Partial discharge risk under space charges generation and transport effects

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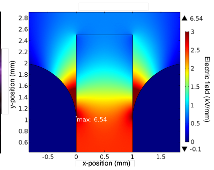

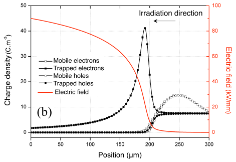

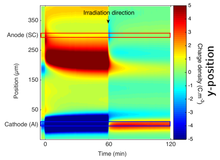

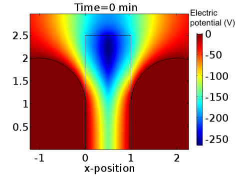

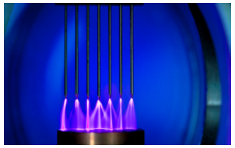

STUDY CONTEXT AND PROBLEMATIC

COMSOL® IMPLEMENTATION & SIMULATION MODEL

MAIN SIMULATION RESULTS

① Electronics components

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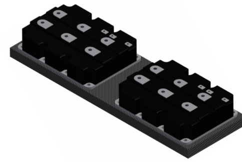
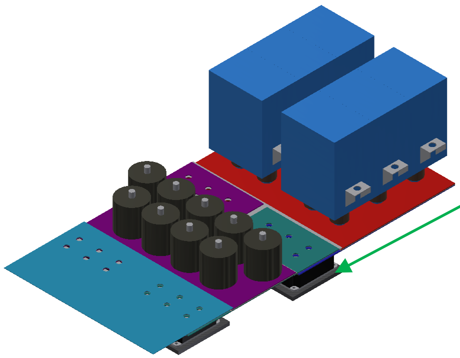
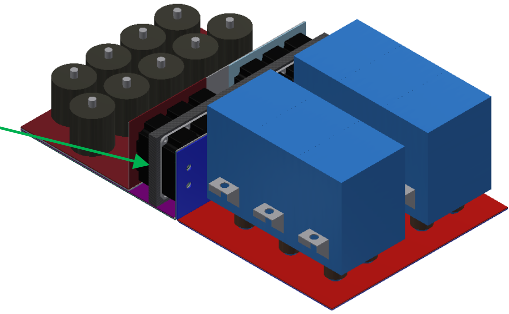




② Power Converters



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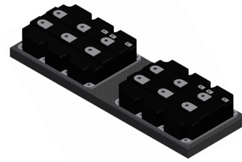

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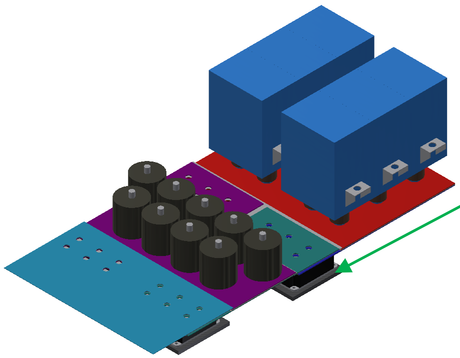
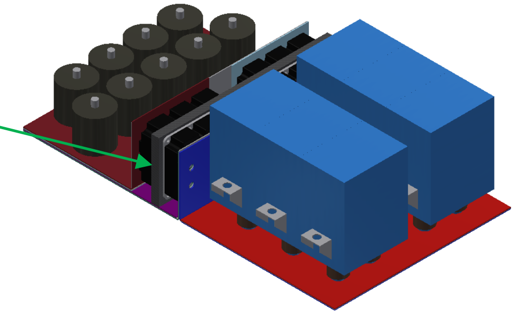
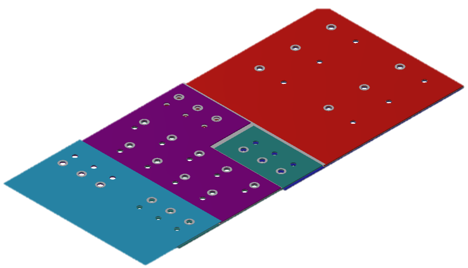
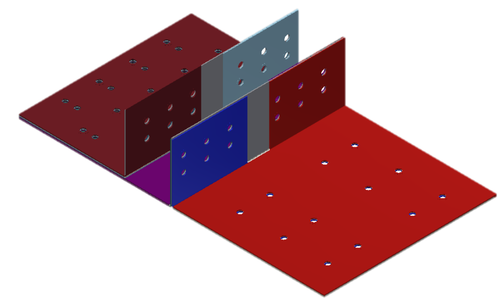




③ Busbars powered by a HVDC 2.5kV voltage bus





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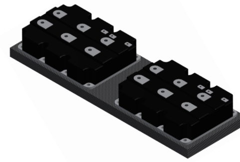

