Change in The Structure of Polyme Polyacetylene When Irradiated by Low-Energy X- Ray Taken by Tem

Hoang Van Ngoc
Institute of Applied Technology, Thu Dau Mot University, No 6, Tran Van On Street, Thu Dau Mot city, Binh Duong province, Vietnam
ngochv@tdmu.edu.vn

Abstract. Plastics or synthetic plastics are products that are not naturally available, but are made by humans. They have a long decomposition time, can last up to hundreds, thousands of years (plastic bottles, plastic straws and plastic bags take 10 years to 1000 years to decompose). Plastic waste is the plastic products after being used and are discharged into the environment such as plastic bags, plastic bottles, plastic straws, synthetic plastics. Here polymer being studied is polyacetylene, polyacetylene is a plastic film, polyacetylene is projected by low-energy x-rays with different projection doses, thereby analyzing the structural change of the polyacetylene. The changing structure leads to a change in polymer decomposition time, which can reduce environmental pollution.

1. Introduction
Plastic is commonly used in society today, but its drawback is the long decomposition time, therefore, causing many negative impacts on the environment (worsening urban landscape, clogging of sewers, etc). Currently, the problem of plastic waste treatment is very concerned around the world. The problem is finding a method that can change the structure of the plastic and change the decomposition time [1-4]. Plastic waste is rising to an alarming level, the harm that they cause to the environment is not small, specifically: Plastic waste is difficult to decompose in the natural environment. Each type of plastic has different years of decomposition with very long time, ten of years sometimes thousands of years [5-7].

Polyacetylene is a polymer with the formula (C\text{2}H\text{2})\text{n}. Polyacetylene consists of a long chain of carbon atoms with single and double bonds alternating between them, each of which has a hydrogen atom.

Worldwide, the study of the physical and chemical properties of polymers with irradiation effects began to be studied in the early 1960s. Many scientists have used interferometers and tools to study the effects of gamma irradiation on the optical properties of polymers [7-10]. Low-energy X-rays are a commonly used radiation in laboratories. The application of x-rays in irradiation to polyacetylene is a new problem. Due to the good absorption of low energy X-rays by polyacetylene, its structure will change and lead to a change in the decomposition time. Decomposition time is reduced to help plastic decompose faster in nature, which brings a great effect for environmental protection, partly solving the problem of plastic pollution.

2. Material and method
The sample used in the study is polyasetylene films in the laboratory, which is cut into rectangular sheets, each plate is 0.02mm thick, stacked 10 pieces on each irradiation (total thickness ~ 0.2 mm). Polyasetylene film samples are projected by the X-ray generator MBR-1618R-BE (Hitachi).
Figure 1. Polyacetylene structure

X-ray generator MBR-1618R-BE (Hitachi) is used in the fields of application of radiation beams related to materials research, food preservation, killing microorganisms, gene mutations. The generator operates in the voltage range of 35 - 160 kV, the current is about 1 - 30 mA [1-5].

Polyacetylene samples were irradiated with different dose doses. With different poly samples, we change the distance from the x-ray source to the sample, then change the projection time. The samples are stored away from direct sunlight, at room temperature. After the projection is completed, the polyme samples are broken down to the nanoscale and they are taken by the TEM machine to show any changes in the structure.

3. Results and discussion

When X-ray enters the material, the intensity of X-ray will be reduced: $I = I_0 \exp(-\mu x)$ with $I_0$ and $I$ are the intensity of the incident and emergent rays; $x$ is the thickness of the material, $\mu$ is the absorption coefficient. The graph of dependence of $I$ on the thickness of the polyacetylene sheet has been plotted with the following values: $I_0 = 2000$ cd [2]; $\mu = 3.10^6$ m$^{-1}$ [3];

Figure 2. The dependence of $I$ on the thickness of the polyacetylene sheet.

The graph shows the dependence of beam intensity on the thickness of the polyacetylene sheet. When the thickness of the polyacetylene sheet is bigger, the intensity of the emerging beam decreases but the level of reduction is very small compared to when we increase the thickness significantly. This demonstrates that the X-ray energy is less absorbed by polyacetylene, which is largely released. In order for polyacetylene to absorb a large amount of energy, we must increase the irradiation time. The polymer samples after being broken to the nanoscale will be taken by the TEM machine. We have 4 samples taken TEM in which one has not been irradiated and 3 samples have been irradiated. Through the results of TEM images we can see the structural change of polymers.
After irradiation of polyacetylenes, these samples are broken down to the nanoscale and taken by a TEM device at $\lambda = 100\text{nm}$ and $\lambda = 20\text{nm}$.

Looking at Figure 3 and Figure 4, we see that the structure of the polymer is relatively evenly distributed, the black spots show more distribution of monomers than the white spots.

