Characterization of Bi-Layer XLPE/EPDM and PP-blend/EPDM Insulations for HVDC Cable Accessories

R. E. Diaz[1*], B. Diban[1], G. Mazzanti[1], P. Seri[1], I. Rytöluoto[2], K. Lahti[3] , M. Niittymäki[3]
[1]*University of Bologna,* Italy, [2]*VTT Technical Research Centre of Finland*, Finland, [3]*Tampere University,* Finland,
*rolandoezequiel.diaz@unibo.it

Objectives

- Investigate the role of interface morphology and material compatibility
- Assess their impact on:
  - space charge accumulation
  - charging current
  - breakdown strength
- Compare XLPE/EPDM and PP-blend/EPDM bi-layer systems

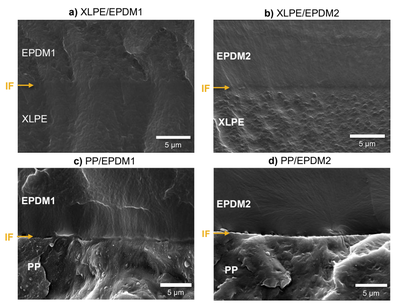
Studied materials

- Four bi-layer insulation systems investigated
- Cable insulation:
  - XLPE (reference material)
  - PP-blend (emerging alternative)
- Accessory insulation:
  - EPDM with low and high diene content
- Bi-layer specimens obtained by hot pressing to ensure fused interfaces (no partial discharges at the interface)

Specimen Code	Layer 1	Layer 2
XLPE/EPDM1	XLPE	EPDM (low diene content)
XLPE/EPDM2	XLPE	EPDM (high diene content)
PP/EPDM1	Binary PP-blend	EPDM (low diene content)
PP/EPDM2	Binary PP-blend	EPDM (high diene content)

Bi-layer thickness ≈ 200 µm

Interface morphology

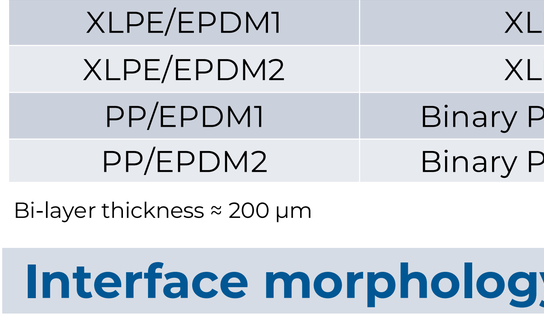


SEM cross-section of interfaces

- Interface morphology is governed by material compatibility
- XLPE/EPDM → smooth and diffused interface
  - good compatibility and co-crosslinking
- PP/EPDM → sharp and distinct interface
  - limited compatibility and weak bonding

Charge dynamics

Thermally Stimulated Depolarization Current (TSDC)

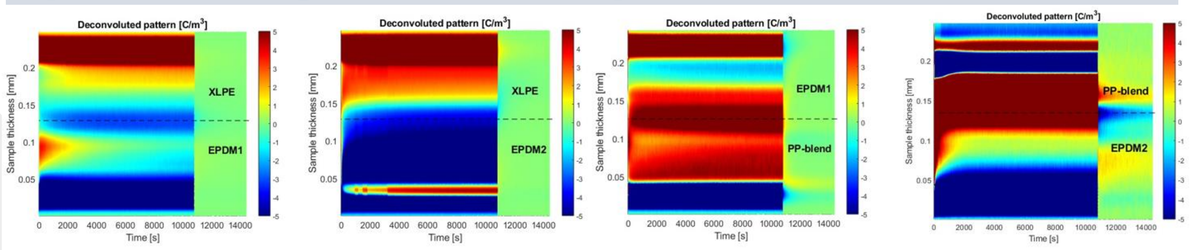


Trapped charge release (TSDC) during thermal depolarization

Charge injection during polarization

- XLPE/EPDM1 → minimal TSDC peaks and lowest charging current
  → reduced charge injection and trapping
- PP/EPDM systems → higher current levels and broader TSDC peaks
  → enhanced charge accumulation

