

What Can Cosmic Radiation Cause in Polymers?

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Abstract. In our research the influence of the cosmic radiation on different types of polymers was investigated. Main focus was on the mechanical properties, which includes elongation at break, tensile strength and impact strength. Polypropylene, polyamide 6.6 and polycarbonate were used as materials. All of the test pieces were injection molded with the same technological settings. These specimens were placed at ground laboratory and different flying height airplanes (on Earth, at 5500 m, at 12000 m). Mechanical properties were investigated. We found that cosmic radiation may induce change in some of the mechanical properties of polypropylene, polyamide 6.6 and polycarbonate.

1. Introduction

Both passenger and commercial airplanes are being bombarded by high-energy particles. These particles come from source called cosmic rays. Most of them interacts the Earth's magnetic field but a lot of them can penetrate it and reach the atmosphere. The radiation rate increases by higher altitudes. There were three types of widely used polymers in our focus. These polymers were polyamide 6.6, polycarbonate and polypropylene. The main question was how these polymers behave, how their chemical, physical and other properties change during the radiation, how the specific polymers mechanical properties will change after a relatively short exposure to this type of radiation [1-9]. Finally, these ongoing degradations how seriously affect their lifetime. Standard specimens were made by injection molding method, later they were placed on two types of planes. Then the returned specimens were investigated with different mechanical analytic techniques.

1.1. Cosmic radiation

There are various types of particles which can be found in cosmic radiations; mainly protons, accelerated atoms, electrons [10-16]. These particles come from deep space and from our Solar system. Cosmic radiation levels increase due to the low activity of the Sun. These particles firstly collide with Earth's magnetic field and if they have enough energy they can reach the atmosphere where they hit atoms or particles which results new but weaker particles.

There are three types of cosmic radiation: galactic cosmic rays (weakest), anomalous cosmic rays (weak) and particles from the Sun (strong).

Galactic cosmic rays are the weakest of all because of the distance between Earth and the source. Supernova events, eruptions, neutron stars black holes are the sources. They contain protons and alpha particles.

The other two types come from the Solar system. Anomalous cosmic rays are ionized particles which are accelerated by the solar wind meeting interstellar space associated with magnetic field. After



reaching the heliopause UV radiation ionizes these particles, the solar wind moves toward interstellar space colliding with the magnetic field where these particles can freely travel back into the solar system. The strongest radiation comes from the solar system's central star in forms of solar wind and solar eruptions. Radiation can be soft X-ray and hard X-ray. The solar wind contains mostly protons.

2. Experimental

Tensile test pieces were made by injection molding method with a Sumitomo DEMAG IntElect 100-500 injection molding machine using basic, additive-free polypropylene, polyamide 6.6 and polycarbonate. The technology settings were the same during the production, each polymer had its own technological settings, including temperature, pressure. Later these test samples were placed in a ground laboratory (above sea level ~110 meter) as reference and on two different flying altitude airplanes (5500 and 12000 meter).

The airplanes were an An-26 (a) and a Boeing 737 Cargo (b) which can be seen in figure 1. An-26 had an average flying altitude of 5500 meters. On this altitude the specimens were exposed for a total of 2.97 μSv radiation dose. The Boeing 737 had an average flying altitude of 12000 meters, the specimens were absorbed a higher dose of radiation of 51.8 μSv . Radiation doses were calculated after the flights with meteorological ballon data. The reference samples were in a special box, with the help of it the influence of the cosmic rays could be increase to ~ 0 μSv .

After the flying the samples were investigated. 10 samples were used for each test. Charpy impact strength was measured with a CEAST IMPACTOR II with a 5 J hammer. Elongation break and tensile strength were measured with an INSTRON 3366, 10 mm/min was used as preload speed, measurement speed was 200 mm/min. The tests were executed in room temperature.



Figure 1. Airplanes used during the experiment

3. Results and discussion

3.1. Results of polyamide 6.6

3.1.1. Charpy impact strength

Charpy impact strength test results are shown in figure 2. The test samples were shaped in the standard test specimen size for the testing. It's clearly visible that PA 6.6's impact strength had no significant change on the airplane samples. Compared to the ground referential samples both airplane samples impact strengths were greater by ~12%.

