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STUDY OF ELECTRON BEAM IRRADIATION EFFECTS ON MORPHOLOGIC PROPERTIES OF THE PET/PP/PE/EVA POLYMERIC BLEND

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ABSTRACT

Amidst the pollutants, plastics and especially the "PET bottles" packaging type, which comprise of poly(ethylene terephthalate) (PET), polypropylene (PP), polyethylene (PE) and poly[ethylene-co-(vinyl acetate)] (EVA) have been causing big damage to the environment. In this work, the polymeric blend PET/PP/PE/EVA was obtained by mechanical recycling "PET bottles" after consumption, with the objective of finding a solution for this environmental problem. It was also studied the different ionizing radiation dose effects (25, 50, 75, 100, 150, 200, 300, 400 and 500 kGy) on the blend properties using an electron beam accelerator. The morphologic properties of the non-irradiated and irradiated polymeric blend were evaluated by the Light Microscopy (LM) and Scanning Electron Microscopy (SEM). The analysis of the results appeared to be a not mixing and compatible blend. The use of the ionizing radiation improved the homogeneity of the blend. These modifications have been randomized and irregular, depending directly on the dose of applied radiation.

1. INTRODUCTION

The environmental pollution is one of the biggest problems nowadays. Amidst the pollutants, plastics and especially the "PET bottles" packaging type, which comprise of poly(ethylene terephthalate) (PET), polypropylene (PP), polyethylene (PE) and poly[ethylene-co-(vinyl acetate)] (EVA) have been causing big damage to the environment. In this work, the polymeric blend PET/PP/PE/EVA was obtained by mechanical recycling "PET bottles" after consumption, with the objective of finding a solution for this environmental problem [1].

The production of a polymeric blend was chosen obtaining it is an only polymer, all the necessary properties for the final application of the majority of the products so as by means of polymeric blends it is possible to improve the performance of the device and, in some cases, even though to reducing costs, allied to the fact that these materials being comprised of some plastics more consumed in the world [2].

The microscopic properties of the polymeric blend are determined by its morphology, deriving from the mechanical process mixing. It is directly influenced by the composition of each component and the conditions of the manufacturing process.

The morphologic properties of the non-irradiated and irradiated polymeric blend were evaluated by light microscopy and scanning electron microscopy. Moreover, in the last decades, the nuclear techniques have definitely developed, and it has allowed successfully, to expand to several segments of the economy, such as agriculture, health and industry, areas which affect directly the quality of life of our population. In the industrial sector (one of the greatest use of the nuclear techniques, responsible for 31% of the licenses for use of radioactive sources) the nuclear techniques are employed on the quality improvement of processes of the most diverse industrial sectors, as, for example, beverages, paper and cellulose, siderurgic, automobile, naval and aeronautic industry and the petroliferous sector, in which the main applications are in the measurement of thickness and flow speed, in the control of quality of junctions of metallic parts and also in the irradiation of polymeric materials. For example, electric wires and handles, aiming to improve the properties of the material: durability, resistance to the heat, impact, among others.

Industrial use of ionizing radiation has been well successful in applications related to polymeric materials. The advantages of irradiating polymers with high energy radiation has been documented for several researchers in the past [3,4,5,6].

The polymers, in general are categorized in groups according to their response to ionizing radiation. These effects are observed in irradiated polymers simultaneously with the predominance of one or the other depending on the chemical structure, irradiation atmosphere, presence or absence of some additives and dose rate [4].

High-energy radiation has unusual chemical effects on polymers in the solid state, inducing cross-linking, and chains scission by radical reaction [7]. Cross-linking has been widely used for improving physical properties of polymer materials. However, radiation-induced chain scission results in degradation of polymeric materials.

At present, the studies dealing with structural modifications induced in the PET/PP/PE/EVA blends by ionizing performed with doses in the range of 25 – 500 kGy were carried out by means of reflected light microscopy (LM) and scanning electron microscopy (SEM).

2. EXPERIMENTAL

The material used in this study was the beverage packaging "PET bottles" after consumption, deriving from selective collect, with the aid of the Space Life Cooperative in São Bernardo do Campo, São Paulo, Brazil.

