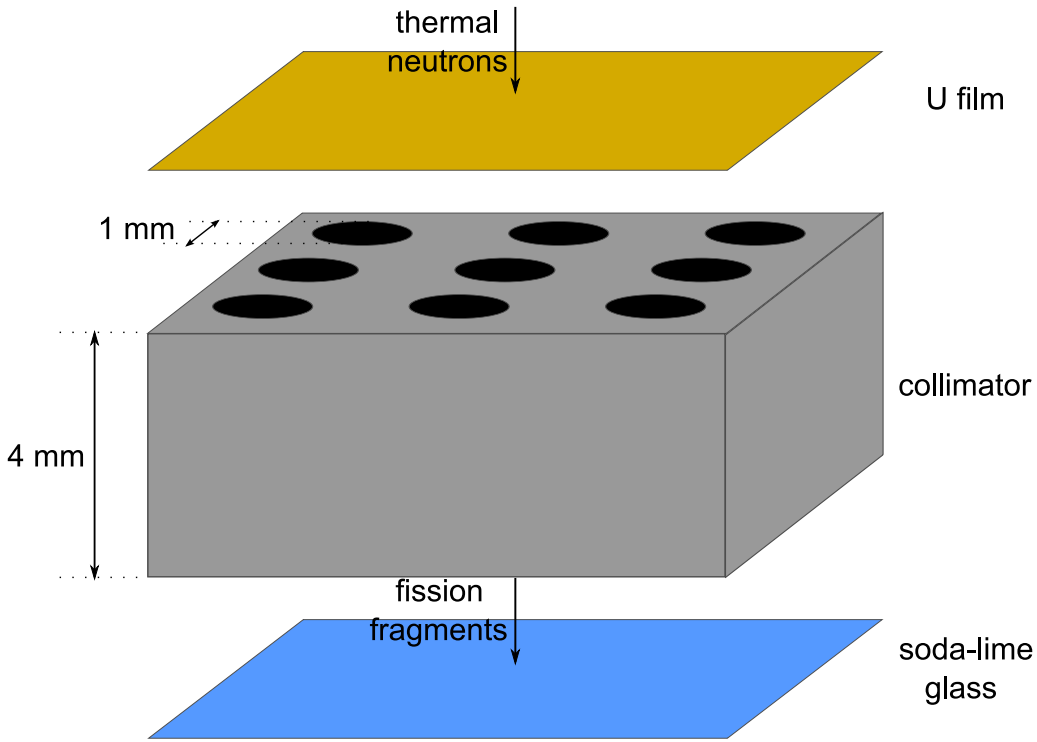
$$V \equiv \frac{V_T}{V_B} = \frac{L}{h}$$

$$\Rightarrow V = 1 + \frac{2d^2}{4h^2 - d^2}$$

Somogyi & Szalay (1973) *Nucl. Instr. and Meth.* **109**, 211.

Sample:

A soda-lime glass detector is coupled to an U film through an acrylic piece (collimator). Irradiated by thermal neutrons ($\phi = 1.0 \times 10^{14}$ cm^{-2}) the film emit fission fragments.



Using software *SRIM* the fission fragments energy loss were simulated.

