Radiation Physics and Chemistry 84 (2013) 163–165

Contents lists available at SciVerse ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

The study of ionizing radiation effects on polypropylene and rice husk ash composite

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ARTICLE INFO

Article history:
Received 1 January 2011
Accepted 1 January 2012
Available online 4 July 2012

Keywords:
Polypropylene
Rice husk ash
Composite
Ionizing radiation

ABSTRACT

The aim of this work was to study the ionizing radiation effects on polypropylene/20% of rice husk ash composites. The composites were irradiated by electron beam at different doses and the mechanical and thermal properties were evaluated using tensile strength, Izod impact, hardness, softening temperature, differential scanning calorimetry (DSC) and thermogravimetry (TG). The results showed that the properties decreased by increasing irradiation dose due to chain scission.

1. Introduction

The combination of particles and fibers with polymer matrices has been used as a way of changing the mechanical, optical, and thermal properties, as well as reducing the cost of the polymer with both, fiberglass and carbon. The mineral fillers, such as precipitated calcium carbonate, talc, and glass bead, which change the resistance according to high or low temperatures, provide an excellent dimensional stability and absorbs less water, depending on the percentage used in the resin composition and have low prices (Saechtling, 1996).

The talc when added to thermoplastics improves the performance of the finished product (Saechtling, 1996). The polymer with talc has great applications in the automotive, mechanical and electronic industry.

Rice husk (RH) is a coating or protective layer formed during the growth of grains of rice. Removed during the refining of rice, these shells have low commercial value, because the SiO_2 and the fibers contained have no nutritional value and are not used in human food or animal ration. Rice husk combustion produces ash with variable structural forms (amorphous or crystalline) depending on the type of heating and burning time. The main properties of rice husk ash (RHA) are low thermal conductivity and high thermal shock resistance, and so it is a desirable component in the composition of ceramic products and impervious and insulating materials that will suffer the action of intense heat and sudden temperature variation.

The RHA has also other applications that have been investigated: in construction (Bui et al., 2005), industry rubber (Salmah and Ismail, 2008; Ismail et al., 2008), ceramic (Bondioli et al., 2007) and polymers (Frouchi and Dabdin, 2007; Yang and Kim, 2007; Bera and Kale, 2008; Ferro et al., 2007).

The interaction of ionizing radiation with matter promotes physical, chemical and physico-chemical events. When the polymer is subjected to ionizing radiation, it undergoes several changes in its physical and chemical structures induced by radiation, leading to crosslinking and scission of molecules phenomena that occur simultaneously, and one of them prevails over the other depending on various factors, such as, material type, irradiation dose and irradiation atmosphere, among others (Charlesby, 1960; Clegg and Collyer, 1991; Goulas et al., 2003). Radiation can produce organic compounds, cations, anions, radicals and excited species that may be trapped for some time in the polymer matrix causing effects after irradiation (O'Donnell and Sangster, 1970).

The aim of this work was to study the ionizing radiation effects on polypropylene/20% of rice husk ash composites.

2. Experimental

The process of obtaining RHA was carried out in two steps. In the first stage, the husk was heated in an oven between 300 and 350 °C for 40 min for the complete volatilization of water and hydrocarbons. Then, the temperature was increased to 600 °C for 1 h to complete combustion, resulting in RHA. After thermal treatment, aiming to reduce the organic matter, the ash was ground to reduce particle size and increase its surface area.

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0969-806X/$ - see front matter
http://dx.doi.org/10.1016/j.radphyschem.2012.06.025

In this work, polypropylene with 20% of RHA for sample preparation was used. Aiming to promote a homogenization of the composite, extruder HASCO brand, model HAAKE RHEOMEX 252 was used. Its capacity was attached to the rheometer, with a maximum working temperature of 300 °C, spindle speed of about 180 rpm and pressures and internal beak fixed.

Once ready, the composite passed through a simple cutter blade, such as a knife, and then turned into pellets. Afterwards, samples of pure polypropylene and polypropylene with RHA were injected. An injector ROMI PRIMAX 65R with characteristics related to temperature zones: zone 1—210 °C, zone 2—190 °C, zone 3—180 °C and finally, zone 4—170 °C, next to the power channel, total dosage of about 21 cm^3, injection pressure equal to 800 bar and flow rate of 70 cm^3/s was used. Subsequently, the samples were irradiated in an electron accelerator at the Center for Radiation Technology (CTR) of the Institute for Energy and Nuclear Research (IPEN-CNEN/SP) with different irradiation doses to study the effects of ionizing radiation in those composites. An electron accelerator type Dynamitron Radiation Dynamics, model DC 1500-JOB 188, with a maximum energy of 1.5 MeV, beam current ranging from 0.3 mA to 25 mA and 37.5 kW power with a dose rate of 11.22 kGy/s was used. The dose was calculated using a cellulose triacetate (CTA) dosimeter calibrated on the same machine conditions (current, energy and number of passes under the electron beam) according to the thickness and density of the material used for irradiation. The samples were placed on trays, made of aluminum and coated wood to minimize the effect of backscattering of electrons. The irradiation doses applied in the samples were 0, 50, 100, 200, 300 and 500 kGy, and the radiation processing was carried out at room temperature in the presence of air. After irradiations, the samples were characterized.