The composition of the polymeric blend (PET(86.0%), PP(11.8%), PE(1.0%), EVA(1.2%)) was determined by the homogenization of each one of the constituent plastic materials of the packaging material "PET bottles", in different types of bottles used for soft drinks, juices, water, among others.

The methodology for confection of the polymeric blend by mechanical recycling followed the basic procedure of the production and manufactures of recycling for injection: collect system of the discarding, choice of the material (separation of the packing type "bottles PET"), milling, washing, drying and injection, being the steps of homogenizing and drawing

suppressed. The samples were injected in the Laboratory of the Müeller Plastic Industry, and molded at high temperature, following the ASTM standard.

After preparing the blends they were irradiated in Electron Industrial Accelerator of the CTR (IPEN/CNEN-SP), with 1.5 MeV of energy, 25 mA of current and 37.5 kW of power, Radiation Dynamics Incorporation model Dynamitron II. The applied radiation doses were 25, 50, 75, 100, 150, 200, 300, 400 and 500 kGy with a dose rate of 28 $kGys^{-1}$.

The evaluation of the homogeneity of the polymeric blends were carried out by light microscopy (LM) and scanning electron microscopy (SEM). The blends were fractured after cooling in liquid nitrogen. The fractures of the samples were analyzed by Optical Microscope Nikon model Eclipse MF – 600, connected to a Samsung SCC – 345 Digital Colour Camera. Reflected light method was used with magnifications of 5, 10 and 20x. SEM studies were carried out for the fractures coated with a fine gold layer applying a JEOL Scanning Electronic Microscope type JSM – 5300. The images were registered at voltage of 10 keV with magnifications of 200 and 2000x.

3. RESULTS AND DISCUSSION

In Figs. 1a (5 x), 1b (10 x) and 1c (20 x) are shown the light microscopy micrographs of non-irradiated and irradiated polymeric blends at different radiation doses (25-500kGy). Light microscopy enabled the study of the microstructure of the section and analysis of the steps, as well as macro-structure and meson-structure of the blend, thus allowing to identify production defects porosity, cracks, inclusions and morphology.

As for the micrographs which allowed a more comprehensive field of visualization throughout the samples, with a lower magnification, enabled to observe on macromolecular level, their morphology. Certain heterogeneity during the production of the blends was observed, which probably happened due to the kind of process used for recycling.

It was used a simplified mechanical recycling method, which consisted of a suppression of the steps of homogenizing and drawing material. Consequently, if these steps are performed a blend with a more homogeneous surface could be expected. It is also possible to observe indications of non-mixed materials during the constitution of the blend.

In Figs. 2a (200 x) and 2b (2000 x), micrographs for the non-irradiated and irradiated at different doses polymeric blends are shown.

The SEM morphological analysis of the surface of the samples supplied structural information of their topographical and chemical composition. Analyzing the micrographs