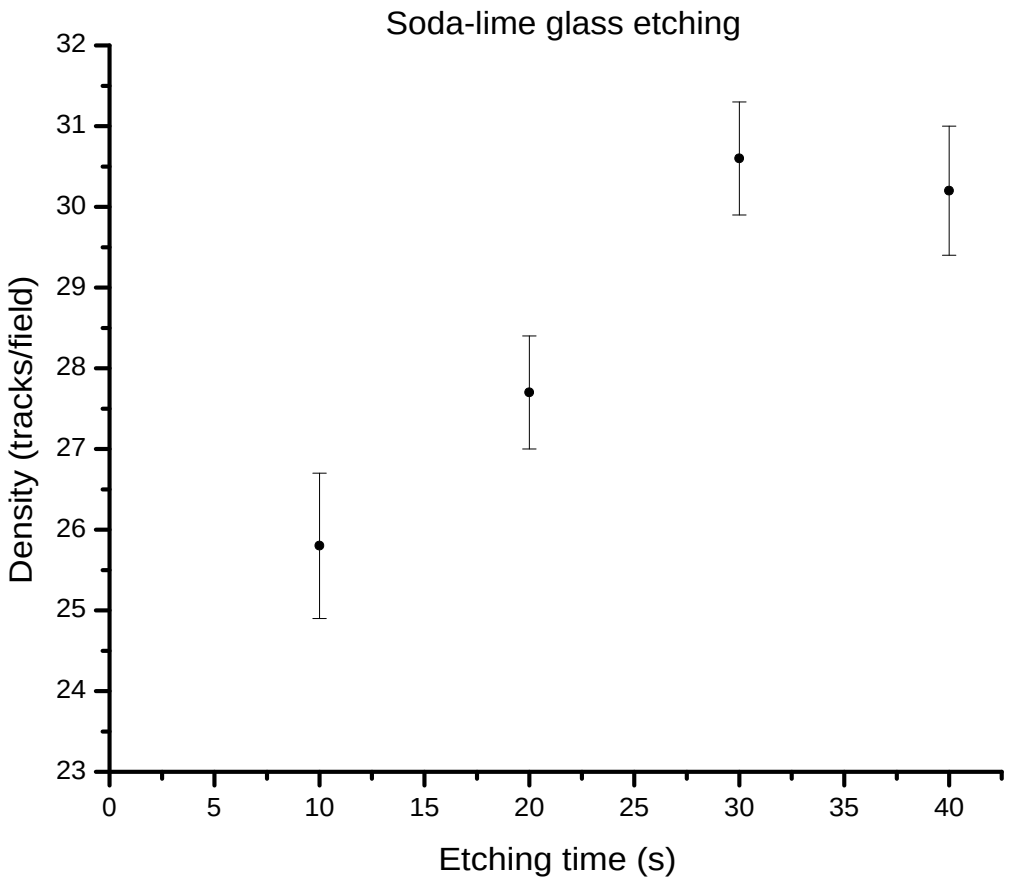
Light fragment (niobium):

Film thickness	**Film loss**	**Air loss**	**Incidence energy**
0.053 μm	0.63 MeV	32.30 MeV	69.07 MeV
0.49 μm	5.78 MeV	31.92 MeV	64.03 MeV
0.93 μm	10.97 MeV	31.53 MeV	59.50 MeV

Heavy fragment (lanthanum):

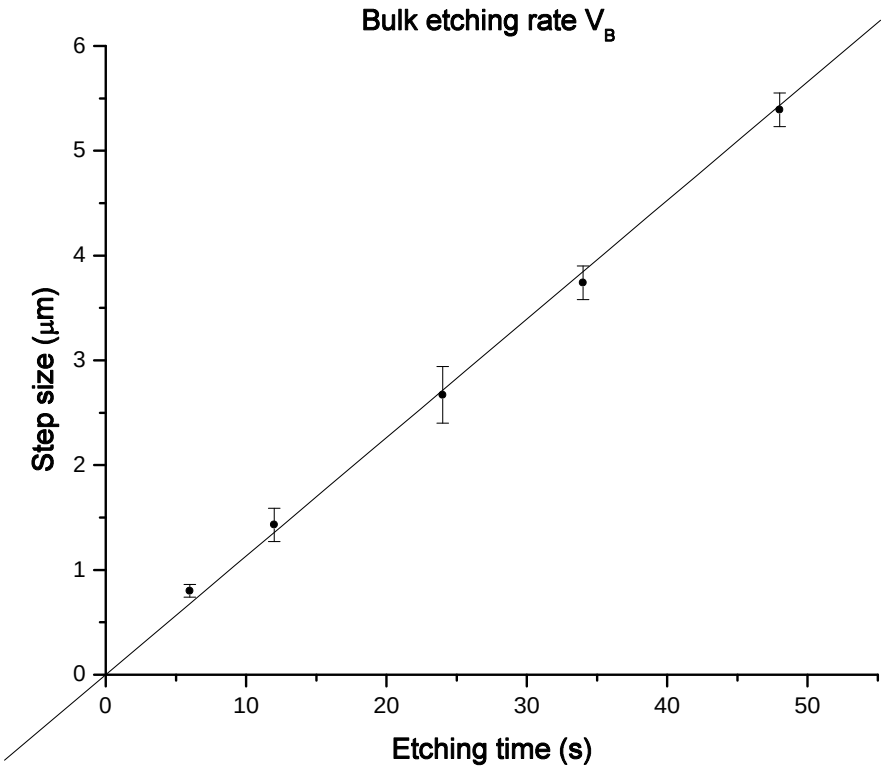
Film thickness	**Film loss**	**Air loss**	**Incidence energy**
0.053 μm	0.57 MeV	30.99 MeV	38.44 MeV
0.49 μm	5.25 MeV	30.09 MeV	34.66 MeV
0.93 μm	9.97 MeV	29.19 MeV	30.84 MeV

