Investigation on dielectric properties of polypropylene/waste low density polyethylene blends

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Polypropylene (PP) and waste recycled low density polyethylene (LDPE) blends were prepared by melt blending technique. Dielectric properties such as dielectric constant ε' and dissipation factor (tan δ) were measured in the frequency range 4-100 kHz, at different temperature ranging from ambient to 160°C. Effect of LDPE incorporation on dielectric constant and dissipation factor of PP has been observed and discussed. It has been found that the blend had three types of relaxations, namely β', α, and α'. These three relaxations have been analyzed. Activation energies determined from the β', α and α', tan δ-peaks for PP-LDPE blend were 55.2, 70.8 and 87.0 kcal/mole.

1 Introduction
Polyethylene has been widely studied for its relaxation process amongst the amorphous thermoplastics. There have been a number of dielectric studies carried out on polyethylene and on pure polypropylene. Polyethylene shows at least three dielectric relaxations α, β, and γ, in order of descending temperature. α-relaxation is associated with main chain of polymer. β-region is dominant in branched polyethylene but much weaker in linear polyethylene.

Polyolefin blends have become important due to the possibility of improving the performance of materials at lower cost as well as their recycleability. Dielectric relaxation in polypropylene-polyurethane blend have been investigated by Banheygi and Karasz. They explained the results based on the phase structure of these systems and interaction between the blend constituents. Several studies are concentrated on the polypropylene morphology change due to the presence of second phase in the blend. Recently polypropylene waste low density polyethylene blend, have been developed by us for using the waste recycled polyethylene. Rheological behavior of this blend is reported in a previous paper. Determination of dielectric properties of this new blend can help in deciding its application in insulation.

In this present study, dielectric relaxation in a new type of PP/waste LDPE blend have been determined and discussed.

2 Materials and Methods
Materials — The commercial grade isotactic polypropylene (PP) was supplied by M/s Shri Ramdev Plastics, India. Recycled semi-crystalline low density polyethylene (LDPE) of density 0.92 g/cm³ of commercial grade was obtained from M/s Monica Plastics, Indore, India.

2.1 Blends preparation
Mixing of polypropylene and low density polyethylene — 80 wt % of PP and 20 wt % of waste recycled low density polyethylene were dried in the air circulating oven. These materials were mixed at 280°C on a single screw extruder for 10 min. The rotation speed of screw was 20 rpm. Method of mixing is reported elsewhere.

Compression molding — PP, LDPE, and PP/LDPE blend sheet of 2 mm thickness were made on a compression molding machine. Composite samples were pressed at 180°C temperature.

Dielectric sample preparation — Circular pellet of 10 mm dia was cut from the above sheet.

Coating — Colloid graphite type air drying conducting paint was applied by brush on the both sides of the circular pellet.

Dielectric Measurements — Dielectric constant (ε') and dissipation factor (tan δ) values of the polymer blends were determined by using a Hewlett-Packard LCR-meter model number 4274 A. ε' and tan δ value of
PP, LDPE PP/LDPE blends were measured in the temperature range 30-160 °C. Heating rate of the furnace was kept constant at 1 °C/min.

3 Results and Discussion

Fig. 1(a) shows the variation of dielectric constant \( \varepsilon' \) with temperature for polypropylene at different frequencies (4, 10, 20, and 100 kHz). It was found that increase in temperature increases the magnitude of \( \varepsilon' \). Fig. 1(b) shows that the dissipation factor (tan \( \delta \)) of polypropylene (PP) decreases with increasing frequency, when plotted against increasing temperatures. Fig. 1(b) shows that in tan \( \delta \) versus temperature plot, \( \beta' \)-peak appears around 50 °C, which corresponds to antioxidant present in PP. This peak amplitude depends on crystallinity, oxidation, and the presence of impurities and additives. Another peak appeared around 107 °C, which is \( \alpha_c \)-relaxation and is due to the crystalline phase present in PP.

