

Supplementary Information

**Highly Insulating Thermoplastic Nanocomposites based on a Polyolefin Ternary Blend
for High-Voltage Direct Current Power Cables**

Azadeh Soroudi,^a Yingwei Ouyang,^a Fritjof Nilsson,^b Ida Östergren,^a Xiangdong Xu,^c , Zerui Li,^a Amir Masoud Pourrahimi,^a Mikael Hedenqvist,^b Thomas Gkourmpis,^d Per-Ola Hagstrand,^d Christian Müller^{a*}

^aDepartment of Chemistry and Chemical Engineering, Chalmers University of Technology,
41296 Göteborg, Sweden

^bDepartment of Fibre and Polymer Technology, School of Engineering Sciences in
Chemistry, Biotechnology and Health, KTH Royal Institute of Technology, 10044
Stockholm, Sweden

^cDepartment of Electrical Engineering, Chalmers University of Technology, 41296 Göteborg,
Sweden

^dInnovation & Technology, Borealis AB, 44486 Stenungsund, Sweden

*e-mail: christian.muller@chalmers.se

Table S1. Formulations of all materials and σ_{DC} at 70 °C and 30 kV mm⁻¹; ^asingle measurement, a relative error of $\Delta x = 10\%$ is assumed; ^bmean of two measurements of two separately compounded samples, error calculated according to $\Delta x = (x_{max} - x_{min})/2$; ^cdata from ref. [Ouyang et al., *High Volt.*, 2022, 7, 251-259].

	LDPE (wt%)	PP (wt%)	SEBS (wt%)	Al ₂ O ₃ (wt%)	σ_{DC} 30 kV mm ⁻¹ (10 ⁻¹⁵ S m ⁻¹) 70 °C
LDPE	100	-	-	-	43.0 ± 4.3 ^a
LDPE:Al ₂ O ₃	98.7	-	-	1.3	9.6 ± 1.5 ^b
LDPE:Al ₂ O ₃	97.7	-	-	2.3	3.7 ± 0.6 ^b
PP	-	100	-	-	1.4 ± 0.1 ^c
PP:LDPE	75	25	-	-	20 ± 2.0 ^a
PP:LDPE:Al ₂ O ₃	72.8	25	-	2.2	2.5 ± 0.4 ^b
SEBS	-	-	100	-	10.1 ± 1.0 ^a
SEBS:PP:LDPE	71	24	5	-	11.6 ± 1.2 ^a
SEBS:PP:LDPE	42	38	20	-	4.3 ± 0.4 ^a
SEBS:PP:LDPE:Al ₂ O ₃	68.9	24	5	2.1	2.89 ± 0.4 ^b
SEBS:PP:LDPE:Al ₂ O ₃	40.7	38	20	1.3	2.6 ± 0.4 ^b