Chemical etching: HF 20% 15°C.
The standard etching observed was 30s.



V_B measurement:

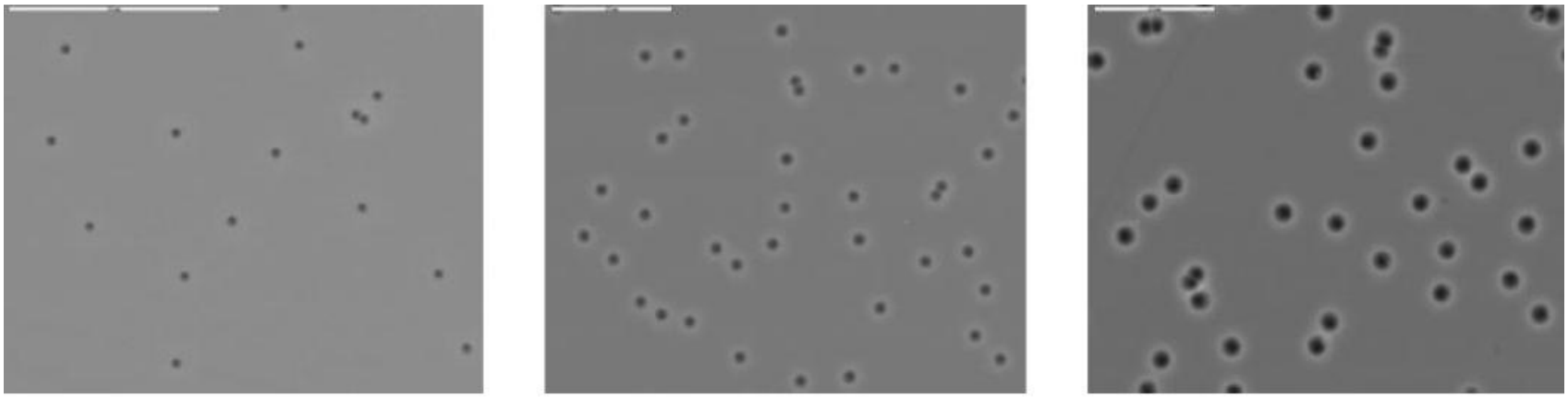
Part of the glass surface was recovered with *AZ 30 12 Photo Resist* during the chemical etch. The steps were measured with a Profilometer (soft touch).