Fig. 2(a) shows the variation of dielectric constant (\( \varepsilon' \)) as a function of temperature for LDPE at four frequencies (4, 10, 20, and 100 kHz). It was found that the plateau length of LDPE increases with increase in frequency from 4 kHz to 100 kHz. \( \varepsilon' \) value reaches from 2.2 to 2.56 at 100 °C, which is higher than in comparison to pure PP values (2.47).

The dissipation factor (tan \( \delta \)) plotted against temperature at different frequency of LDPE is shown in Fig. 2(b). It is seen that dissipation factor of LDPE decreases with increase of frequency. In this tan \( \delta \) plot, \( \alpha \)-peaks appeared at 60, 62, 68, and 75 °C corresponding to 4, 10, 20 and 100 kHz frequencies, respectively. This \( \alpha \)-relaxation corresponds to long chain (-CH\(_2\)\(_n\))-relaxation by Crankshaft relaxation mechanism in amorphous phase.

Fig. 3(a) shows the variation of dielectric constant with temperature for PP/LDPE blends, having 80/20 wt%. It is seen that permittivity (\( \varepsilon' \)) of LDPE and PP increases with increasing temperature, which is similar to PMMA/PVDF blends. At 100 °C the dielectric constant of polypropylene is lower than LDPE. It is also found that the plateau length of PP/LDPE blends disappeared. This is because PP does not have any plateau length.

Fig. 3(b) shows the temperature dependence of dissipation factor for PP/LDPE blend having composition 80/20 (weight per cent) at different frequencies. The presence of three distinct peaks can be seen around at 60, 78 and 100 °C at 4 kHz and corresponds to \( \beta' \), \( \alpha_c \), and \( \alpha \)-peaks. The lower temperature \( \beta' \)-relaxation in PP cannot be seen.

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**Fig. 1(a,b)** — Variation of dielectric constant (\( \varepsilon' \)) and dissipation factor (tan \( \delta \)) with temperature for pure PP ([4 kHz (A); 10 kHz (O); 20 kHz (x); 100 kHz (j)]).

**Fig. 2(a,b)** — Variation of dielectric constant (\( \varepsilon' \)) and dissipation factor (tan \( \delta \)) with temperature for Pure LDPE. ([4 kHz (A); 10 kHz (A); 20 kHz (O); 100 kHz (j)].)
be associated with the glass transition of the amorphous phase, while the higher temperature peak corresponds to crystalline transition. β'-peak is due to amorphous phase of PP[8]. Second α'-peak is due to LDPE and shows Crankshaft relaxation mechanism. Last peak α'-peak which is due to relaxation in crystalline portion of PP. β'-peak shift from 60 to 72 °C, α'-peak shifted from 78 to 95 °C, and at last α'-peak shifted from 100 to 105 °C, respectively with increase of frequency for PP/LDPE blends. Dissipation factor or dielectric loss in pure polymer is due to the perturbation of phonon system by the application of dielectric field, the energy transferred to the phonon dissipation in the form of heat. Blending of polymers modifies the perturbation of phonon during application of electric field[11].

Activation energy \((E_a)\) for β' and α relaxations of pure polypropylene calculated by using the relation reported by Yagi[12] were 51.2 and 74.61 kcal/mol.

The activation energy values of the new PP/LDPE blend for β', α and α-relaxations calculated from the Arhenius plot (Fig. 4) values are 55.1, 70.8 and 87.0 kcal/mole. Activation energy increases from β' to α-relaxation. At higher temperature LDPE becomes soft and provides more freedom for relaxation and increases the activation energy \((E_a)\) of α-relaxation present in the blend.

4 Conclusions
Finally based on the above observation it can be concluded that:

1. PP/LDPE blend shows a new type of relaxation behaviour which is different from pure PP and LDPE polymers. PP' and PP/LDPE blend showed β', α', and α-relaxations.
2. α'-crystalline relaxation was found in PP and PP/LDPE blend.
3. α-relaxation was found in LDPE and PP/LDPE blend. This relaxation is due to amorphous phase present in LDPE and is by the Crankshaft relaxation of (-CH₂-)ₙ units.
4. Activation energy \((E_a)\) increased for higher temperature relaxations due to the softening of LDPE at higher temperatures.

![Figure 4](image-url)
References