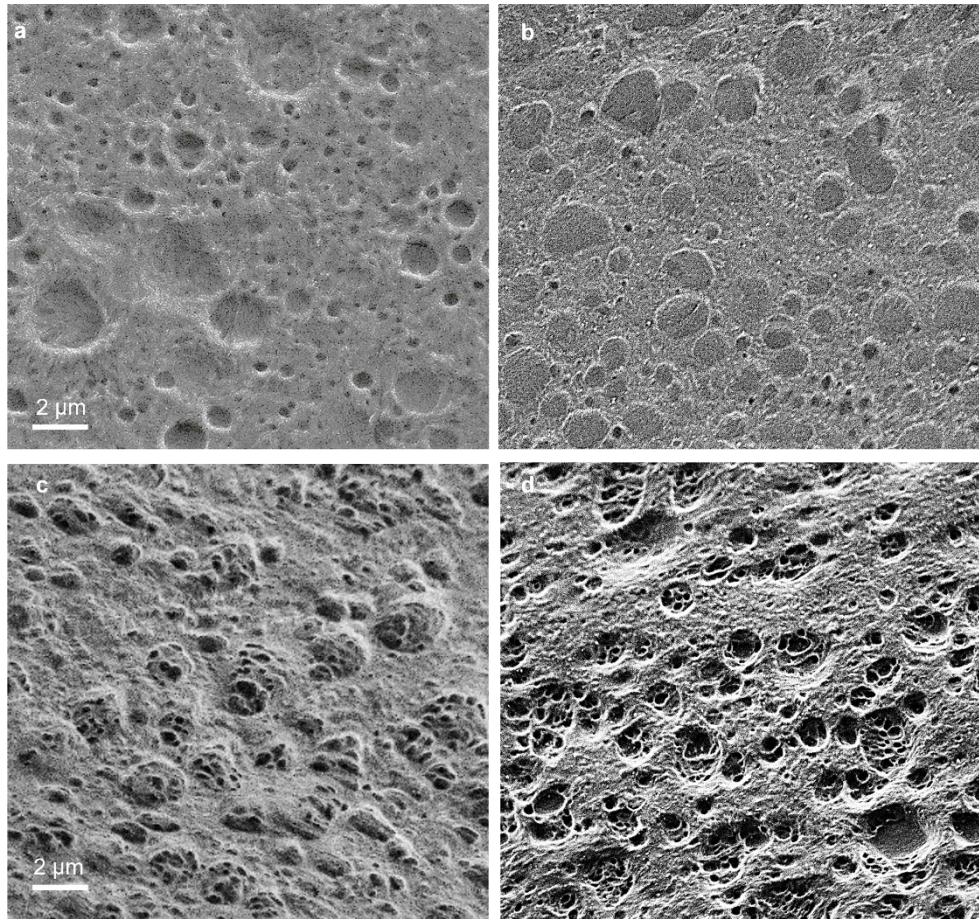


Figure S1. SEM micrographs of the cryofractured, etched and sputtered surfaces of (a): 25:57 PP:LDPE binary blend, (b): 25:72.8:2.2 PP:LDPE:Al₂O₃ binary blend nanocomposite, (c) 5:24:71 SEBS:PP:LDPE ternary blend , and (d) 5:24: 68.9:2.1 SEBS:PP:LDPE:Al₂O₃ ternary blend nanocomposite.

Table S2. Peak melting temperatures, T_m^{PP} and T_m^{PE} , and crystallization temperatures, T_c^{PP} and T_c^{PE} , of PP and LDPE extracted from first heating and cooling DSC thermograms as well as the crystallinity of PP and LDPE, X_c^{PP} and X_c^{PE} , calculated according to $X_c = \Delta H_f / \Delta H_f^0$ where ΔH_f is the enthalpy of fusion of the PP and LDPE fraction, respectively, and $\Delta H_{f,PP}^0 = 207 \text{ J g}^{-1}$ and $\Delta H_{f,PE}^0 = 293 \text{ J g}^{-1}$.

	LDPE	PP	SEBS	Al ₂ O ₃	T_m^{PP}	T_m^{PE}	T_c^{PP}	T_c^{PE}	X_c^{PP}	X_c^{PE}
	(wt%)	(wt%)	(wt%)	(wt%)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)
LDPE	100	-	-	-	-	112	-	96	-	42
LDPE:Al ₂ O ₃	98.7	-	-	1.3	-	114	-	97	-	43
PP	-	100	-	-	167	-	110	-	38	-
SEBS	-	-	100	-	-	-	-	-	-	-
SEBS:PP:LDPE	42	38	20	-	167	115	112	96	39	39
SEBS:PP:LDPE:Al ₂ O ₃	40.7	38	20	1.3	164	111	115	98	37	36