$V_B = (0.113 \pm 0.003)\mu\text{m/s} \quad \chi^2 = 4.8 \quad \nu = 4 \quad P(\chi^2) \approx 0.3$

SEM measurements:

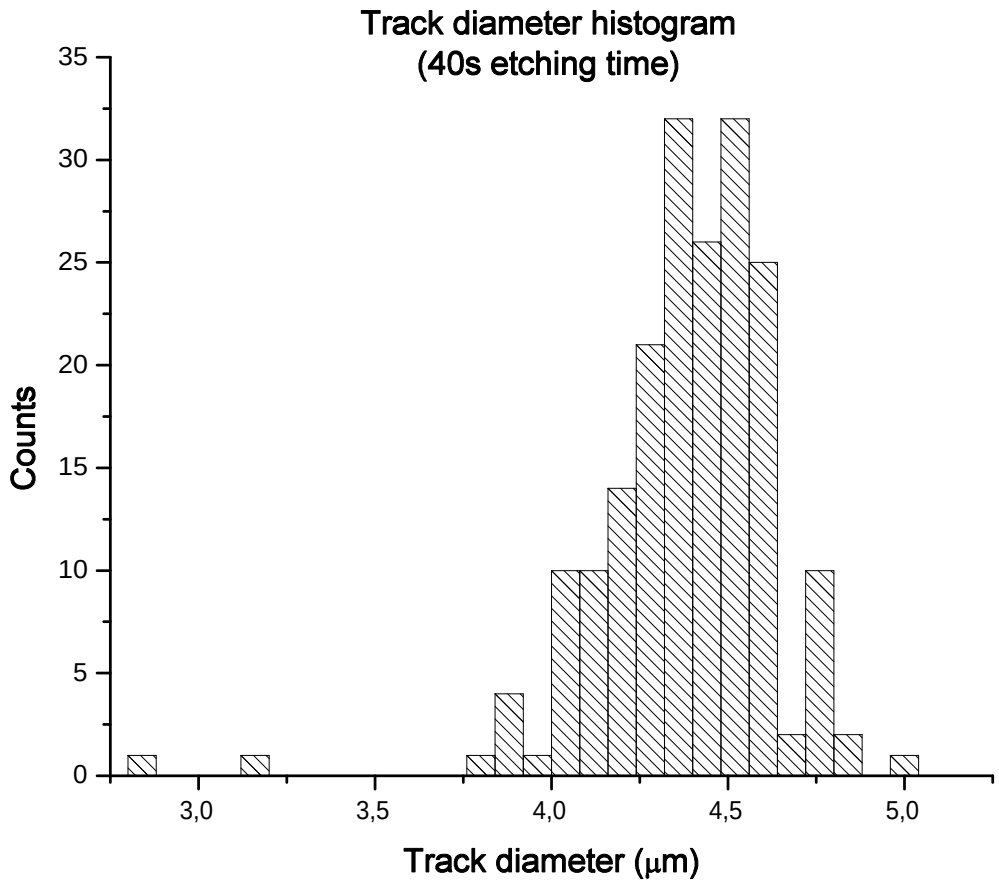
At vacuum (7×10^{-2} mbar) a thin carbon layer is deposited upon the glass sample to avoid charging.



