Thermal and dielectric characterizations of Poly(butylene succinate) (PBS) / Polypropylene (PP) with different blend ratio

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Abstract

The main goal of this work is the investigation of the dielectric properties of the immiscible Polypropylene/Poly(Butylene Succinate) (PP/PBS) blends. The mixtures were successfully prepared using an internal mixer with different weight ratios of (PP/PBS); (100/0), (80/20), (70/30), (50/50), (20/80) and (0/100). Broadband Dielectric Spectroscopy (BDS), over a large temperature domain varying between 20 °C and 100 °C and a frequency range from 0.1 Hz to 1 MHz, was considered to probe the molecular mobility and interfacial transitions of the investigated blends. Furthermore, thermal study, using Differential Scanning Calorimetry (DSC), was also performed to further evidence the immiscibility of (PP/PBS) blends. The dielectric permittivity spectra displayed the different intrinsic material interfacial polarizations and were perfectly adjusted by the general Havriliak-Negami that permits to well discuss the obtained phenomena.

Studied materials

The apolar Polypropylene PP polymer, is one of the most used materiel in our daily life thanks to their particular mechanical and dielectric properties, which make it used as potential candidate for high-frequency insulator. The polar poly(butylene succinate) PBS polymer, is a biodegradable synthetic aliphatic polyester which has a balanced profile of physical and mechanical properties. The investigated materials are ; 100/0, 0/100 virgin Polypropylene (PP) and Poly(Butylene Succinate) (PBS) polymers and four different blends : 80/20, 70/30, 50/50 and 20/80 (wt %) which covers the cases of PP dominant 80/20 and 70/30, PBS dominant 20/80 and intermediate 50/50.

