Evaluating Space Charge Behavior of Polypropylene Blends Using TSDC Measurements

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Introduction

Polypropylene (PP)-based thermoplastics are considered promising alternatives to cross-linked polyethylene (XLPE) for future HVDC cable insulation systems. Compared to XLPE, PP offers simpler processing, improved recyclability, and higher operating temperatures. Nevertheless, neat PP suffers from high stiffness. By blending PP random copolymers with elastomeric components mechanical limitations can be resolved while preserving good electrical performance. This work aims at the dielectric characterization of PP random copolymer-based blends, to evaluate the effectiveness of a novel additive for mitigating space charge accumulation, and to investigate whether variations in polarization duration influence the relative comparison of materials and the conclusions drawn from TSDC measurements.

Studied materials

The studied insulation blends comprised three main PP components, an antioxidant package and space charge mitigating additive:

i. homophasic polypropylene random copolymer (RACO)
ii. heterophasic polypropylene copolymer containing an ethylene–propylene rubber phase (HECO)
iii. propylene-based elastomer (PEC)
iv. antioxidant package comprising of a synergetic 1:1 blend of a hindered phenolic antioxidant and a phosphite processing antioxidant (AO)
v. selected formulations contained polypropylene grafted with maleic anhydride (PP-g-MAH)

Material	Polymer component ratio			PP-blend composition		
	RACO	HECO	PEC	Polymer [wt-%]	Additive [wt-%]	AO [wt-%]
Blend-1	0.55	0.20	0.25	99.70	N/A	0.30
Blend-2	0.55	0.20	0.25	98.70	1.0	0.30
Blend-3	0.70	0.30	N/A	99.70	N/A	0.30
Blend-4	0.70	0.30	N/A	98.70	1.0	0.30

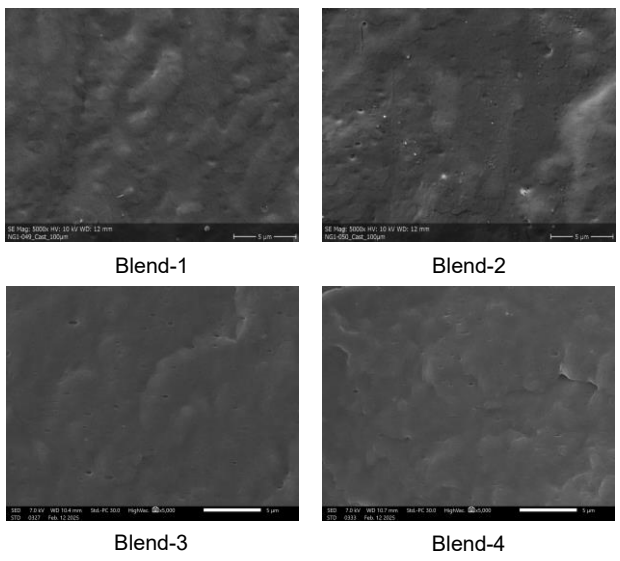

Fig.1 Exemplified SEM cross-sectional morphologies of studied binary and ternary blends with and without additive.

- Relatively homogeneous surface morphology.
- No large agglomerations or severe phase separation.
- Additive did not introduce major morphology changes.
- Higher fusion enthalpy observed for binary blends in DSC.

Dielectric properties

Breakdown strength (BDS)

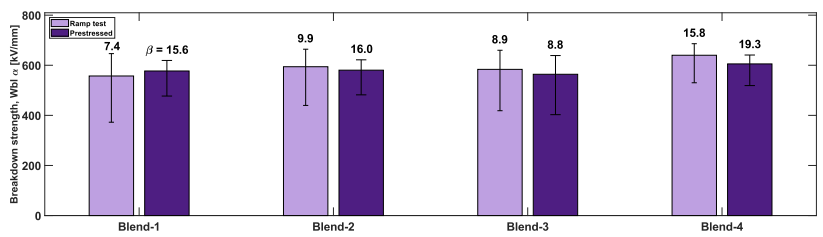

Fig.2 DC breakdown strength of ramp tested and prestressed PP blends.