10s 20s 30s

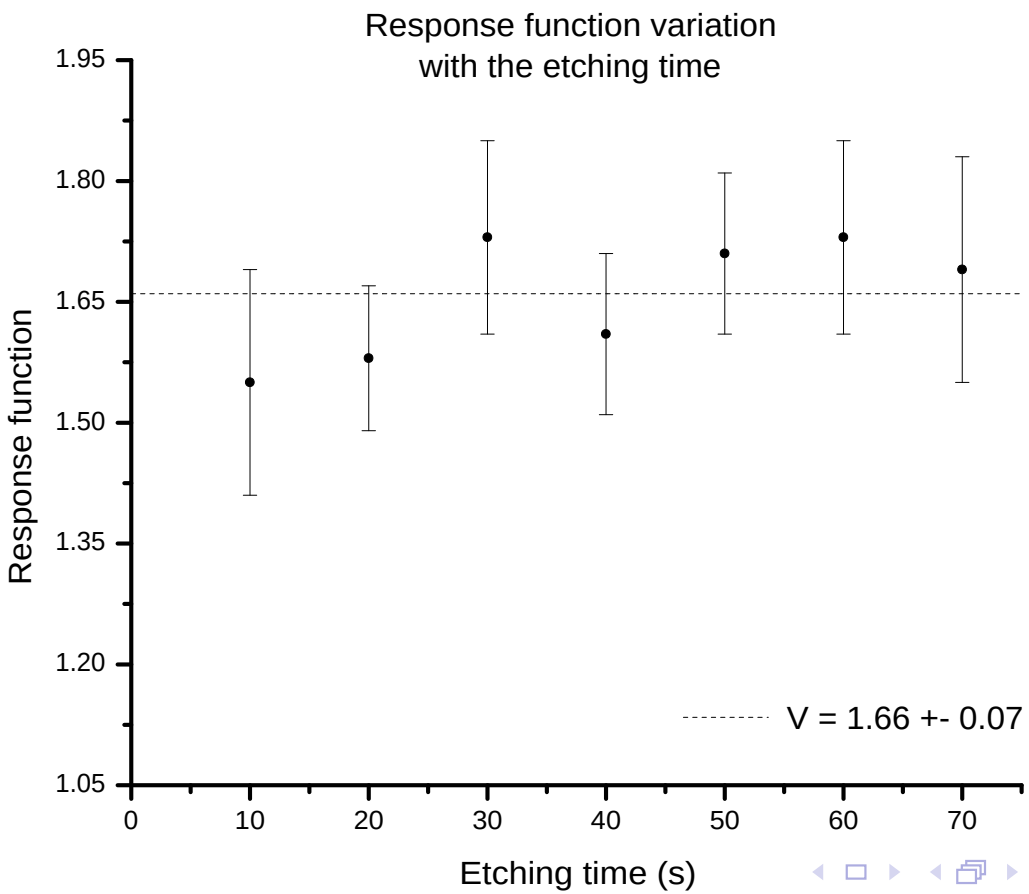
The white bar on the top of each image is the scale (20μm).

Although the incidence energy of light and heavy fragments is different this cannot be observed in track diameter distribution.



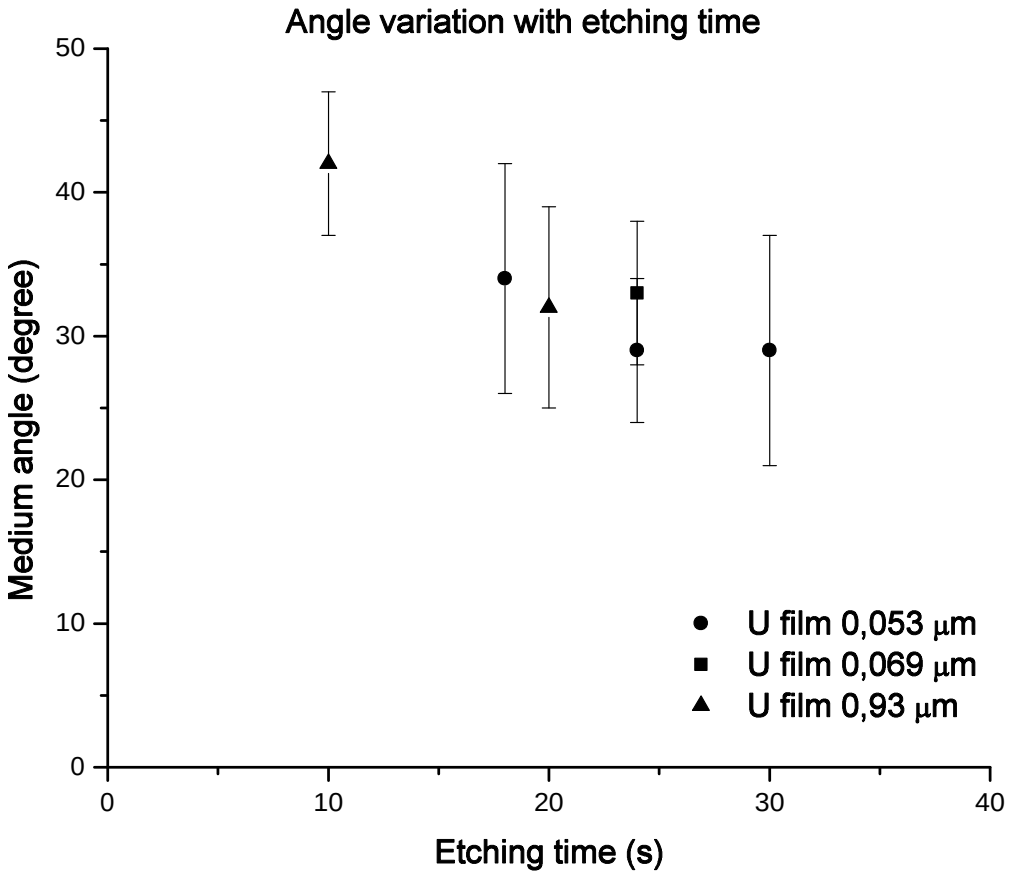
Track diameter was measured with the software *Image Tool*.