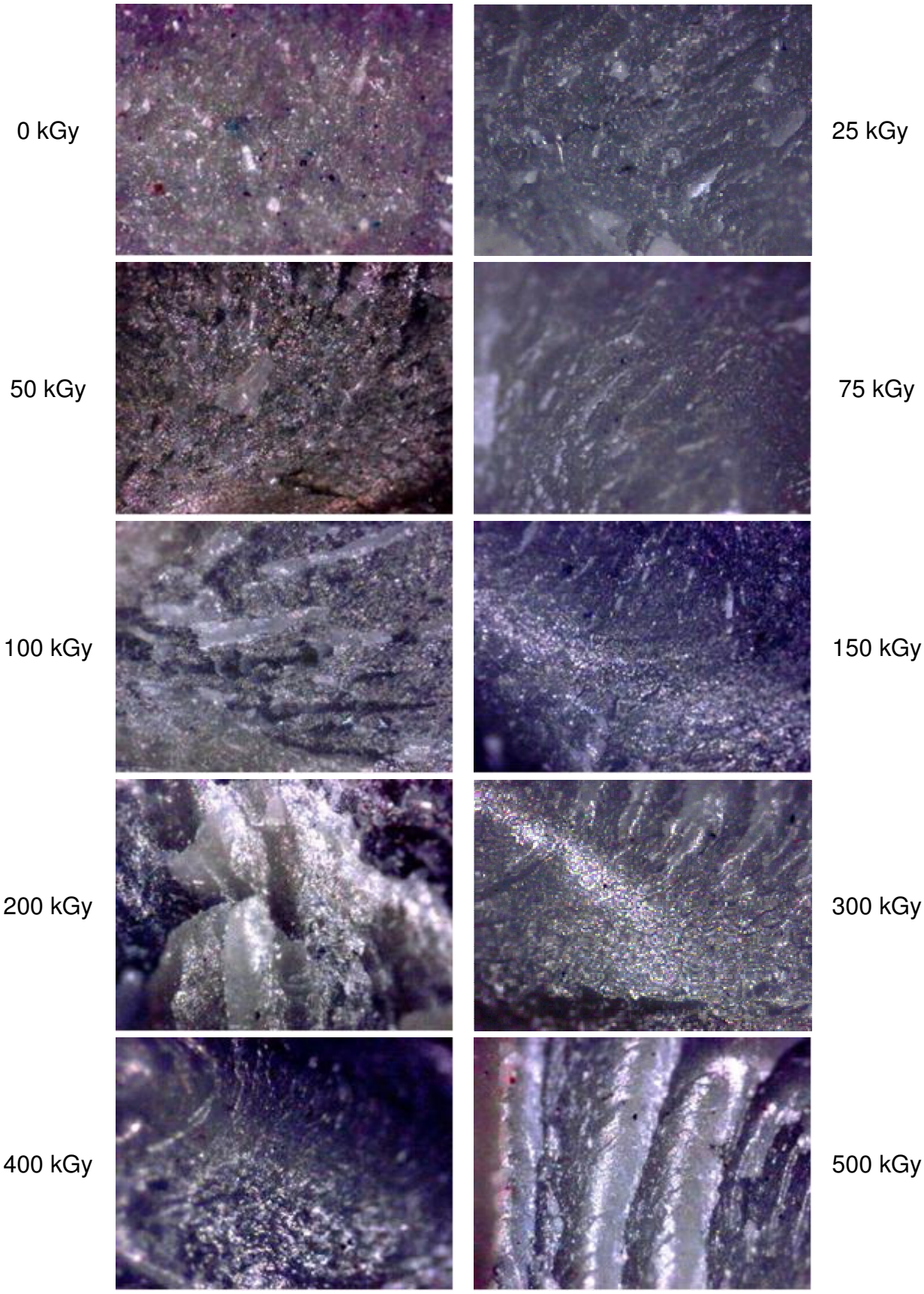

Fig. 1a. LM micrographs of the non-irradiated and irradiated polymeric blend on absorbed dose range was 25 to 500 kGy (5 x)