Thermally stimulated depolarization current (TSDC)

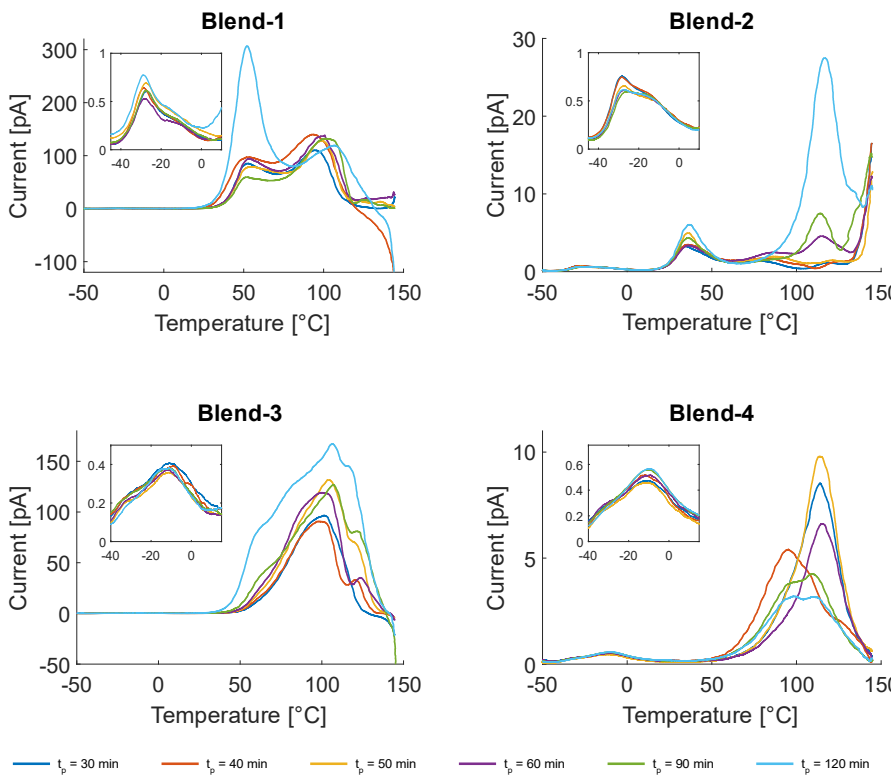

Fig.3 Thermally stimulated depolarization current (TSDC) spectra with variable polarization time 30, 40, 50, 60, 90 and 120 minutes. Inset shows closer view of the relaxation behavior around glass transition region.

Accumulated charge in TSDC

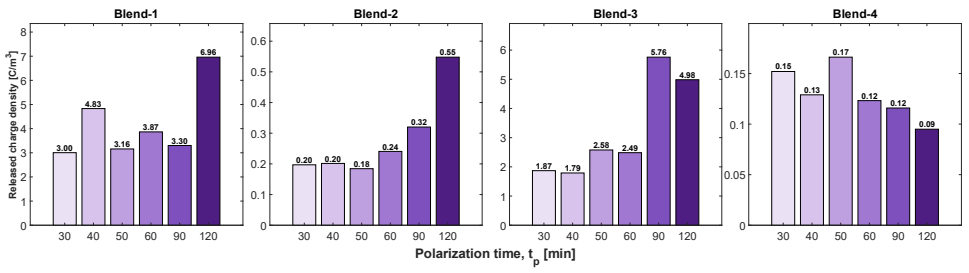

Fig.4 Total released charge density obtained from integrated TSDC spectra for different polarization times.

Space charge (PEA)

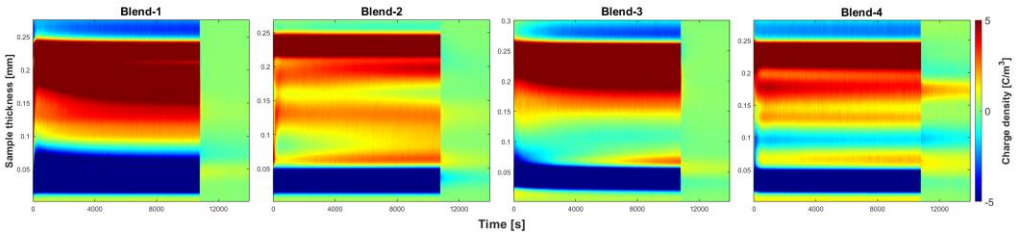

Fig.5 Space charge density profiles of the investigated PP blends during volt on and volt off.

Conclusions

- PP-g-MAH reduced space charge accumulation in TSDC and PEA.
- Investigated PP-based blends exhibited relatively high DC breakdown strengths.
- Additive-containing blends showed reduced statistical scatter and higher Weibull shape parameters.
- Polarization time had no significant effect on the conclusions drawn from TSDC measurements when comparing different materials.

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