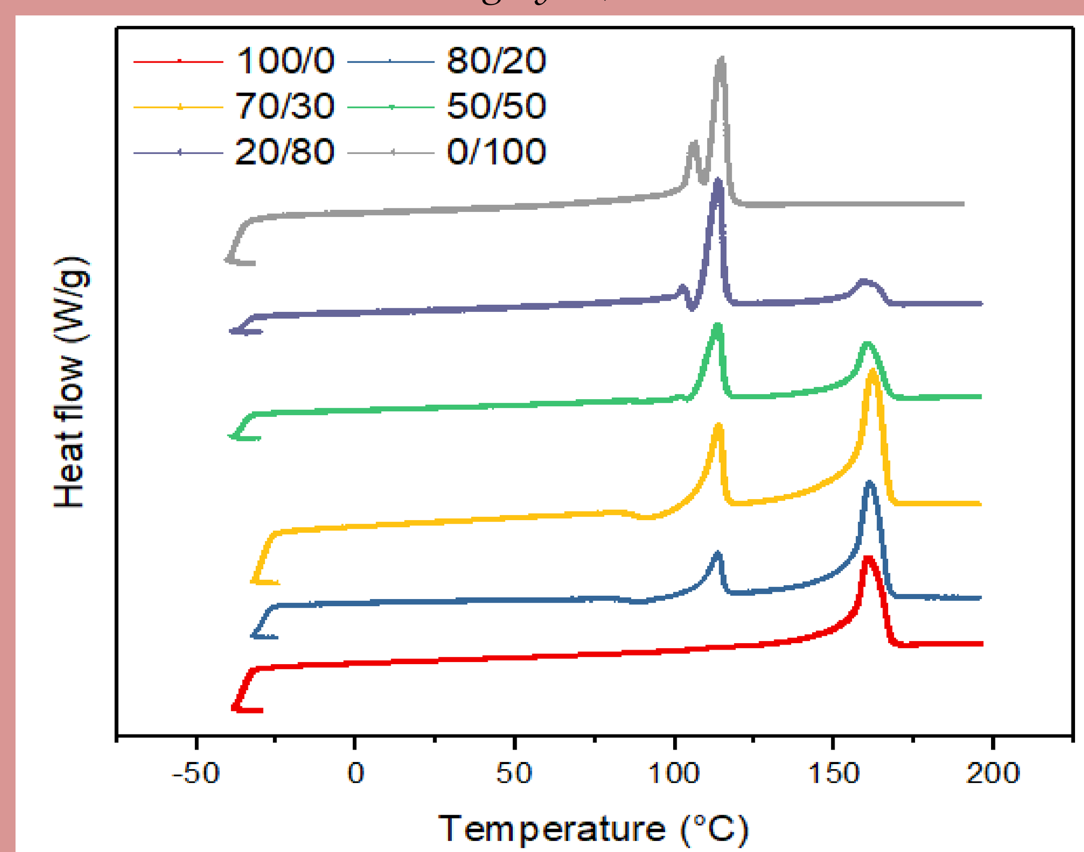
Results and discussion

1. Differential Scanning Calorimetry (DSC) analysis

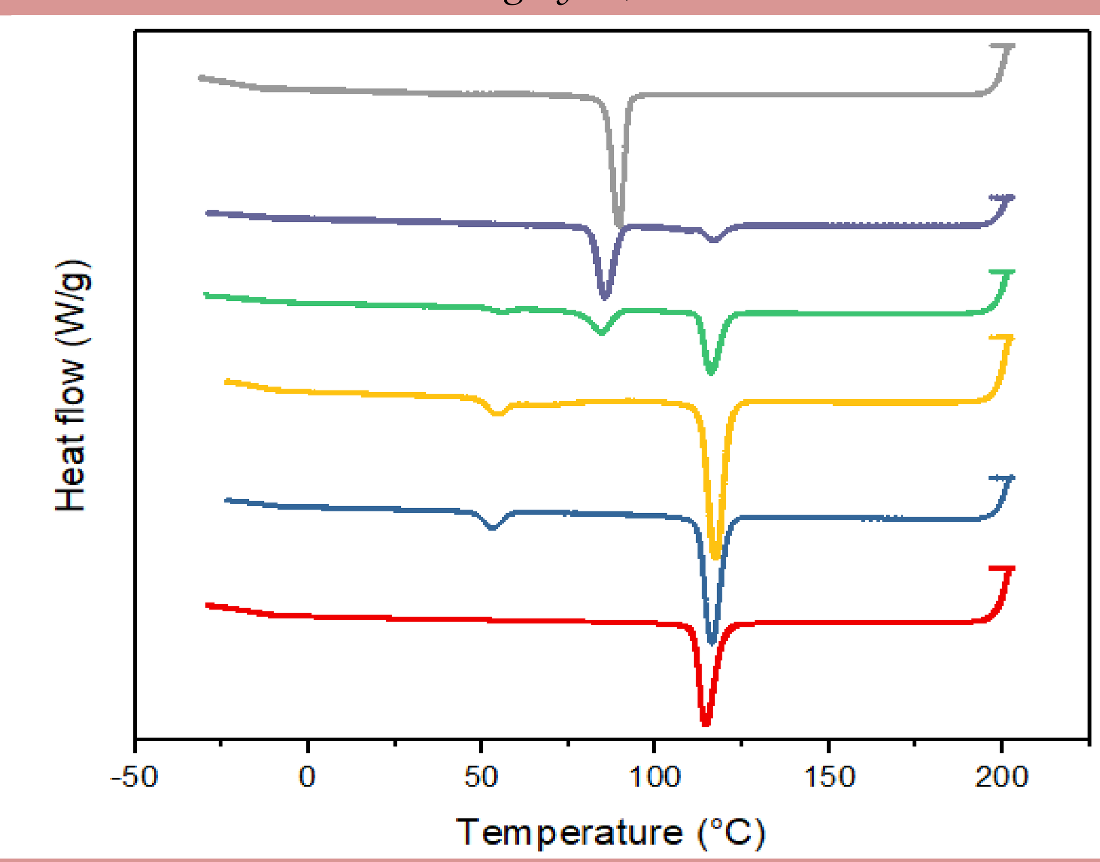
- DSC thermograms for heating and cooling cycles presents a single melting peak at 161.19 °C for the pure PP, and double melting peaks for the pure PBS located at 106.03 °C and 114.70 °C, such behavior was explained by the melting of two distinct populations of crystals. The melting and crystallization phenomena are detected only for semi-crystalline polymers that prove the semi crystalline character for both PP and PBS polymers. The existence of two well-separated melting peaks in the DSC thermograms for all blends indicates the low compatibility and immiscibility of the binary PP/PBS blend.

