LATENT TRACK STRUCTURE IN POLYMERS AS OBSERVED BY A HIGHLY SENSITIVE ELECTROLYTICAL CONDUCTIVITY MEASURMENT

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Abstract. First results of a new electrolytical conductivity cell are reported concerning the initial stage of the pore opening process during track etching in vitreous solids. On the basis of the soft mode (low energy excitation) model for track etching, see ref.[4], a distribution function for the number of performed micropores as function of time is calulated, by accounting for the radial etch rate as function of the effective pore radius.

1. INTRODUCTION

The interaction of heavy ions with solids (thin films) produces a narrow cylindrical core of primary damage. The actual nature of the damage and the mechanism of its formation is not fully understood. In some recent publications, see refs [1,2,3,4], a new model was introduced based on the assumption that the incident ion causes a disturbed structure adjacent around its trajectory characterized by vitreous properties, the model of low energy excitations. The new experimental set-up described here is sufficiently sensitive to allow to measure the initial stage of the radial etch process and to determine the systematics of the pore formation.

2. MODIFIED ACTUAL ADVANCED EXPERIMENTAL SET-UP

The substitution of the fixed reference resistance by a resistance decade and a lock-in amplifier is the most important change of the former set-up. The resistance decade, consisting of five resistances about 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, and 1 MΩ, enables to adapt to the time-dependent foil resistance over a wide range. For optimizing the sensitivity of the voltmeter, an amplifier with variable gain steps 1, 10, 100 and 1000 has been used. Furthermore, programmable devices such as a sine generator, a scanner, and a voltmeter, are installed in order to carry out various measuring methods. Fig. 1 represents the modified experimental set-up. Another significant difference to the measuring principle used until now, is the introduction of the direct voltage method. Since foil capacity influence can be eliminated by applying current, this method is useful especially in the range of very high foil resistance. During opening of the first pores, associated with a high foil resistance, electrolytical effects can be neglected, because during this phase, currents are too small to cause chemical electrode polarization. When the foil resistance reaches about some MΩ, the a.c. voltage method is started, otherwise would distort, the measurement.

Fig.3 represents the time function of the foil resistance obtained by the modified experimental set-up. Since the part of the curve close to the transition point from dc to ac measurement can be differentiated, the whole function R(t) can be used to calculate the time

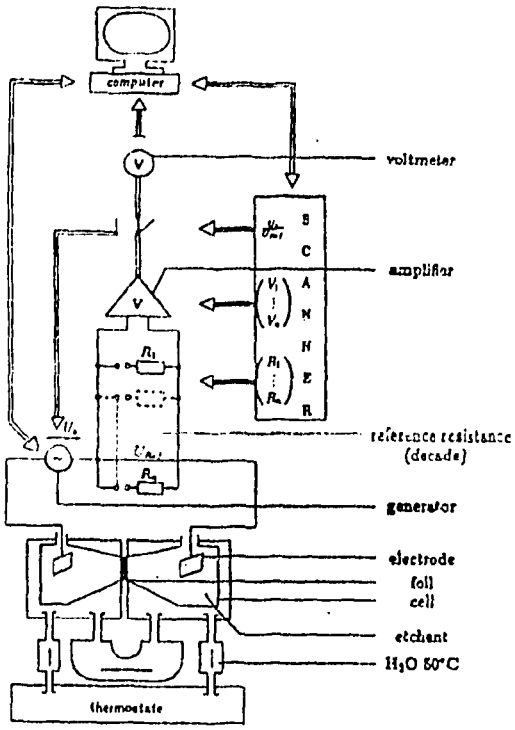

Fig. 1. Topical measuring system for investigations of smallest etching microporos

dependent pore radius and its time derivative. This is shown in Fig. 4. The differentiation of effective $\bar{r}(t)$ - curve [7], corresponds to the etchrate, as function of the effective radius, shown in Fig. 5. For calculating $\bar{r}(t)$, the number of the perforated pores N is assumed to be constant. Since during etch the pores do not break through simultaneously, and therefore a time dependent size N(t) has to be considered, for values $\bar{r} < r_L$ (see Fig. 5) the curves, shown in Fig. 4 and 5, are incorrect. By means of the model of low energy excitation [4,5,6,7] it is possible to derive the time distribution, of the number of the opening pores $N_{exp} = N(t)$. To calculate this distribution the following steps are necessary:

- Fit the model parameters with the experimental data in the interval [rv,rL] (see Fig.5);
- Extend calculateded curve to values smaller than rv;
- Calculate $\bar{r}(t)$ from theoretical etch rate $\bar{v}_R$. These values are defined as $\bar{r}_{lee}(t)$ (lee-low-energy excitations).

The corrected r(t)-curve turns asymptotical to a constant r-value of about 0.2 nm. In the case of a single pore, N=1 and $\bar{r} = r$, this value can be interpreted as the smallest measurable radius of the pore at the beginning of its opening process.