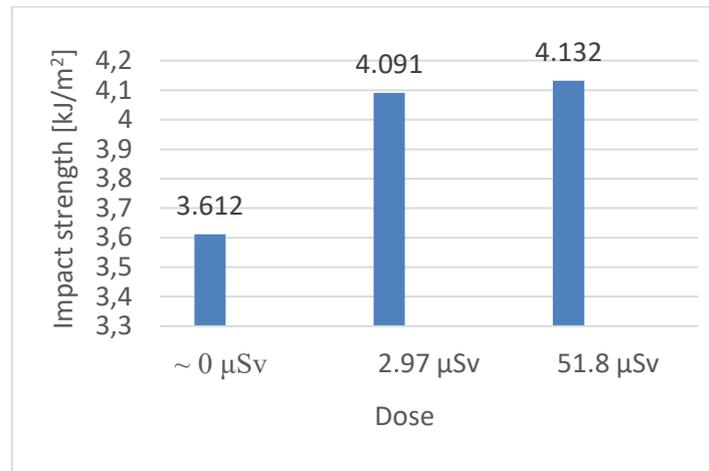


Figure 2. Charpy impact strength of polyamide 6.6

3.1.2. Tensile strength and elongation at break

Polyamide 6.6's tensile strength results can be seen in figure 3. Compared to the ground referential samples the 5500-meter flying altitude specimens had almost negligible difference. While the 12000-meter flying altitude samples had almost the same results as the ground samples, the 5500-meter samples had ~5% lower tensile strength compared to the two other samples.

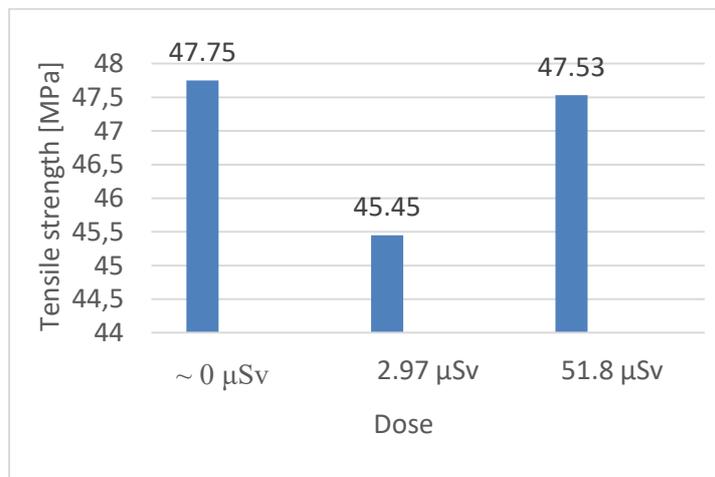


Figure 3. Tensile strength of polyamide 6.6

Elongation at break results can be seen in figure 4. It is shown that the elongation increasing depending on the altitudes. Both airplane samples' elongation break increased. 5500-meter specimens increased by 4.2%, while 12000-meter samples increased by 10.8% in elongation.

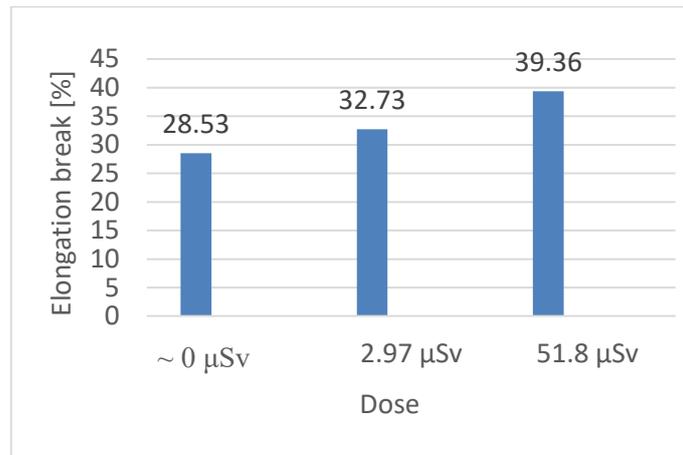


Figure 4. Elongation at break of polyamide 6.6

3.1.3. Brinell hardness

Brinell hardness is shown in figure 5. Both the ground and the 5500-meter specimens values stayed the same. The 12000-meter samples hardness value decreased by 2.5%.