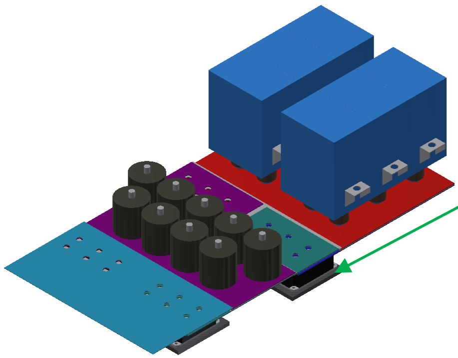

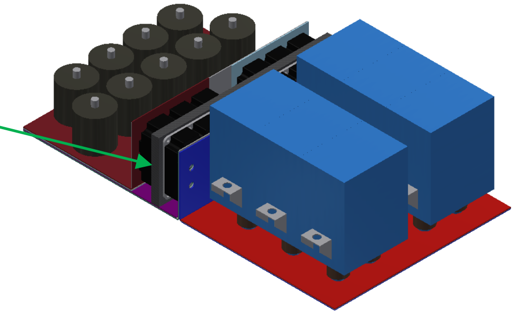

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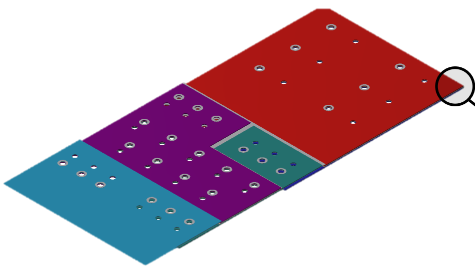
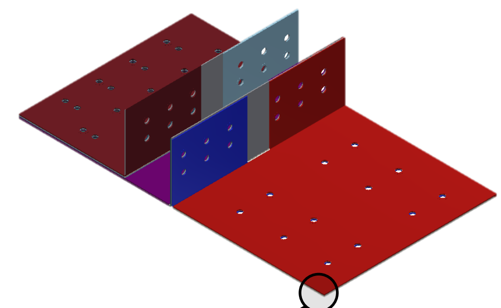




④ **Triple point =**

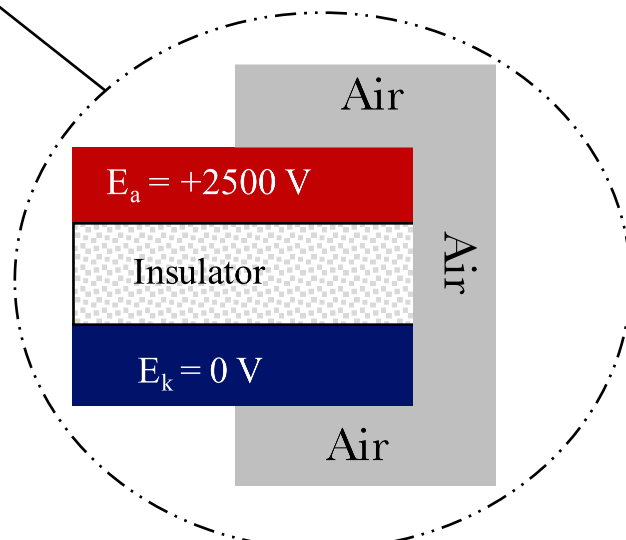
Conductor(busbar)

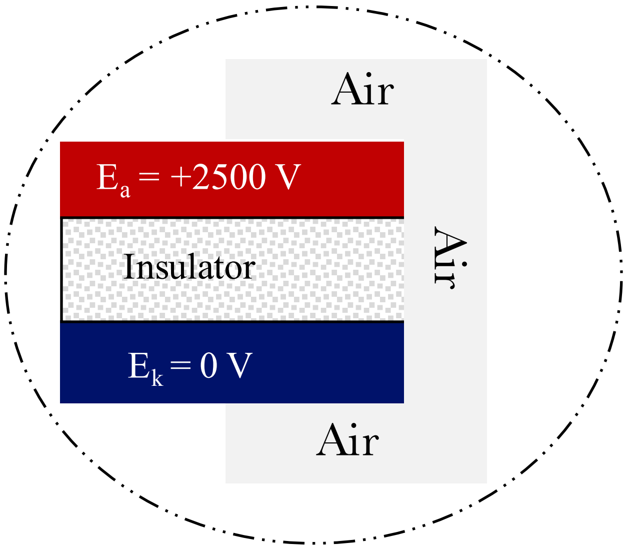
+

dielectrics(insulator)