3. CONCLUSION

By means of the model of low-energy-excitations, the following interpretation of the functional dependence of the radial etching rate of heavy ion tracks in polymers on the pore radius can be given:

- in the range $0 \leq r \leq r_V (r_V \cong 5$ nm):

The structure of the matter has features of a vitreous solid, i.e. local polarized regions should exist depending on the radius of the pores. With increasing pore radius, the size of the polarized regions is growing too. The reason for this is shown in Fig. 5 representing the dependence of the radial etch rate as function of the pore radius. In comparison with the undisturbed structure the vitreous region has more

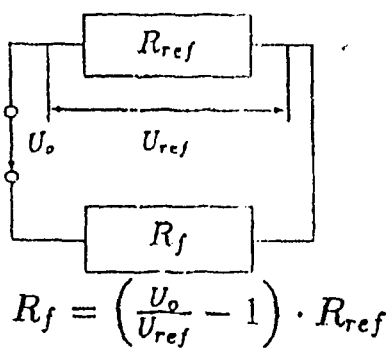

Fig. 2a. Equivalent circuit in the case of direct voltage measurement

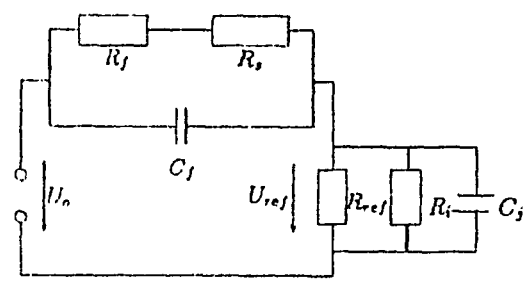

Fig. 2b. Equivalent circuit in the case of alternating voltage measurement

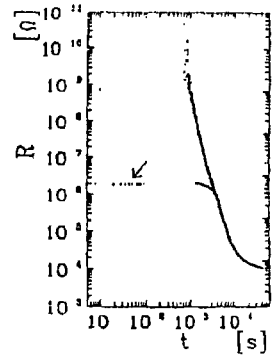

Fig. 3. Time dependence of the foil resistance. The arrow shows the bogin of the measurement with alternating voltage method

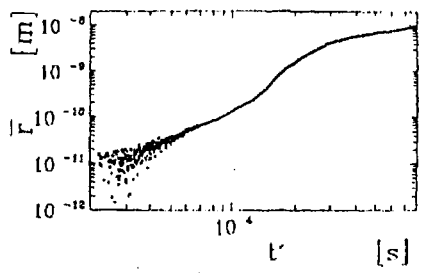

Fig. 4. The measurement effective radius in dependence on the time

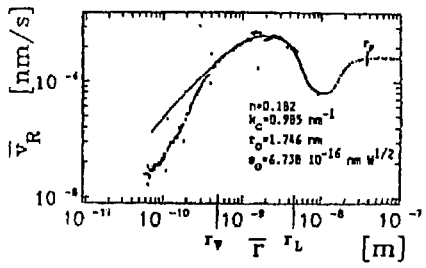

Fig. 5. The etching rate versus the effective radius of etched pores

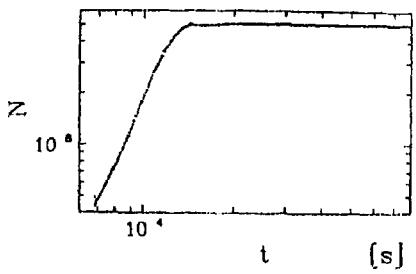

Fig. 6. The number of opened pores as function of time

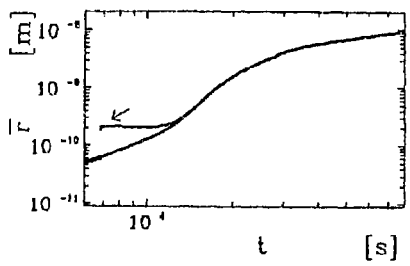

Fig. 7. The measured and corrected effective pore radius

local free charges, corresponding oto the locally polarized regions of, see ref. [5,6,7]. The peak in Fig. 5 can be explained by a high local density of free charges in this range, associated with a high radial etch rate.

- for the range $r_V \leq r \leq r_p$:

In comparison with the undisturbed material this region has a deficit of localized free charges. That is the reason of the minimum in Fig. 5 in our model.

- for the range $r > r_p$:

Transition to the undisturbed structure. By means of the model of low-energy excitations it is possible to determine the pore opening as function of time (see Fig.6). The measurements indicate that the pore opening during etching has a regular behaviour. Further justification of this behaviour will be the subject of future work.

Taking into account the time distribution N(t) of the pore opening process, the effective radius function $\bar{r}(t)$

can be corrected. The constant $\bar{r}$-value at the beginning of the pore opening process, shown in Fig.7, can be interpreted as a smallest measured effective radius of an already opened pore. This limit in value can be explained by the finite sizes of the electrolyte ions, passing through the micropores, which cause smallest measurable electro-chemical currents.

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