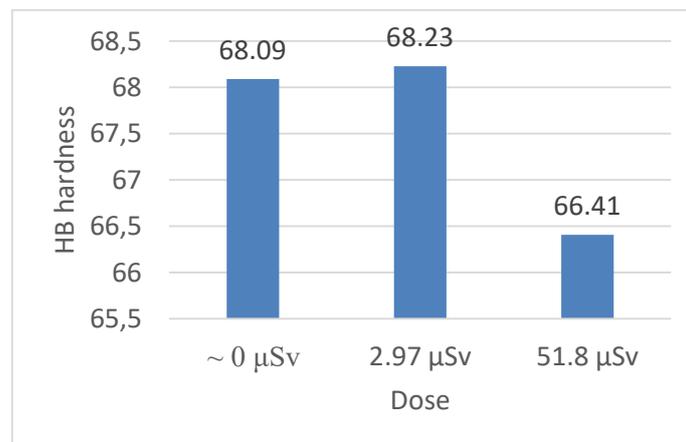


Figure 5. Brinell hardness of polyamide 6.6

3.2. Results of polycarbonate

3.2.1. Charpy impact strength

Polycarbonate impact strength results can be seen in figure 6. All the samples impact strength values stayed close to the ground referential specimens' values. While 5500-meter airplane samples had a slightly increase in the impact strength (~7%), the 12000-meter airplane specimens impact strength decreased (~3%) but not significantly.

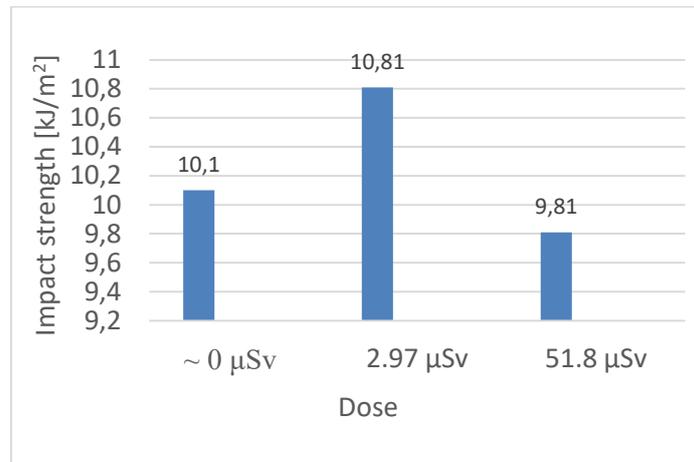


Figure 6. Impact strength of polycarbonate

3.2.2. Tensile strength and elongation at break

Tensile strength results can be seen in figure 7. Both airplane samples had an increase in tensile strength compared to the ground specimens. Both airplane samples had an increase in tensile strength by 7-9%.

Elongation at break results can be found in figure 8. In this case the results were interesting. It is known that cosmic radiation is more likely localized not effecting the whole system. This can be a sign to this effect, more high energy particles reached the 5500-meter airplane samples. Compared to the ground specimens, the 5500-meter airplane samples elongation break increased by 14.4%. The 12000-meter airplane samples increased only by 2.5% and remained the closest to the original referential values.