The thermal properties analyzed were

- Vicat softening temperature according to ASTM D-1525;
- Differential Scanning Calorimetry (DSC);
- Thermogravimetry (TG).

The mechanical properties analyzed were

- Shore D hardness according to ASTM D-2240;
- Hardness according to ASTM D-2240;
- Tensile strength according to ASTM D-638.

3. Results and discussion

Vicat softening temperature results for pure PP and PP+RHA irradiated with different irradiation doses are shown in Fig. 1.

As the irradiation dose increased, the Vicat softening temperatures for the composites of PP+RHA decreased. The same behavior occurred with the pure PP indicating that the RHA has not contributed to this decrease, since the proportion of PP is greater than RHA prevailing thermal properties of polymer matrix.

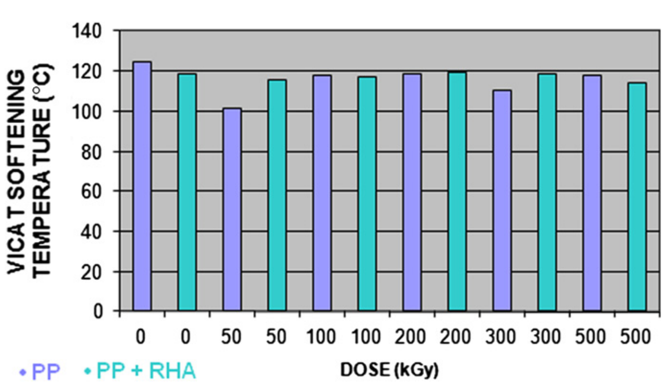

Fig. 1. Vicat softening temperature results for pure PP and PP+RHA irradiated with different irradiation doses.

DSC analysis results for pure PP and PP+RHA irradiated with different irradiation doses are shown in Table 1.

According to the differential scanning calorimetry (DSC) analysis, the onset melting temperature of both samples of pure PP, and PP+RHA decreased as the dose of irradiation increased, due to the mechanism of division of the polymer chains, which induced the reduction of polymer molecular weight.

Melting enthalpy value for 100% crystalline PP is 209 J g^{-1}. According to the data presented in Table 1, a decrease in the degree of crystallinity of PP with increasing irradiation dose may be indicated.

TG results for the samples of irradiated and non-irradiated pure PP and PP with rice husk ash are shown in Table 2.

Thermogravimetry (TG) results are coherent because in the case of pure PP, samples lost nearly 100% of their mass, and the composites of PP with RHA lost almost that part of the polymer that is 80%, leaving about 20% of mass corresponding to RHA.

Fig. 2 shows the results of Shore D hardness of samples of PP and PP+RHA submitted to different irradiation doses.

The graph in Fig. 2 shows no significant variation in the values of hardness in the samples studied, when the irradiation dose increased. Comparing the results of hardness between the samples of pure PP with PP+RHA, it can be observed that the hardness of the composites increased due to the presence of RHA.

Fig. 3 shows the results of Izod impact tests for pure PP and PP+RHA at different irradiation doses.

When the irradiated dose increased, it was observed that there was a decrease in Izod impact indicating that the absorbed energy decreased. In this case, there was a reduction of the toughness of the material. The tenacity is probably associated with split chains because with shorter chains, the molecular rearrangement process is not able to absorb the applied load. When comparing the results of samples of non-irradiated pure PP with PP+RHA, it was observed that there was an increase in the values of the impact due to the presence of RHA in the composites.

Fig. 4 presents the results of tensile strength tests for pure PP and PP+RHA at different irradiation doses.

Table 1
DSC analysis results for pure PP and PP with rice husk ash (RHA) irradiated with different irradiation doses.

Dose (kGy)	T_{onset} (°C) PP	T_{onset} (°C) PP+RHA	Enthalpy (ΔH) (cal/g) PP	Enthalpy (ΔH) (cal/g) PP+RHA
0	152.7	165.3	−27.5	−22.2
50	148.5	148.5	−23.5	−24.0
100	144.0	141.0	−26.0	−21.0
200	140.0	139.2	−15.0	−18.0
300	133.4	137.0	−19.0	−13.1
500	125.2	127.6	−13.0	−10.2

Table 2
TG results for pure PP and PP with rice husk ash (RHA) irradiated with different irradiation doses.