$$V = 1 + \frac{2d^2}{4\,(V_B\ t)^2 - d^2}$$

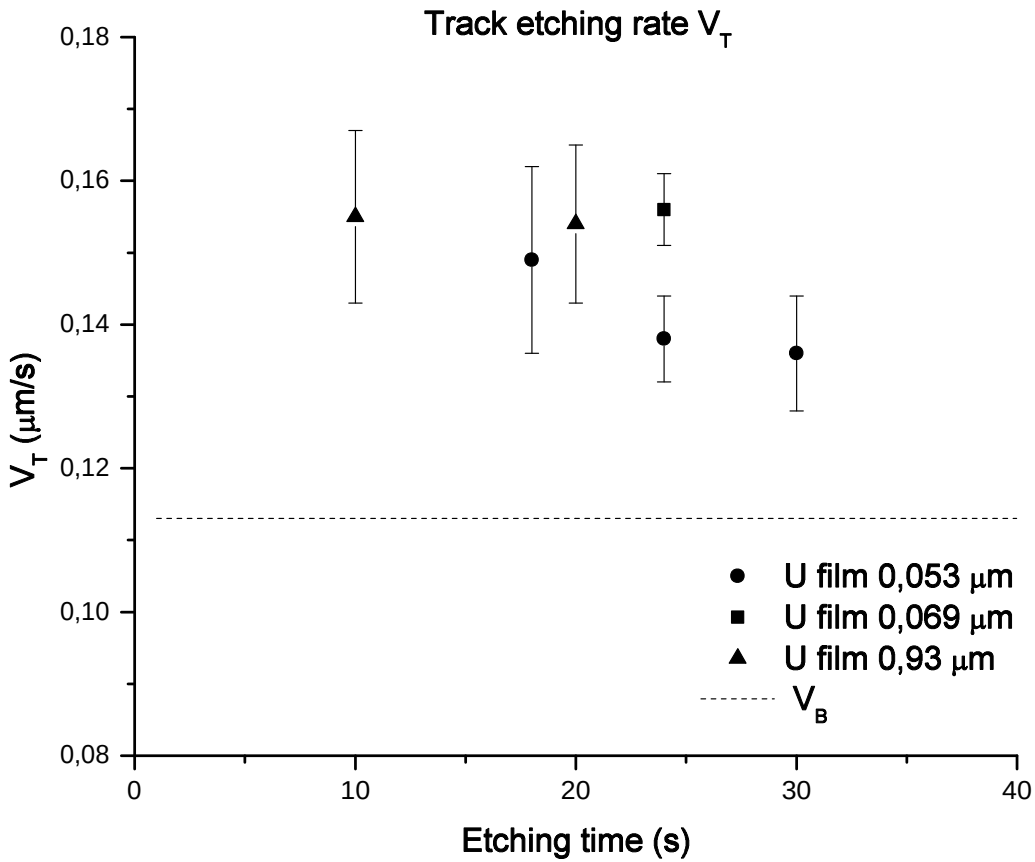


AFM measurements:

Track diameter and complementary of cone angle were measured in different etching times (non-contact mode).