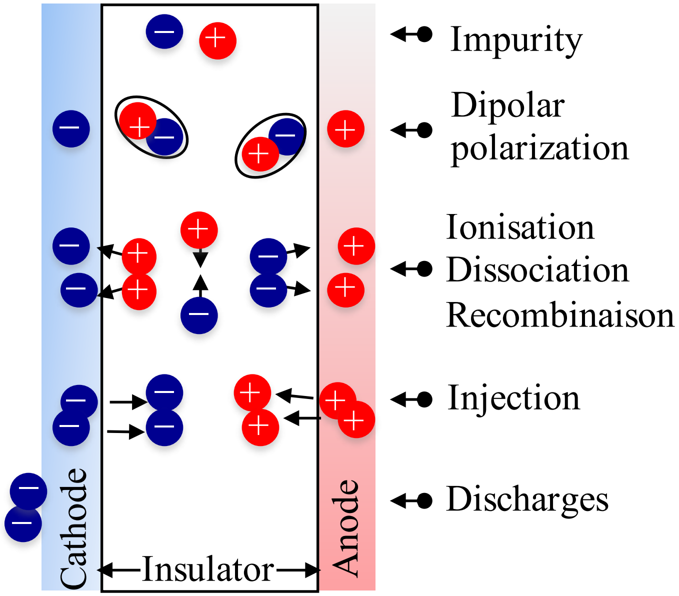
+

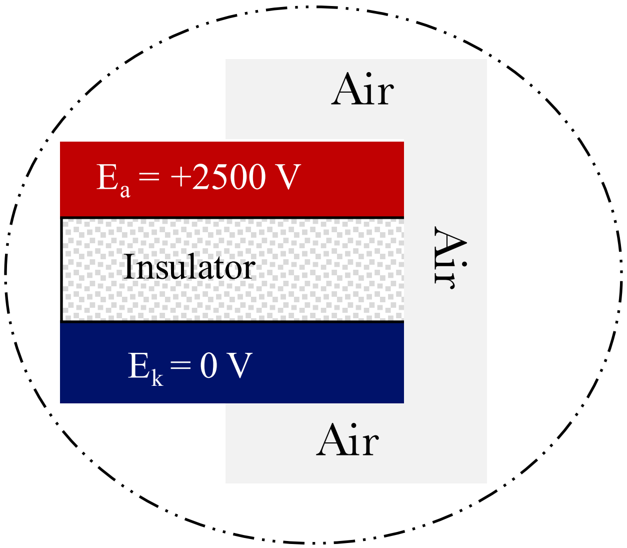
Air contact region





Main charge generation mechanisms





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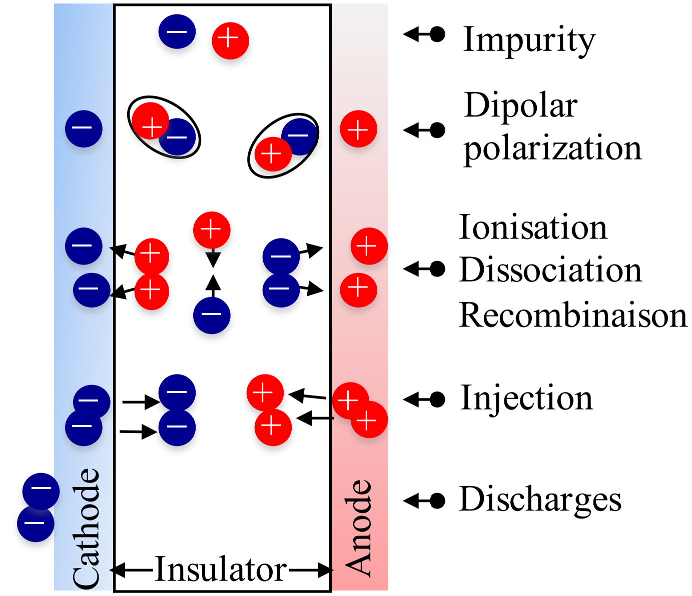