- The degree of crystallinity of the different PP/PBS blends can be estimated by measuring the area under the crystalline melting endothermic peaks. It is observed that the crystallinity of the PP decreases with increasing PBS content. However, the increase of PP content in the PBS reduced their and crystallinity and crystallization temperature. This indicates that the PP can restrict the mobility of the PBS polymer chains in the PP/PBS blend. The decrease of the crystallinity for both PP and PBS polymers in the PP/PBS blends, can be attributed to the low compatibility and immiscibility of these two kinds of materials.

DSC thermograms of (PP/PBS) blends (Case of the heating cycle).



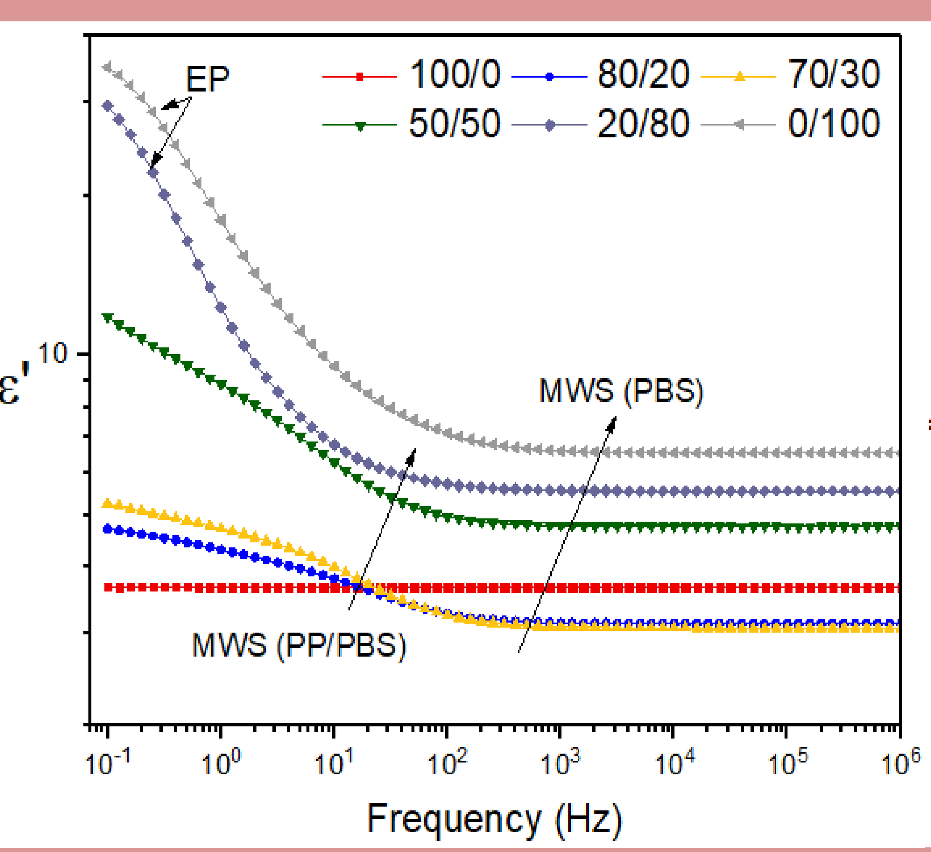
DSC thermograms of (PP/PBS) blends (Case of the cooling cycle).