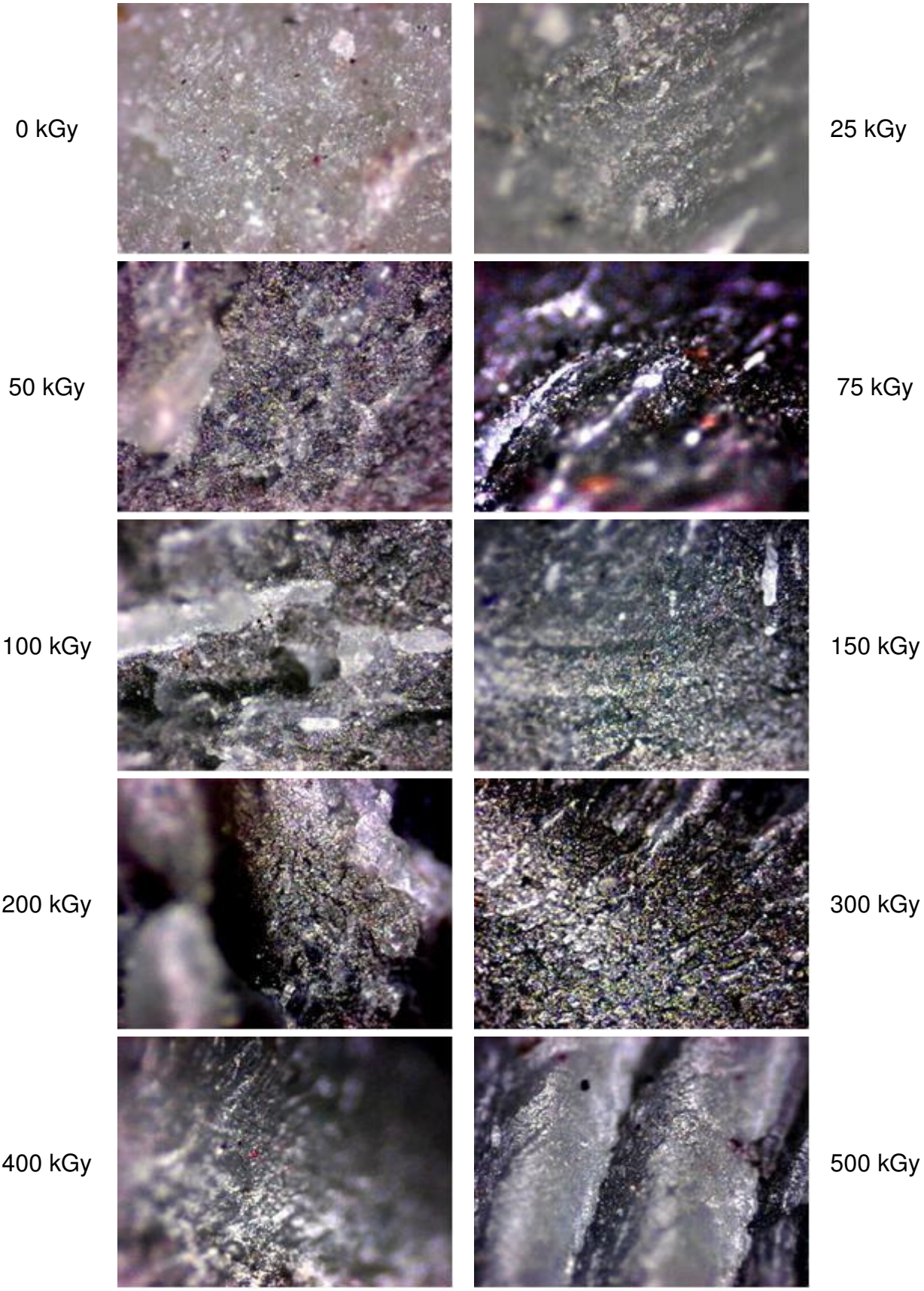

Fig. 1b. LM micrographs of the non-irradiated and irradiated polymeric blend on absorbed dose range was 25 to 500 kGy (10 x)