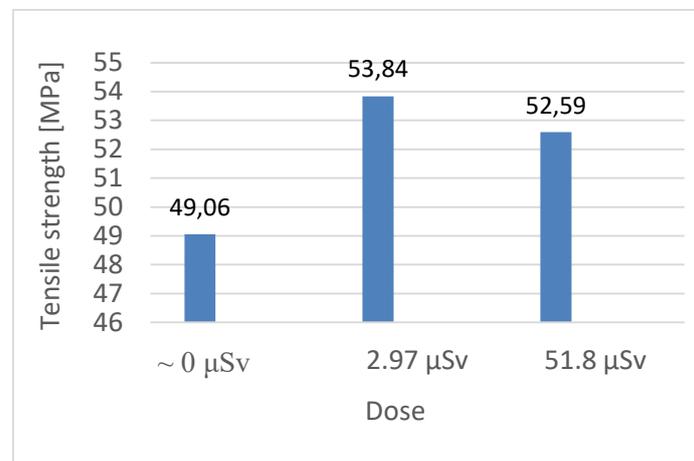


Figure 7. Tensile strength of polycarbonate

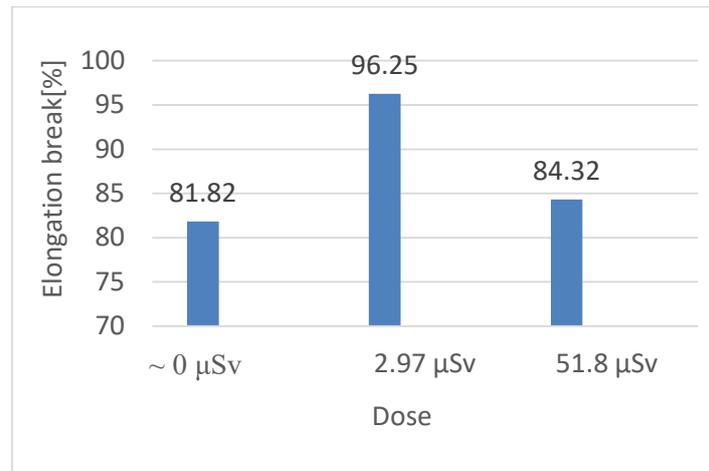


Figure 8. Elongation at break of polycarbonate

3.2.3. Brinell hardness

The results of Brinell hardness can be found in figure 9. These are very interesting data. Compared to the ground samples both airplane specimens' hardness increased. While the 5500-meter sample with „only” 3.1%, the 12000-meter sample increased by 10.6%. This can be the clearest indication of a degradation event which ended up in increased hardness.

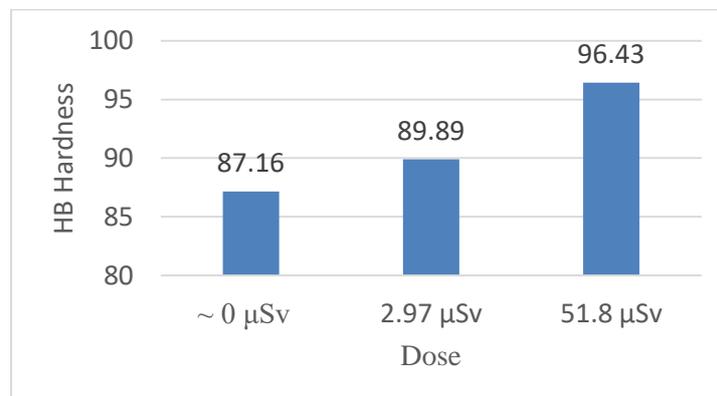


Figure 9. Brinell hardness of polycarbonate

3.3. Results of polypropylene

3.3.1. Charpy impact strength

Polypropylene had the least significant change in impact strength. There is only ~ 0.1 kJ/m² difference between the samples. While 12000-meter airplane samples kept the same values as the ground reference, 5500-meter airplane sample had 0.1 kJ/m² difference. Cosmic radiation had almost no effect on this property of polypropylene. The results can be seen in figure 10.

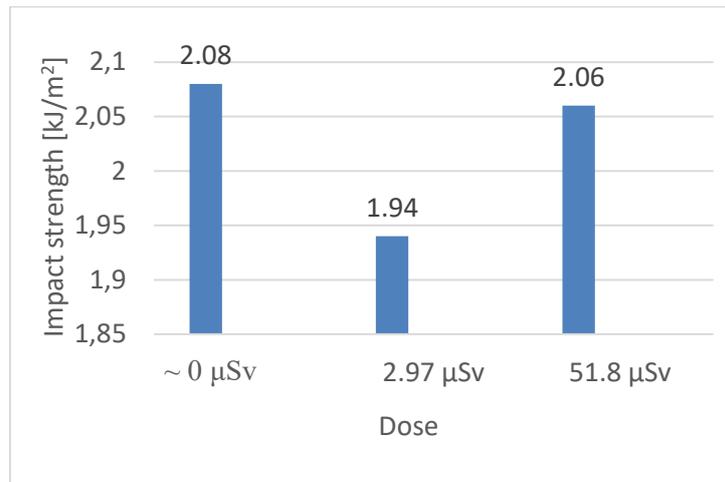


Figure 10. Impact strength of polypropylene

3.3.2. Tensile strength and elongation at break

While it has a really slow and steady decreasing tendency it can be the effect of the increasing radiation dose on the samples. Compared to the ground samples all of the airplane specimens' tensile strength decreased but with an almost negligible value. The highest decrease is only 1.2 %. Tensile strength results can be seen in figure 11.