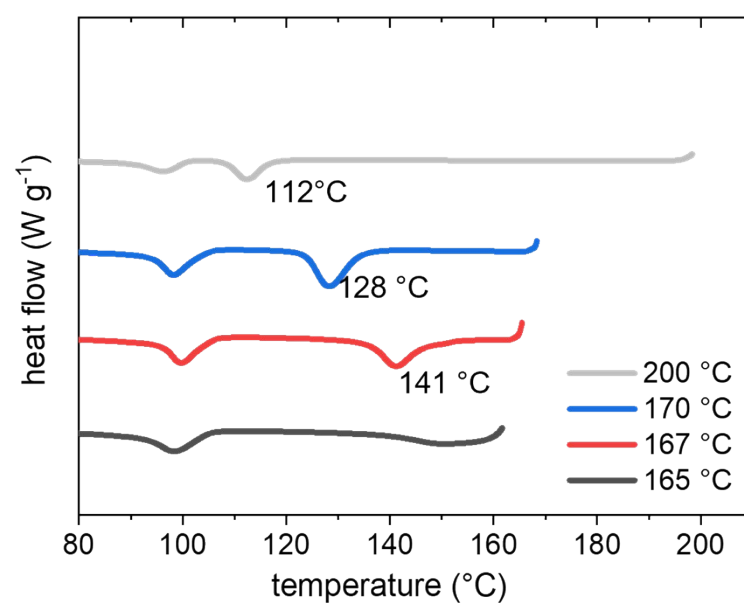


Figure S2. DSC cooling thermograms of 20:38:42 SEBS:PP:LDPE ternary blend after complete melting at 200 °C (gray) and after partially melting at different self-seeding temperatures (blue, red and black), yielding a peak crystallization temperature of optimally nucleated PP of $T_c^{Max} \approx 141$ °C.

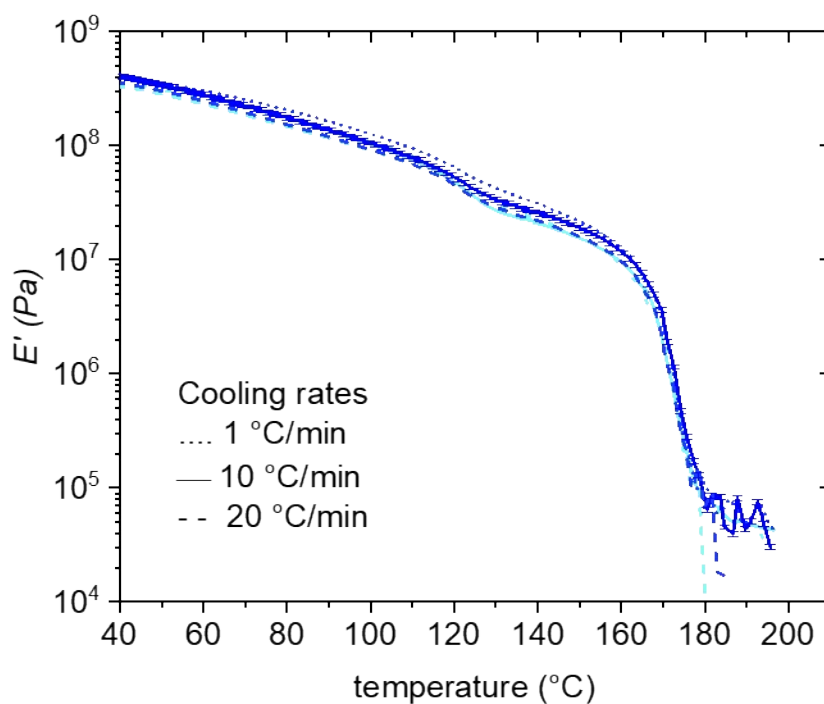


Figure S3. DMA heating thermograms showing the storage modulus E' of 20:38:42 SEBS:PP:LDPE ternary blends (sky blue) and 20:38:40.7:1.3 SEBS:PP:LDPE:Al₂O₃ ternary blend nanocomposites (blue), prepared with different cooling rates: -1 °C min⁻¹ (dotted), -10 °C min⁻¹ (solid) and -20 °C min⁻¹ (dashed).