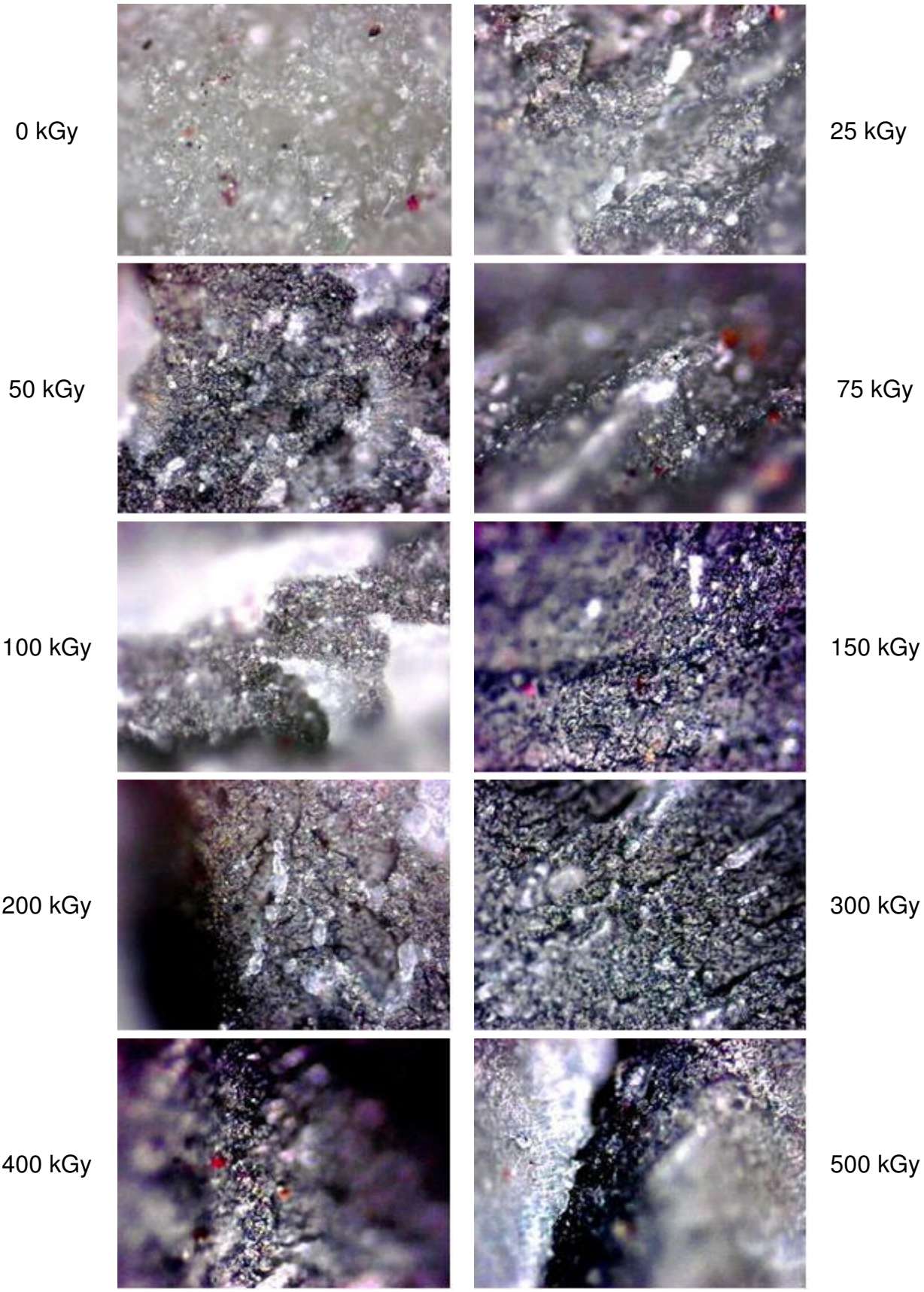

Fig. 1c. LM micrographs of the non-irradiated and irradiated polymeric blend on absorbed dose range was 25 to 500 kGy (20 x)

