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THE INCREASE OF CARBONATE GROUPS IN POLYCARBONATE PLASTICS TO INCREASE RESOLUTION IN NUCLEAR TRACK DETECTION

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Abstract

With the aim of increasing the efficiency in resolution and sensibility for Cosmic Ray detection by SSNTD, we have developed several plastic polycarbonate polymers caracterized by a high density of carbonate groups in the polymeric chains. The validity of such a procedure is extensively discussed.

1. Introduction.In nuclear track studies, it has been shown that policarbonates are the most sensible materials for particle detection. In particular CR-39 (dietilen glicol bis allyl carbonate) is the nuclear track detector with the best sensibility and resolution . It has also been shown, that when CR-39 is doped with DOP (dioctyl phtalate), the plastic increase its resolution but decrease its sensibility (Tarlé,1981). If we compare Lexan, another policarbonate used as a nuclear track detector,we see that the difference between the two policarbonates, is that Lexan is a linear polymer considered as a termoplastic (so it can be melted in its molecular unit and then polimerized again) and CR-39 is a polymer with a three dimensional structure considered as a thermoset (so it can not be melted and polymerized again, instead it is degraded). This difference and the facts mention earlier together with the relative low resolution of Lexan compared to CR-39, lead us to the conclusion that the efficiency in sensibility and resolution of the plastic as a nuclear track detector is related to the physical structure of the plastic as well as to its chemical composition.

On a previous work (Pérez-Peraza et al., 1983,1984) which had the intention of evaluating the effect of temperature during energy deposition of particles going through the detector , we found some relationship between the sensibility and resolution of the detector with the macroscopic and microscopic elasticity properties of the detector material, namely Young's modulus (Y) and the interatomic elasticity constant (ks).From this work , we used several dopants in the polimerization process with the intention of inciding on these macroscopic and microscopic parameters by relating them with empirical or laboratory parameters able to be handled, as well as explaining some properties of nuclear track detectors that are not well understood as it is the increase in resolution of CR-39 when doped with DOP (Laville et al.,1985,1986).

From the works mentioned before, we found that sensibility and resolution depend mainly on the physical structure of the net as well as on its chemical composition. For instance, the difference between Lexan and CR-39, is that being Lexan a linear polymer its recombination probabilities, after its bonds are broken, are higher than those of CR-39, and the presence of an aromatic group makes the mean dissociation energy of its bonds to be high, which in turn makes it insensible to particles of lower energy than its mean dissociation energy. As another example considered the difference between CR-39 doped with DOP and CR-39 plain: in this case the doping causes that the elasticity constants decrease and the reticulation of the net becomes

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more "open", in the sense that the spacing between polymer chains is wider in all directions homogeneously. So, particles with different but close energies, will have close but distinguishable ranges, giving a plastic with more resolution however, because of the presence of the benzoic ring in the dopant, the mean dissociation energy increases and low energy particles which were still detected by CR-39 plain may not be detected any more.

Considering all these factors, we concluded from those works that we need a plastic with a stable three dimensional net that should have enough cohesion, to lower the probabilities of recombination in contrast with Lexan, as in CR-39,and at the same time should present an "open" net, as in CR-39 DOP, and have a lower mean dissociation energy, lower than CR-39, in order to obtain a plastic with more sensibility that CR-39 and more resolution than CR-39 DOP. The solution is to develop a polymer made out of a monomer with a high content of carbonate groups per monomeric unit, to give a lower mean dissociation energy, separated by a long chain of atoms within the same monomeric unit, to produce an "open" net, in such a way it polymerizes in a three dimensional net, to give stability and lower probabilities of recombination. With this goal we have developed several new carbonate esters, that are in the process of polymerization and calibration, for testing their efficiencies as nuclear track detectors.

2. Theoretical Approach. As a point of departure let us take the main thesis presented in (Laville et al., 1986). This states that the Young modulus may be increased or decreased by changing the separation between chains, which in turn has an effect on the "opening" of the net and consecuently on the resolution of the material. The interatomic elasticity constant can be changed by changing the mean dissociation energy of the net, which in turn makes more sensible the material in consideration. To understand this consider three different particles $Ei > Ej > Ek$. Suppose now, for instance CR-39 has a mean dissociation energy Eo and that its unitary cell is cubic and has a length Lo (fig 1a). Consider that particles Ei,Ej, $>$ Eo but Ek $<$ Eo and that $\Delta E = Ei-Ej < Eo$. So particles Ei,Ej, will go trough the material but cause almost the same damage, and because $\Delta E = Ei-Ej < Eo$ the difference in damage can not be descriminated so the particles are undistinguishable and we say that this plastic can not resolve particles Ei, Ej from each other. Particle Ek can not go through the material because Ek $<$ Eo and we say that this plastic is insensible to particle Ek. Now let us open the chains and make a softer net while at the same time we make the mean dissociation energy decrease so that $L1 < Lo$ and that $Eo > E1$, $E1 < \Delta E = Ei-Ej$ and $E1 < Ek$ (fig.1b). With this new material particles Ei, Ej can also go through but, because in this case $\Delta E = Ei-Ej > E1$ the new mean dissociation energy, the difference in damage from Ei to Ej is now distinguishable and we say that the material resolves particle Ei from particle Ej, and because $Ek > E1$ particle Ek can now go through the material and cause enough damage to be seen so, we say that now the material is sensible to particle Ek. Remember that when we refer to the mean dissociation energy, we are taking into account the dissapearance of tracks by etching effects.