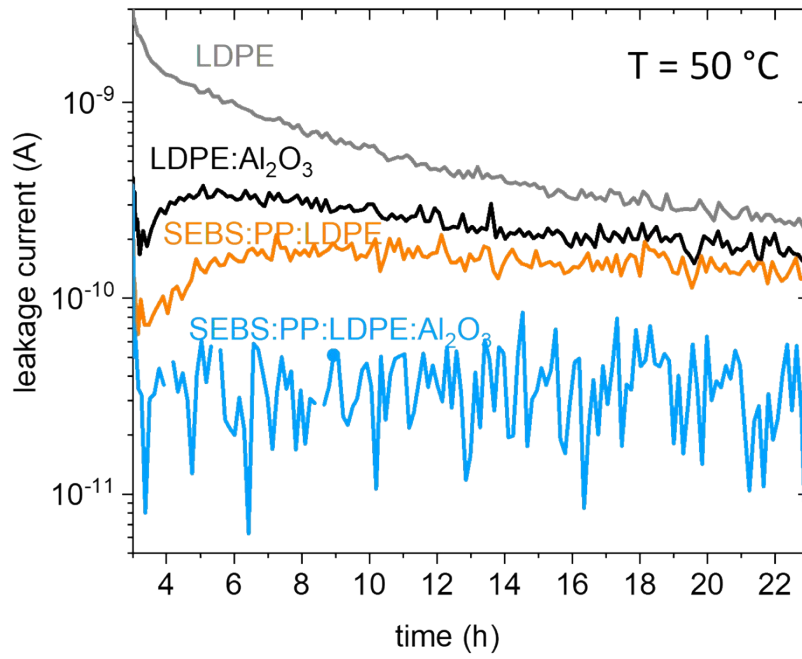


Figure S4. Leakage current at 50 °C and 30 kV mm⁻¹ as a function of time of neat LDPE (gray), 98.7:1.3 LDPE:Al₂O₃ (black), 20:38:42 SEBS:PP:LDPE (orange), and 20:38:40.7:1.3 SEBS:PP:LDPE:Al₂O₃ (blue); yielding σ_{DC} values of $3.9 \cdot 10^{-15} \text{ S m}^{-1}$, $2.5 \cdot 10^{-15} \text{ S m}^{-1}$, $1.6 \cdot 10^{-15} \text{ S m}^{-1}$ and $0.5 \cdot 10^{-15} \text{ S m}^{-1}$, respectively.

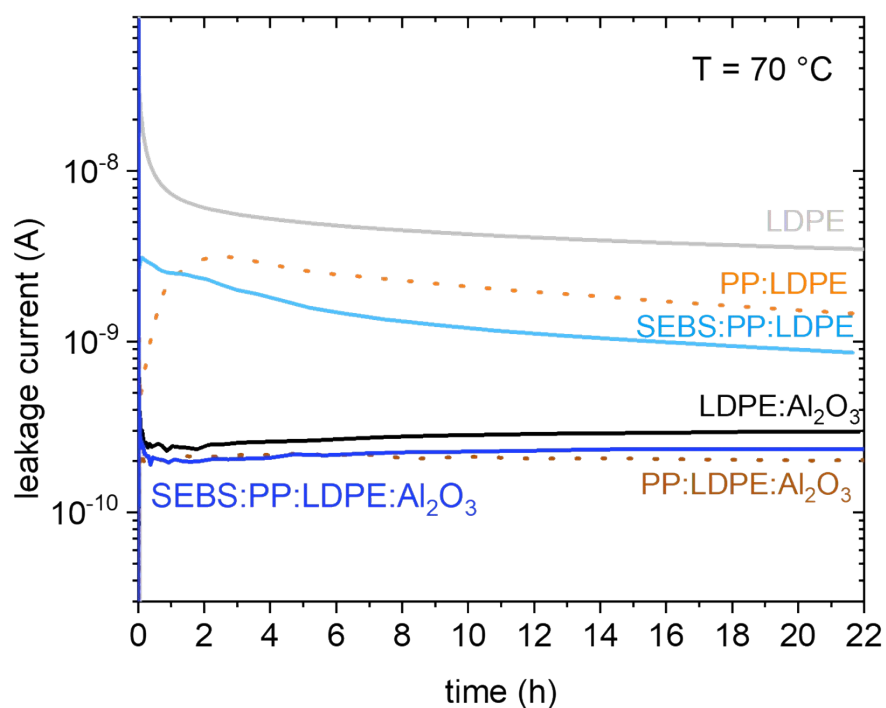


Figure S5. Leakage current at 70 °C and 30 kV mm⁻¹ as a function of time of neat LDPE (grey), 25:75 PP:LDPE binary blends (orange), 5:24:71 SEBS:PP:LDPE ternary blends (sky-blue), 97.7:2.3 LDPE: Al₂O₃ (black), 25:72.8:2.2 PP:LDPE:Al₂O₃ (brown) and 5:24:68.9:2.1 SEBS:PP:LDPE:Al₂O₃ (blue).