Dose (kGy)	T_{onset} (°C) PP	T_{onset} (°C) PP+RHA	Weight loss (%) PP	Weight loss (%) PP+RHA
0	322.1	359.9	97.3	80.9
50	319.1	319.7	97.4	82.6
100	310.5	309.5	97.7	81.1
200	287.5	307.1	89.7	81.4
300	250.5	300.7	97.2	72.4
500	274.2	314.3	94.7	76.4

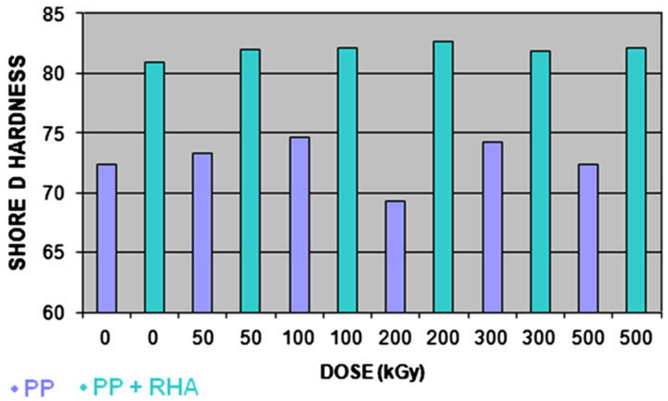

Fig. 2. Shore D hardness results for pure PP and PP+RHA irradiated with different irradiation doses.

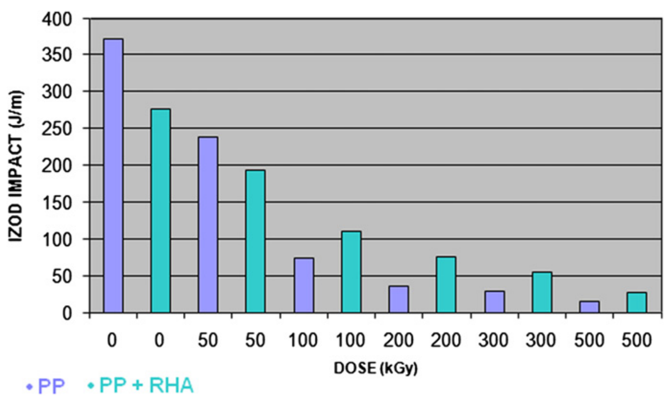

Fig. 3. Izod impact Test results PP and PP+RHA irradiated with different irradiation doses.

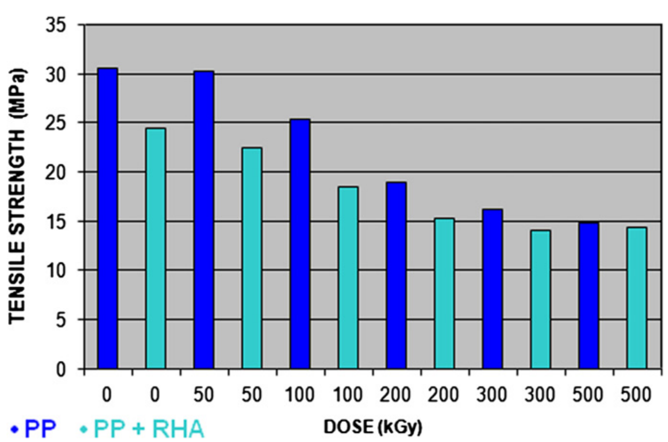

Fig. 4. Tensile strength tests results for pure PP and PP+RHA irradiated with different irradiation doses.

According to the results presented in Fig. 4, it was observed that the tensile strength of samples of PP and PP+RHA decreased. This behavior is consistent with what was observed in the impact tests that revealed a decrease with increasing irradiation dose. These two properties are indicators of the plasticity of the material, and showed that the PP has a tendency for the occurrence of fracture with increasing irradiation dose.

4. Conclusions

Based on the first stage of this work, it can be concluded that the properties of PP compound with a charge of 20% rice husk ash produce results inferior to those obtained when using 20% of talc filler. The RHA can be used as filler for other uses less noble than PP. Also, it is giving a destination for the waste that is now discarded in the environment, contributing to its preservation, and reducing the product cost.

According to the results obtained when samples of pure PP and PP+RHA were irradiated, it can be said that PP is a semi-crystalline polymer, and therefore, its morphology is changed when exposed to the radiation processing. This fact is attributed to the mechanisms of degradation and scission of polymer chains, a fact that it is consistent with literature.

Acknowledgments

The authors are grateful to IPEN-CNEN/SP and CNPq for the financial support and also to Elisabeth Somessari and Carlos Gaia for samples' irradiation.

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