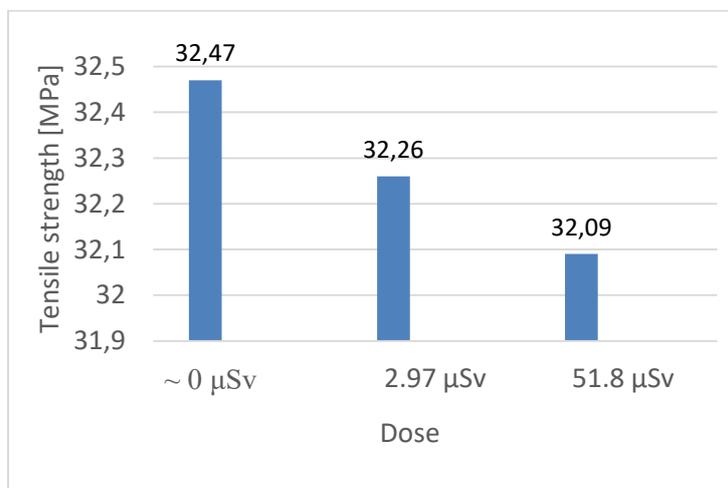


Figure 11. Tensile strength of polypropylene

Elongation at break had an interesting result (figure 12). The reason can be the same: the cosmic radiation localized degrading effect. The 5500-meter airplane samples' values had the same results as the ground reference, while the 12000-meter specimens had an increase but only about 0.2%.

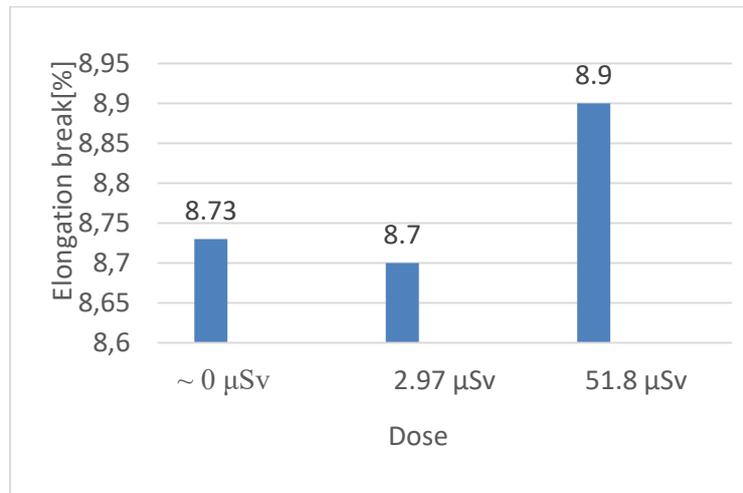


Figure 12. Elongation at break of polypropylene

3.3.3. Brinell hardness

There is not a big difference between the sample results, most of these remains in a limit; no significant changes can be seen. The 5500-meter sample's values had the lowest of all; compared to the ground it has 3.6% lower hardness.

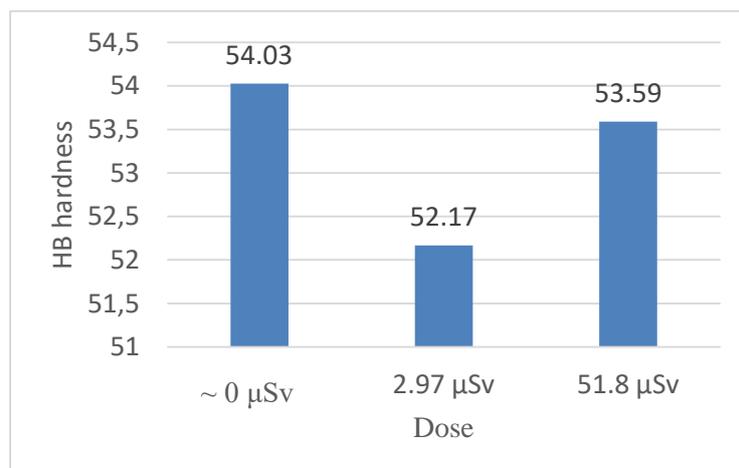


Figure 13. Brinell hardness of polypropylene

4. Summary

Polymers can exhibit various and large scale of radiation effects. Chemical reaction can occur during an irradiation. For example new chemical bonds can occur, some chains can break up, which leads to irreversible events. These events can be investigated by changes of appearance, chemical, physical, mechanical and thermal properties. Radiation induced degradation shows up in the form of elongation break increase and decrease, tensile strength, hardness changes. In this case, our aim was to find any possible mechanical alteration that could be induced by cosmic radiation. It is clear in the results that, a very low change was showed up. On the other hand, these properties shifts are visible, compared to the ground reference, because they were made by the same technological settings. The results show that this short period of flight time and a low radiation dose can be enough for induce a radiation degradation which shows up on the interestingly increasing hardness in polycarbonate. These materials are still useable and the radiation had no fatal effect on them but foreseeably these changes by the time can lead

to risk these materials and the products made from them. More experiments are needed with these and other types of materials. It is planned to use bigger surface, longer radiation doses and the ability to examine these materials on molecular level searching for visible radiation induced degradation.

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