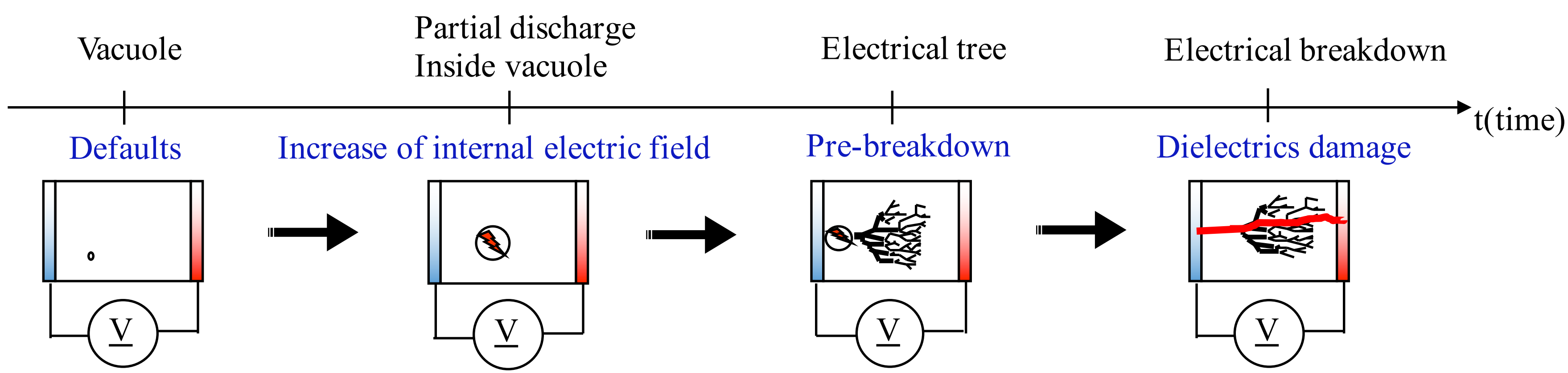

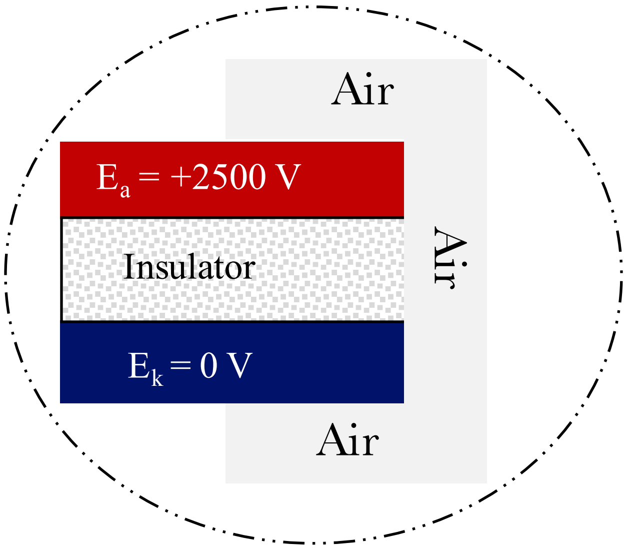

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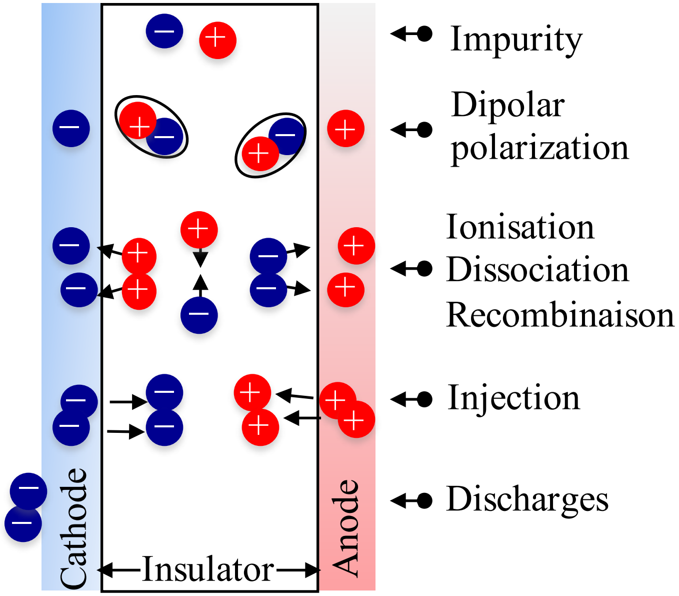
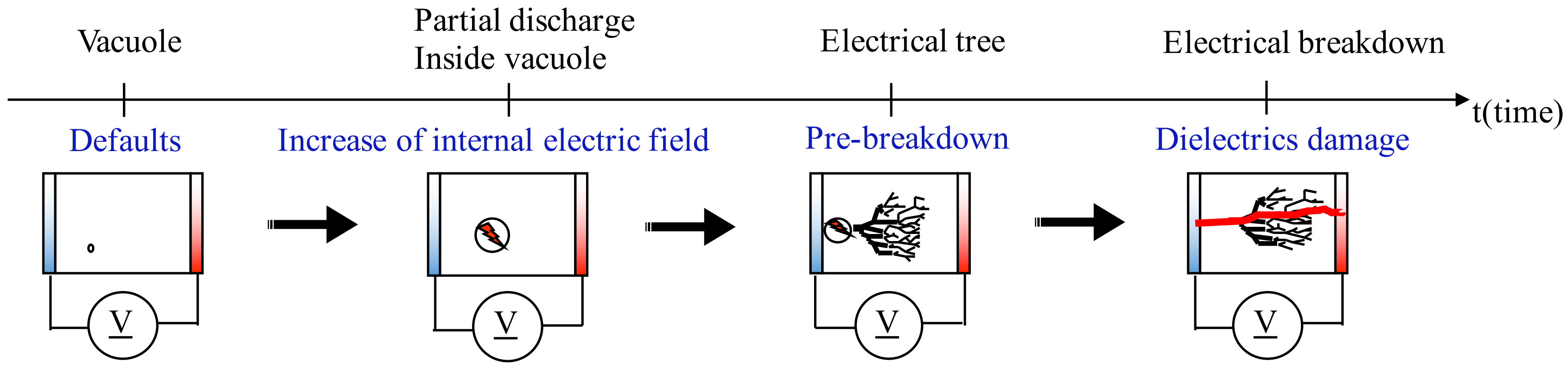




A better characterization of charge mechanisms in dielectrics material to prevent partial discharge risk in air surrounding HVDC power systems.