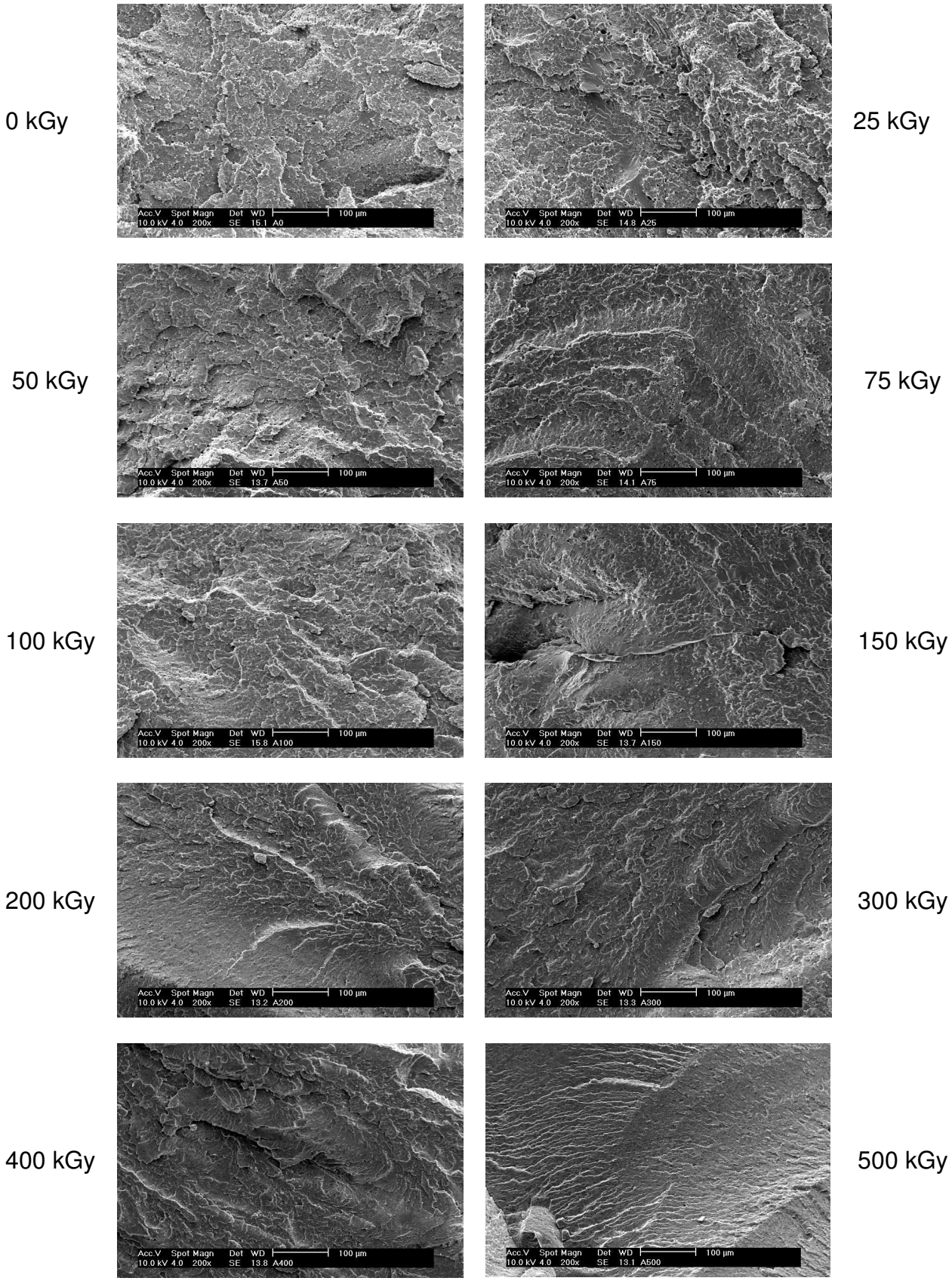

Fig. 2a. SEM micrographs of the non-irradiated and irradiated polymeric blend on absorbed dose range was 25 to 500 kGy (200 x)