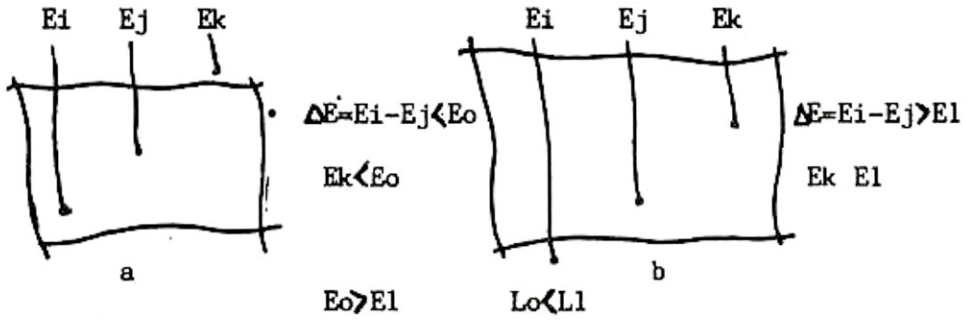

Fig. 1. Effect of the softening of the net and the decrease in the mean dissociation energy. (a) CR-39 normal net (b) Softer net with decreased dissociation energy

Going into practical purposes the theory described above can be implemented by considering that the increase in carbonate groups makes the material to have a lower mean dissociation energy, and that the separation of the active part of the molecule can produce the corresponding separation between chains and a softer net. If we make that the unitary molecule has a doble bond in both ends of the molecule as the active part, in this way we obtain a three dimensional net for stability and low recombination probabilities purposes. The logical idea is to part from monomeric esters that are similar to CR-39 and which fabrication process is similar to that of CR-39. Having synthetized in our laboratory dietilen glicol bis allyl carbonate (CR-39), we were able to synthetize five other carbonate esters for polimerization and calibration as nuclear track detectors. This esters are trietilen glicol bis allyl carbonate, etilen glicol bis allyl carbonate, diallyl carbonate, propilen glicol bis allyl carbonate and triallyl glicerol carbonate.

From the chemical structure (fig. 2) we can make some expectations according to the theory above, about the expected sensibility and resolution. The confrontation of our theory with the calibrated plastics will bring some ligth about the reality of our thesis, but in any event the behavior of this new plastics as nuclear track detectors will be established. Compare first on fig 2 the very similar trietilen glicol bis allyl carbonate (TGBAC) and etilen glicol bis allyl carbonate (EGBAC) with dietilen glicool bis ally carbonate (DGBAC). We see that the carbonate groups are the same but that the separation between the active parts of the monomeric unit is different and is shorter for EGBAC, followed by DGBAC, and the longer is the TGBAC. From this, we expect a softer net for TGBAC and a tighter net for EGBAC, so that TGBAC will have more resolution than DGBAC and EGBAC will have lower resolution than DGBAC. Because having the same number of carbonate groups, we expect almost the same mean dissociation energy and consequently the same sensibility. If we now compare this with propilen glicol bis allyl carbonate (PGBAC), we can see that the effect should be very likewise EGBAC. However, if we now put our attention to diallyl carbonate (DAC) and to triallyl glicerol carbonate (TAGC), we can see that DAC has only one carbonate group while TAGC has three, so that in the case of these two monomers we expect: a decrease in the mean dissociation energy on TAGC, giving us a more sensible material, and an increase in the case of DAC, giving us a less sensible material. We can also see that both would form a very compact net which would produce materials with worst resolution than DGBAC.

$CH_2=CH-CH_2-O-CO-O-CH-CH_2-O-CH_2-CH_2-O-CH_2-CH_2-O-CH_2-CH=CH_2$
TRIETILEN GLICOL BIS ALLYL CARBONATE

$CH_2=CH-CH_2-O-CO-O-CH_2-CH_2-O-CH_2-CH_2-O-CO-O-CH_2-CH=CH_2$
DIETILEN GLICOL BIS ALLYL CARBONATE

$CH_2=CH-CH_2-O-CO-O-CH_2-CH_2-O-CO-O-CH_2-CH=CH_2$
ETILEN GLICOL BIS ALLYL CARBONATE

$$CH_2=CH-CH_2-O-CO-O-CH_2-\underset{\displaystyle CH}{\underset{|}{CH}}-O-CO-O-CH_2-CH=CH_2$$
PROPILEN GLICOL BIS ALLYL CARBONATE

$CH_2=CH-CH_2-O-CO-O-CH_2-CH=CH_2$
DIALLYL CARBONATE

$$\begin{array}{l} CH_2-O-CO-O-CH_2-CH=CH_2 \\ | \\ CH-O-CO-O-CH_2-CH=CH_2 \\ | \\ CH_2-O-CO-O-CH_2-CH=CH_2 \end{array}$$
TRIALLYL GLICEROL CARBONATE

Fig.2. Chemical formulas of the monomeric esters synthetized

3. Conclusions. From the previous analysis we make some conclusive remarks:
-TGBAC, EGBAC, and PGBAC are monomers that would probably give better resolution than DGBAC but the same sensibility.
-DAC will decrease both resolution and sensibility.
-TAGC will increase sensibility but will decrease the resolution of the detector.
-From fig 2 it seems quite interesting to have a polimer that has the separation between active parts of the molecule as in TGBAC, together with a big number of carbonate groups (as has for example the TAGC). So, a combination of this two monomers (TGBAC and TAGC), will give rise to a copolymer with a high number of carbonate groups, which will lower the mean dissociation energy and consequently increase sensibility., and great separation between active parts of the molecule giving a softer net and a better resolution.

Results of calibrations and plastic efficiencies for nuclear track detection will be published elsewhere, once patents will be definitely granted.

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