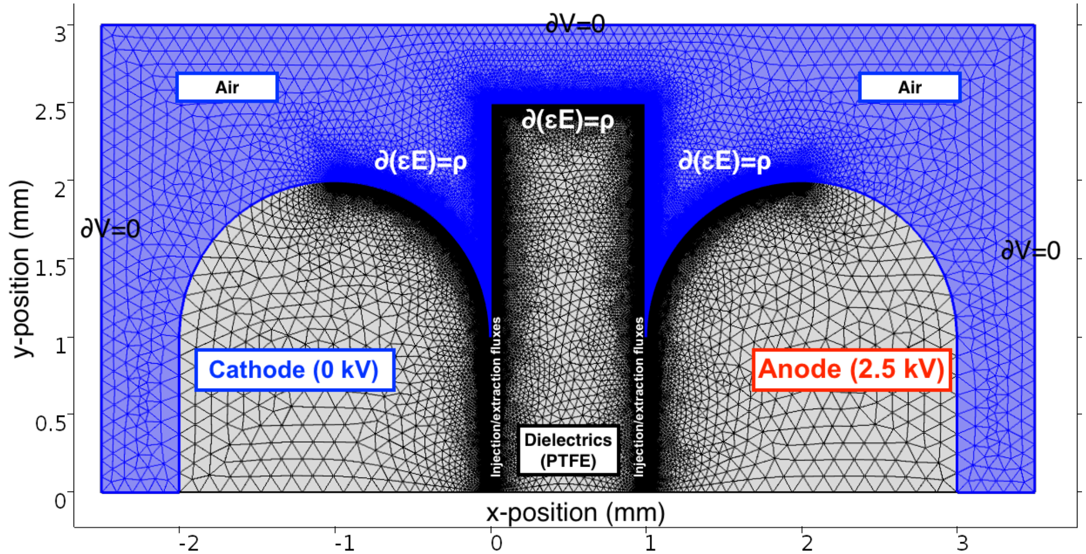
STUDY CONTEXT AND PROBLEMATIC

COMSOL® IMPLEMENTATION & SIMULATION MODEL

MAIN SIMULATION RESULTS

☞ Geometry and meshing

- 2D-simulation model
- 162 k domain elements
- ~4 M Finite elements
- Interfaces refinement
- 50 Boundary layers