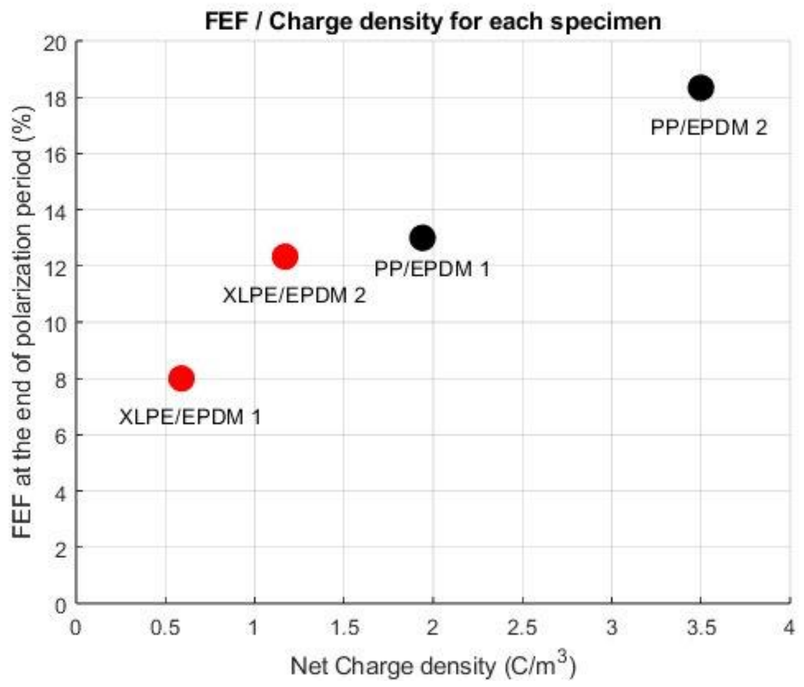
Space charge behavior: patterns



Space charge density profiles during polarization and depolarization

- Space charge accumulation is governed by interface properties
- XLPE/EPDM1 → low charge density
  - limited accumulation at the interface
- XLPE/EPDM2 and PP/EPDM → higher charge density
  - accumulation in EPDM layer and interface

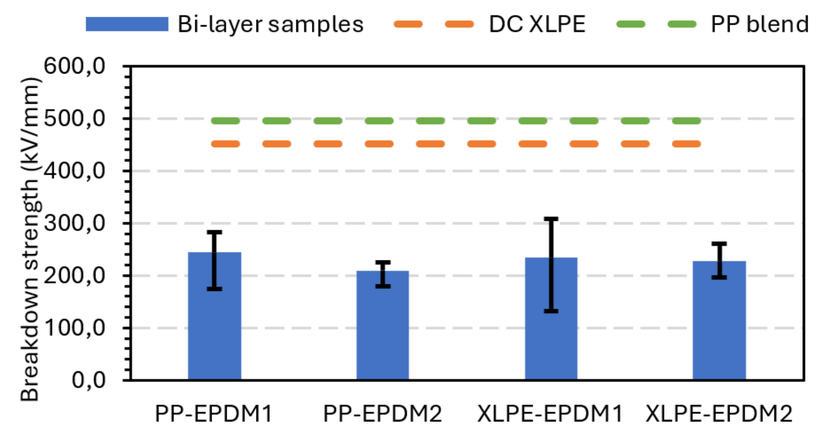
Space charge behavior: summary



Field enhancement factor (FEF)

- XLPE/EPDM1 → lowest charge and field enhancement
  → best performing system
- EPDM2-based systems show higher charge accumulation
  → increased field distortion
- Low diene EPDM improves interfacial performance

Reduced strength in bi-layer systems



Conclusions

- Bi-layer XLPE/EPDM and PP/EPDM systems were investigated for HVDC applications
- Interface morphology strongly affects charge accumulation and charging current
- Smoother interfaces (XLPE/EPDM) lead to reduced charge accumulation
- All bi-layer systems show reduced breakdown strength compared to bulk XLPE and PP-blend insulation

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