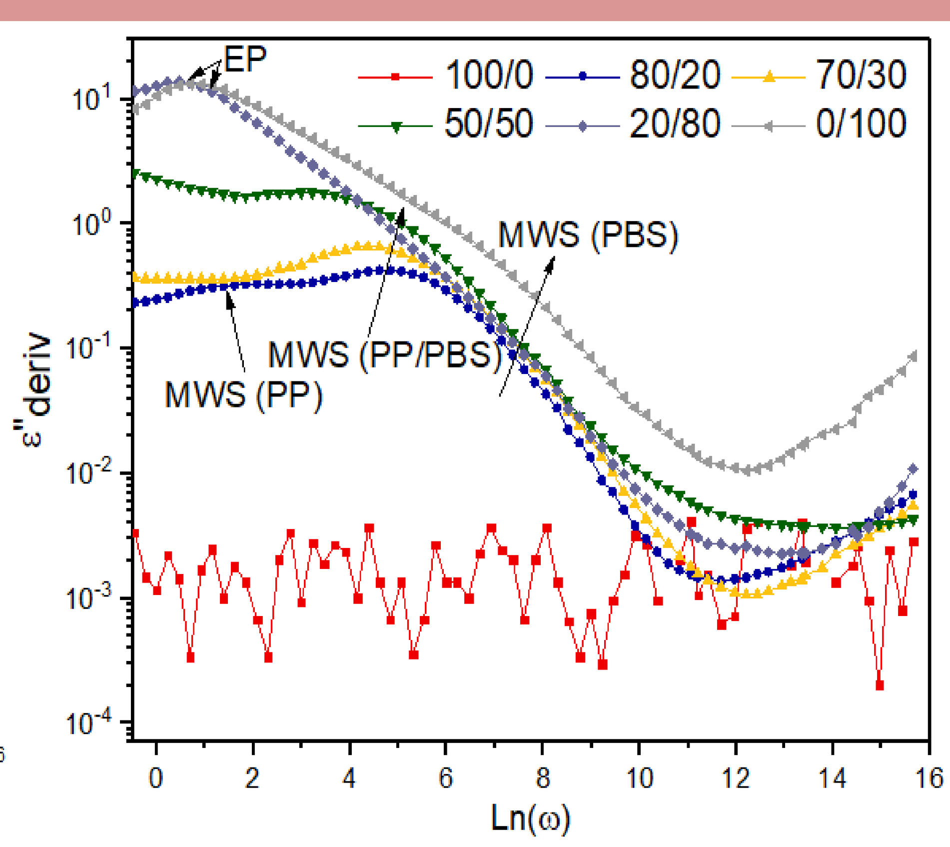


DSC Parameters of PP/PBS blends

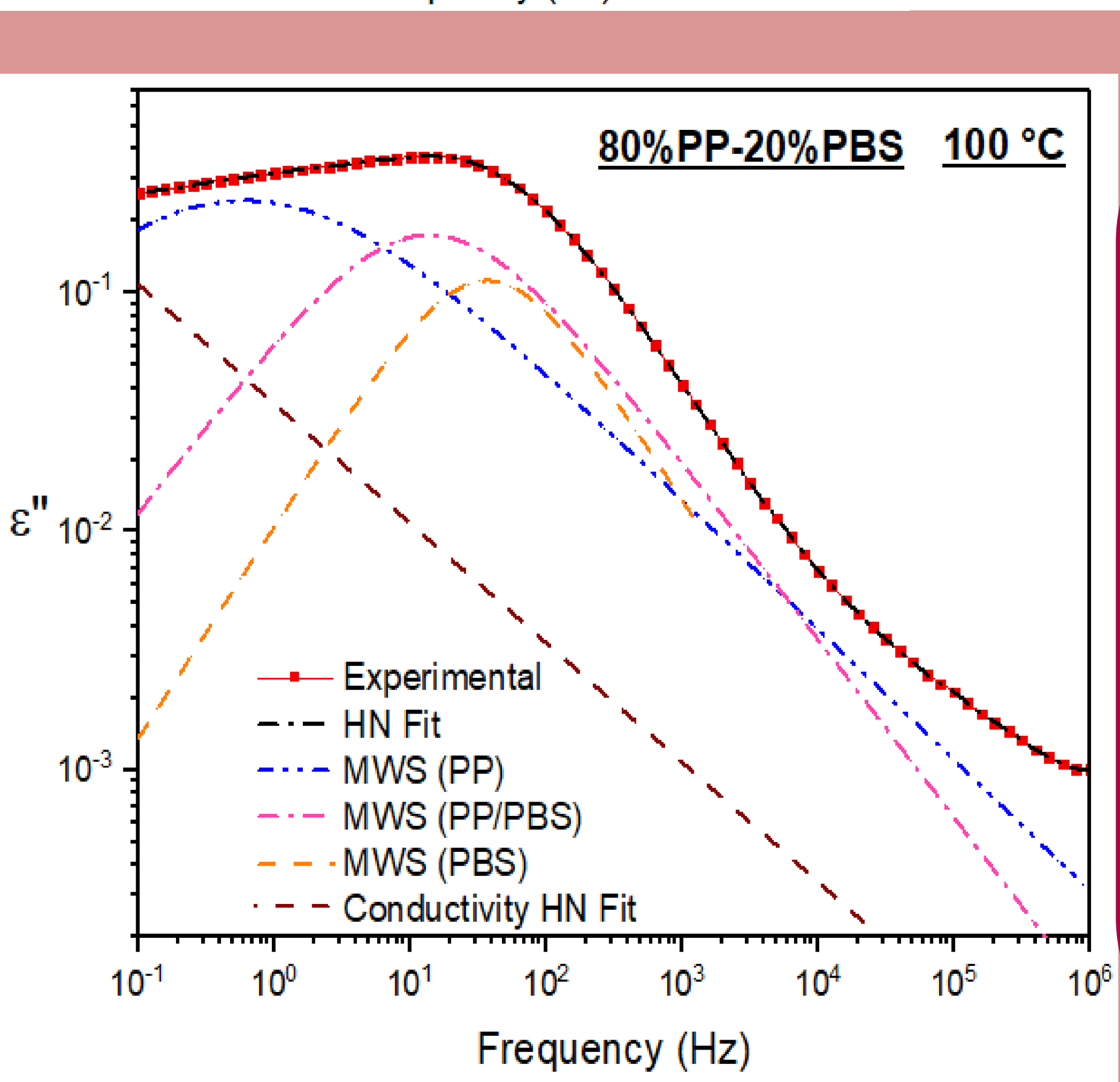
	T_c(°C)		T_m(°C)		χ_c(%)	
PP/PBS	**PP**	**PBS**	**PP**	**PBS**	**PP**	**PBS**
100/0	114.14	-	161.19	-	37.22	-
80/20	116.19	53.06	161.31	113.56	28.64	13.10
70/30	117.26	54.25	162.12	113.69	23.87	19.43
50/50	116.05	T_{c1}=55.60 T_{c2}=84.43	160.41	T_{m1}=101.71 T_{m2}=113.49	16.89	29.23
20/80	116.90	85.41	159.38	T_{m1}=102.89 T_{m2}=113.58	5.01	43.14
0/100	-	89.50	-	T_{m1}=106.03 T_{m2}=114.70	-	43.53