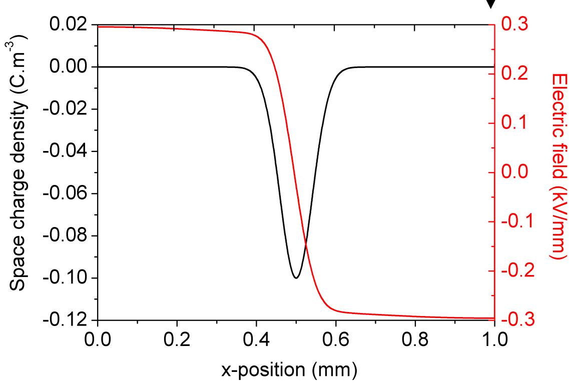
☞ Initial conditions

$$\rho = \textit{Variable distribution}$$

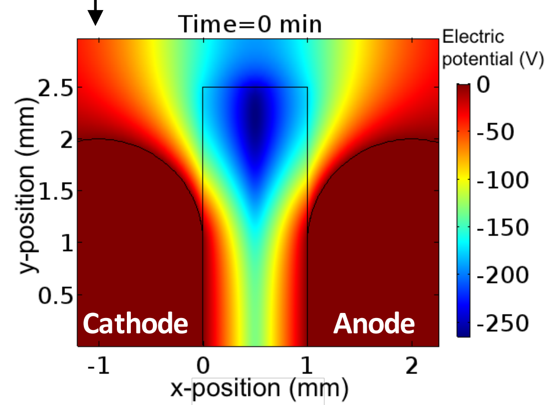
$$p = 1\ bar$$

$$T° \sim 293{,}15\ K\ (20\ °C)$$

Initial charge and associated Electric field distribution



Potential distribution



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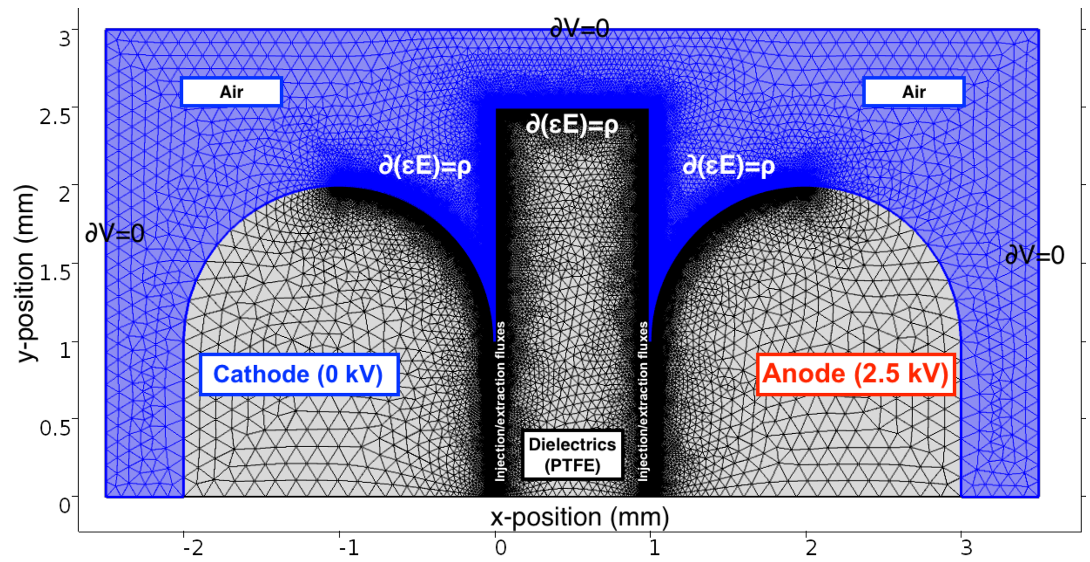

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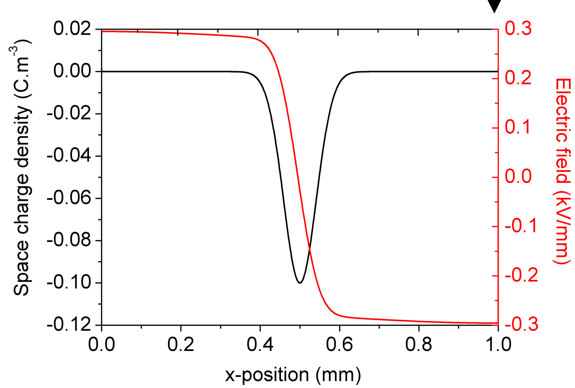

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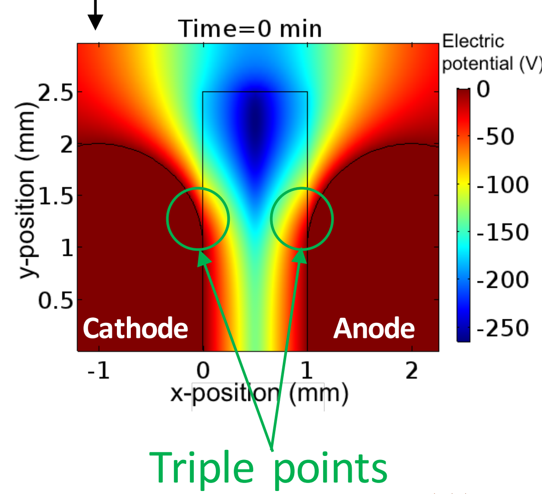

☞ Main model equations

- Poisson equation : $$\frac{\partial E(x,y)}{\partial x \partial y} = \frac{\rho(x,y)}{\varepsilon_r \varepsilon_0}$$
- Transport equation $$j(x,t) = n(x,t) \cdot \mu(E,t) \cdot E(x,t)$$
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- $j(x,t)$ the injection/extraction at interfaces : $J(x,t) = AT^2 \exp\left(-\frac{qW_{e,h}}{k_B T}\right)\left[\exp\left(\frac{q}{k_B T}\right)\sqrt{\frac{qE(x,t)}{4\pi\varepsilon}} - 1\right]$

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11 variables to compute for model solving - Implementation under General-PDE modules