Specifications for irradiating polyacetylenes with low energy X-ray machine are given in table-1.

| Sample | Irradiated height (nm) | Irradiated dose rate (Gy/mm Air) | Irradiated time (minute) | Total irradiated dose (Gy) |
|--------|------------------------|---------------------------------|--------------------------|---------------------------|
| 1      | 250                    | 72.31                           | 120.16                   | 10 000                    |
| 2      | 350                    | 45.26                           | 22.38                    | 1000                      |
| 3      | 400                    | 28.86                           | 14.25                    | 200                       |

After irradiation of polyacetylenes, these samples are broken down to the nanoscale and taken by a TEM machine. Pictures of samples after being taken by the TEM machine are shown in Figure- 5.
Figure 5. TEM image for sample 1 after irradiation

Figure 6. TEM image for sample 2 after irradiation

Figure 7. TEM image for sample 3 after irradiation

Figure- 6, Figure- 7. Looking at the two pictures in Figure 5, we can see that sample 1 after irradiation varies a lot from the original sample that was not irradiated. The polymer structures are clustered together, the original structures are changed, and on the sample appear more uneven, rough lines like peaks. In Figure 6, there are differences, the black areas are thick polymer bands, the brighter areas are thin polymer bands. It also proves that when irradiated the structure of the polymer changes, there are places where more molecules are concentrated, and places where there are fewer molecules. In Figure 7, similarly, the structure of the polymer changed quite a lot after being irradiated thin bands appear thick bands and peaks.
Figure 5, 6, 7 show that with different irradiation doses and different irradiation times we get different images but basically they change the structure when irradiated. TEM images also show that when the sample is irradiated at a distance nearer to the source of radiation, it will be more effective. Samples with a longer irradiation time also show an effect on the structural change of the polymer. So the irradiation time, the distance from the sample to the irradiation source and the radiation dose are the three basic factors that influence the change in the structure of the polymer.

4. Conclusions
In this paper, polyacetylene samples are irradiated by low-energy x-rays with different doses. The image obtained from the TEM shows that the structure of the polymer has changed. Comparing with unirradiated image we can see that the polymer samples when irradiated are completely different from the original sample. In the irradiated samples we see that there are places where more molecules are concentrated in the formation of black bands in the image, and there are places where very few molecules form lighter bands. Due to the change in the structure of the polymer samples after irradiation, the decomposition time of the samples also changes.

The decomposition time of polymers in nature is very long, so it is possible to use low energy x-ray irradiation methods on polymers to reduce decomposition time as well as reducing environmental pollution. Comparing with unirradiated image can see that the polymer samples when irradiated are completely different from the original sample.

The research results also show that polyacetylene also absorbs a small amount of X-ray energy, in order for the x-ray absorption process to be more effective, the irradiation time must be increased. The thickness of the polyacetylene sheet also has a small effect on the absorption of x-rays, so during experiments, the polyacetylene sheets were stacked to increase the irradiation efficiency.

References
[1] Charlesby A 1960 Atomic Radiation and Polymers International Series of Monographs on Radiation Effects in Materials 1 570
[2] Blackshaw G R J C, Gostling J A, Appleton B N, Pearce N, Thomas G V and Lewis W G 2003 Illumination of x-rays: the usual lights exposed Original article, Postgrad Med J 99
[3] Chuvyrov A N, Lepyanin G V, Kornilov V M, Lebedyev Y A, Mochalov A P and Ladenkova I M 1986 Crystalline polyacetylene: Structure, optical properties and photo-induced spin states Physics and Mathematics Department and Computer Center, USSR Academy of Sciences, Bashkir Branch, Sov Phys JETP 63(1) 160
[4] Chapiro A 1962 Radiation Chemistry of Polymeric System Interscience New York 385
[5] Bertolotti M, Ferrari A, Scudieri F and Serra A 1890 Differential interferometry of gamma-irradiated optical fibers, Appl. Opt. 19
[6] Hamza A A, Kabeel M A and El Said A M 1989 Colour changes in gamma-irradiated polymer fibres Radiat Phys Chem 34 797
[7] Fiki S A E and et al 1996 Investigation of the Effect of Gamma Rays on Optical Properties of Polymers Radiat. Phys. Chem 47(5) 761-764
[8] Waly S A, Shehata M M and Mahmoud H H 2018 Effect of Gamma Irradiation on the Physical and Chemical Properties of Copper-Poly Vinyl Pyrrolidone Composite Films. Arab Journal of Nuclear Sciences and Applications Arab J. Nucl. Sci 51(4) 187-196
[9] Williams M J 2011 Radiochromic film dosimetry and its applications in radiotherapy 4th SSD Summer School: Concepts and Trends in Medical Radiation Dosimetry 75-99
[10] Brunner A J 1972 X-Ray diffraction pattern of poly (Vinyl Chloride) Polymer Letters 10 379-383
[11] Brown K A, Holland M R, Boyd R A, Thresp S, Jones H and Ogilvie S M 2000 Economic Evaluation ofPVC Waste Management AEA Technology
[12] da Silva M A, Vieira M G A, Maçumoto A C G and Beppu M M 2011 Polyvinylchloride (PVC) and natural rubber films plasticized with a natural polymeric plasticizer obtained through polyestierification of rice fatty acid Polymer Testing 30 478-484