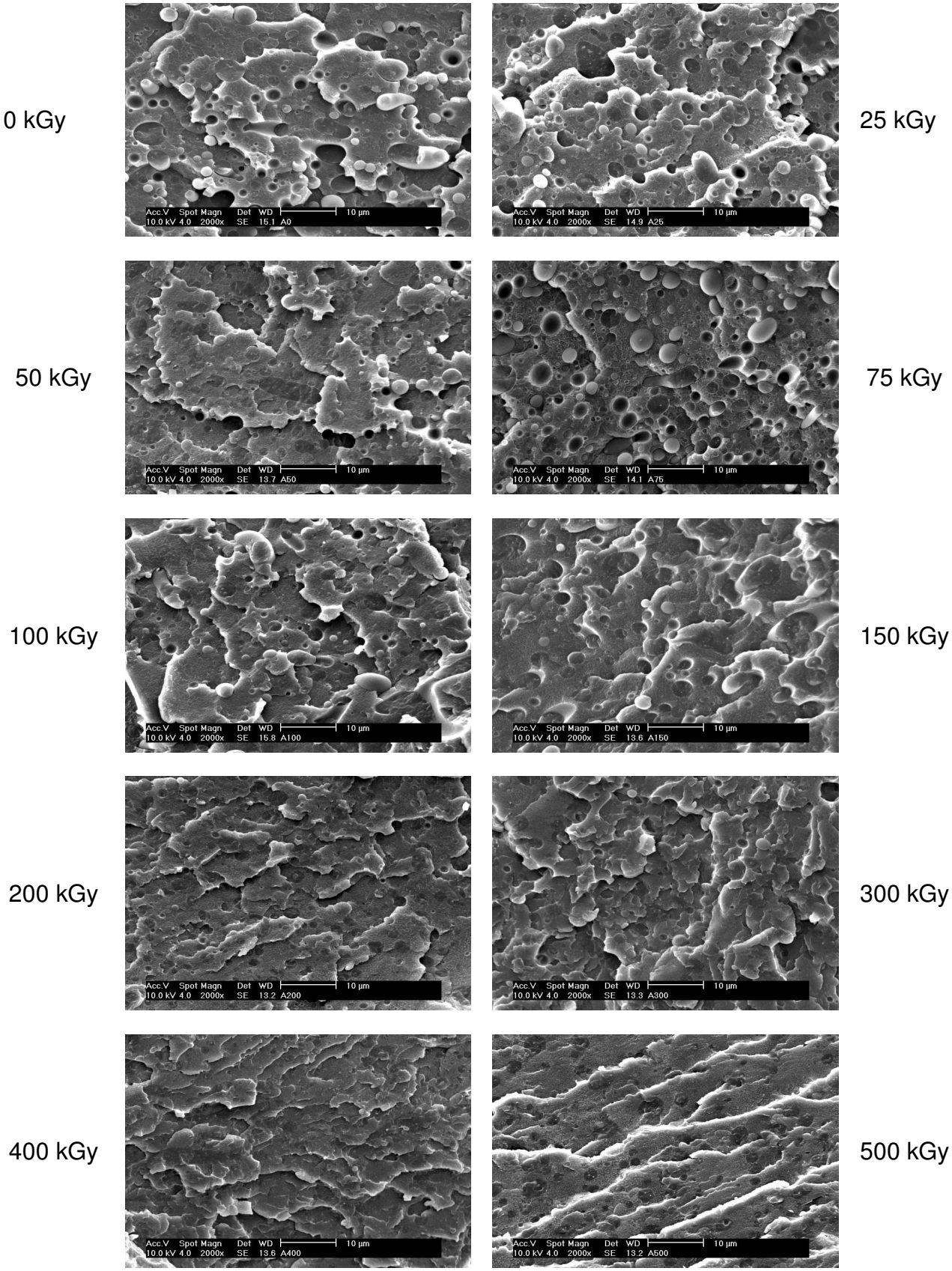

Fig. 2b. SEM micrographs of the non-irradiated and irradiated polymeric blend on absorbed dose range was 25 to 500 kGy (2000 x)

(200 and 2000 x) for the non-irradiated blend, a phase separation was observed, indicating poorly mixed polymers.

However, this high interfacial tension between the phases occurs as a consequence of their separation. One of the polymers, e.g., PET (material with polar characteristics that comprises 86% of the blend) forms the main phase, and the others, PP and PE (material with non-polar characteristics which comprises 11.8w% and 1w% of the blend, respectively) form the dispersed phase. As to EVA, while it plays a role as a copolymer that somehow presents either polar or non-polar characteristic, and stands for PET, during the first phase, as well as PP and PE during the dispersed phase, have similar action as a compatibility agent in the interface of the phases, becoming difficult its identification. It occurs because if it happens in any of the phases, a homogeneous phase can be formed.

It is equally important to point out that EVA is presented only in a small amount (1.2% in the mass), which might minimize its role as a compatibility agent for the constitution of the blend. Analyzing the micrographs (200 and 2000 x), for the non-irradiated and irradiated polymeric blends in different doses, it was observed that the blend presented morphological alterations due to the variation of the applied radiation doses.

As the measure increases, the radiation doses, especially the biggest ones, a non-characterization of the dispersed phase is observed, appearing empty spaces as well as the formation of cracks, especially for the 500 kGy dose. For doses of 400 and 500 kGy, the samples appeared to be fragile, becoming difficult to cut: as the cutting knife hit the sample surface, the sample broke into small pieces, highlighting the fact that the material suffered degradation, due to the effect of radiation.

3. CONCLUSIONS

Polymeric blend PET/PP/PE/EVA was obtained from the packaging materials “PET bottle” after consumption by the process of simplified mechanical recycling. Due to the suppression of homogenizing and drawing steps, it was possible to reduce the processing time and cost.

Microscopy studies showed that the materials used in the blend are non-mixing resulting in a blend in which the main phase consists of PET and the dispersed phase by PP and EVA. The ionizing radiation modified the compatibility of the materials and, consequently, the properties of the blend. Those modifications were random and irregular, becoming directly dependent on the dose of the applied radiation. Therefore, the ionizing radiation constitutes a viable alternative for the improvement of the morphological properties of this material.

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