STUDY CONTEXT AND PROBLEMATIC

COMSOL® IMPLEMENTATION & SIMULATION MODEL

MAIN SIMULATION RESULTS

Results validation - Paschen limit applied to partial discharges

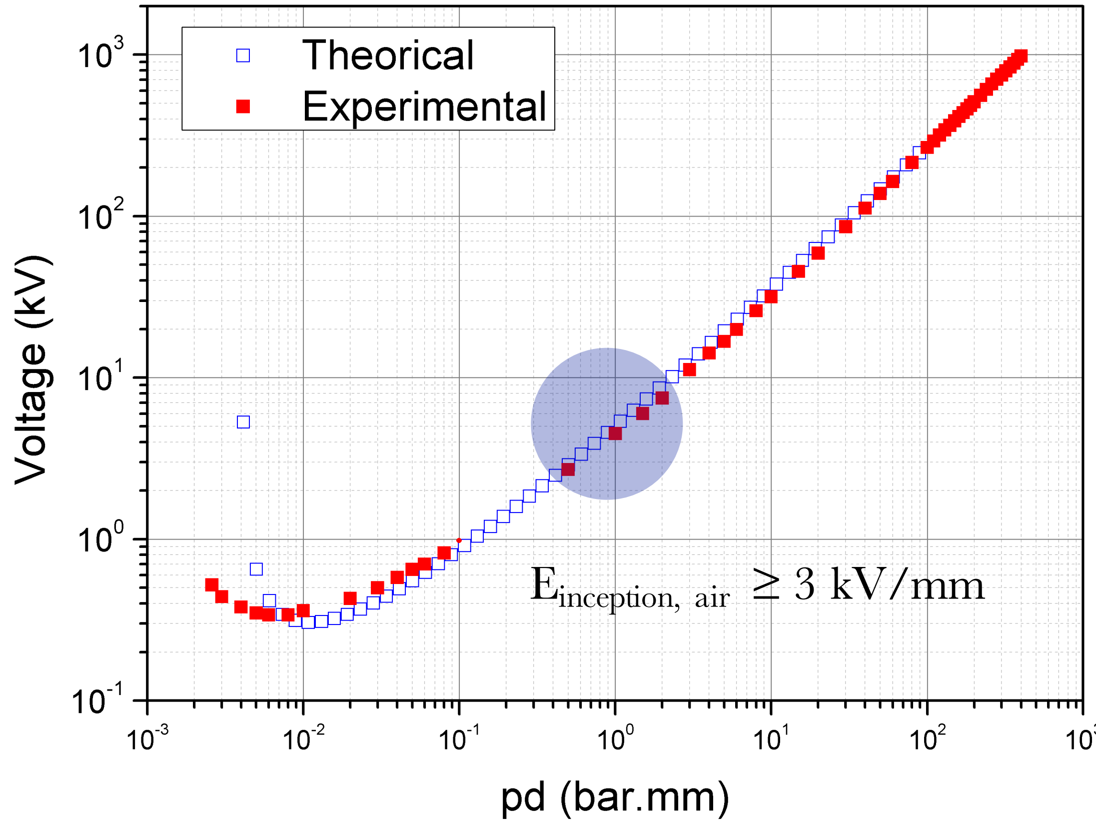
☞ $\begin{cases} (P, T°) = (1{,}013 \text{ bar}, 20°C) ; \\ \text{Uniforme electric field /air gap ;} \\ \text{Plane electrodes ;} \end{cases}$

$$U_p = \frac{B \cdot (pd)}{\ln(pd) + \dfrac{A}{\ln\left(1 + \dfrac{1}{\gamma}\right)}}$$