2. Broadband Dielectric Spectroscopy (BDS) analysis





- By analyzing the dielectric spectra of the investigated materials, we note that the mixture of the PP with PBS brings about a decrease of the permittivity; the dielectric losses and the conductivity values for the PBS polymer and generates supplementary responses. The spectrum of the pure PBS can be split into interfacial polarization process MWS(PBS) as well as electrode polarization (EP) which was masked by the conduction process. The MWS(PBS) polarization was originated from blocking charge carriers at the amorphous/crystalline regions of the semi-crystalline polymer PBS. While the electrode polarization (EP) was caused by the accumulation of charge carriers at the sample/electrode interface during dielectric experiments. As the Polypropylene is a non-polar polymer, its dielectric constant (ε') and the derivative loss factor (ε''_{deriv}) were slightly dependent on frequency. In the dielectric spectra of the PP/PBS mixtures we have identified at intermediate frequencies the MWS (PP/PBS), owing to the trapped charge at the PP/PBS interfaces created due to the immiscibility of the PP and PBS polymers. The semi-crystalline character of the PP is responsible for detecting the MWS(PP) polarization in the dielectric spectra of the PP/PBS blend ratio of 80/20 and 70/30.



Havriliak-Negami (H-N) analysis:

In order to study the effect of blending the PP with PBS polymers, we proposed to analyze the nature of the dielectric relaxations using H-N equation: $\varepsilon^*(\omega) = -i(\frac{\sigma_0}{\varepsilon_0\omega})^S + \sum_{i=1}^{n}(\varepsilon_\infty + \frac{\Delta\varepsilon_i}{[1+(i\omega\tau_{HN_i})^{\alpha_{HN_i}}]^{\beta_{HN_i}}})$

We can clearly distinguish the different interfacial polarizations MWS(PP/PBS) , MWS(PBS) and MWS(PP) process accompanied with a conduction phenomenon for the virgin PBS and the studied blends. The interfacial polarization $\Delta\varepsilon_{MWS(PP/PBS)}$ was calculated and we note it increase when the amount of PBS increases, this may result from the rise in the number of polarized dipoles trapped in the PP/PBS interfaces. The activation energy of MWS(PP/PBS) polarization was also estimated. It increases with increasing PBS content. The rise of the dipole's number at the PP/PBS interfaces requires a deal energy to align the dipoles in the direction of the applied field. The sorted dielectric results demonstrate the poor adhesion and incompatibility between PP and PBS polymers.