Depths were calculated with track cone angles and diameters. Dividing these depths by the etching times track etching rates V_T were obtained.

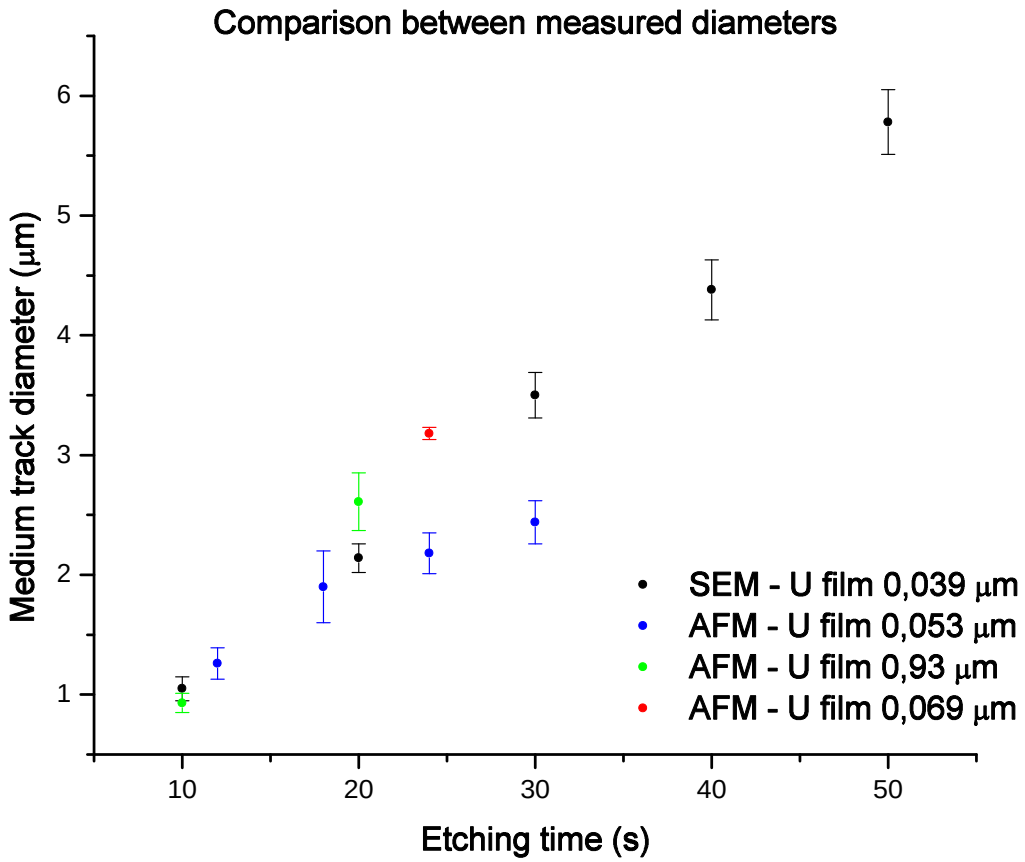


$V_T = (0.148 \pm 0.009)\mu\text{m/s} \quad \chi^2 = 4.9 \quad \nu = 5 \quad P(\chi^2) \approx 0.45$

Response function V calculation:

- By track diameter and geometric model: $V = 1.66 \pm 0.07$;
- By V_T rate calculated by depth: $V = 1.31 \pm 0.09$;

We believe that this difference is caused by limitations related to the AFM cantilever tip size [Nikezic et al. (2002) *Nucl. Instr. and Meth.* **B197**, 293].


Comparison between measured diameters
Medium track diameter (μm)
Etching time (s)
1
2
3
4
5
6
10
20
30
40
50
SEM - U film 0,039 μm
AFM - U film 0,053 μm
AFM - U film 0,93 μm
AFM - U film 0,069 μm

Conclusions:

- Track diameters measured with SEM and AFM techniques agree;
- Bulk and track etching rates measurements yield constant values.
  Thus, the effect produced by fission fragments traversing a soda-lime glass is the production of a homogeneus cylinder of damage.