$$A_{air} \simeq 15 \ (\text{Torr}^{-1}.\text{cm})$$

$$B_{air} \simeq 365 \ (\text{V.Torr}^{-1}.\text{cm}^{-1})$$

$$\gamma_i = \frac{n_{\text{secondary}}}{n_{\text{ion}}}$$

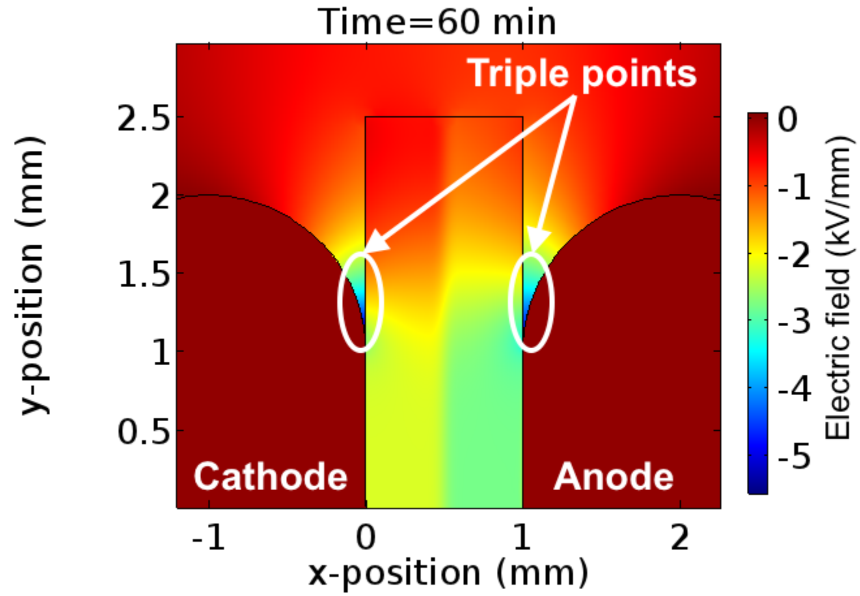


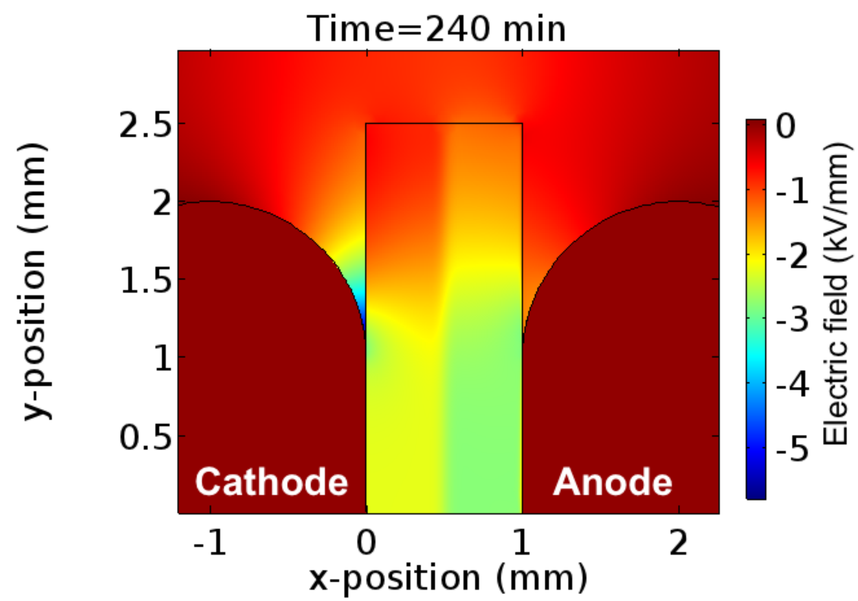
[1] *F. Paschen Über die zum Funkenübergang in Luft, Wasserstoffand Kohlensäure bei verschiedenen Drücken erforderliche Potentialdifferenz, Wied. Annalen der Physik und Chemie.* Wiede-manns Annalen, Ser. 3, **37**(1), 69 (1889)

Electric field at triple points

- $E_{max}(x, t)$ decreases by 72% at anode triple point and increases by 4% at cathode triple point ;
- Implanted charges disturb the electric field distribution in dielectrics ;
- $|E_{max}(x,t)|$ in air ≥ $3\ kV/mm$;

Partial discharge risk at triple points.

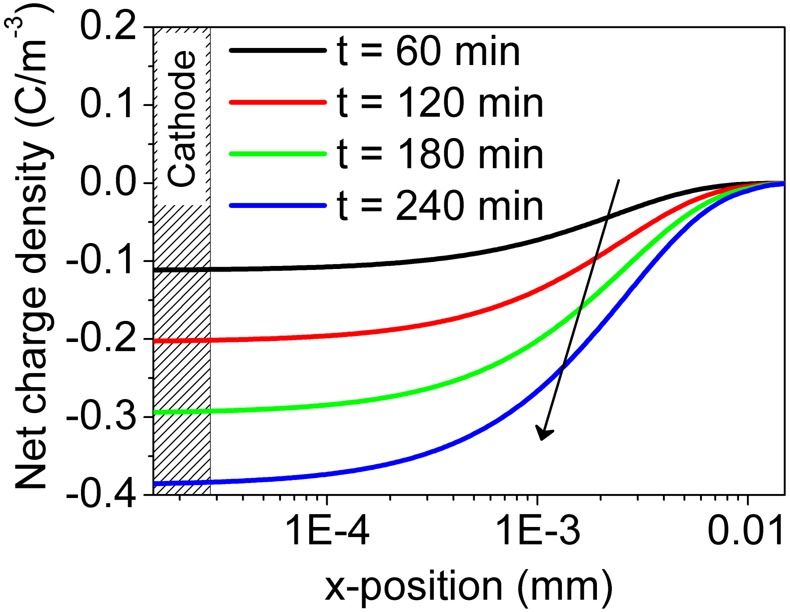


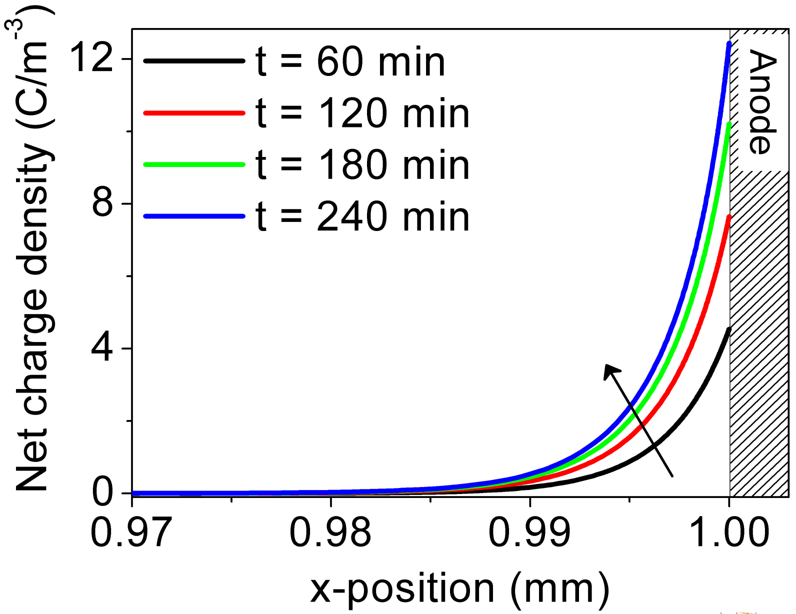


Charge injection mechanism at triple points

- More holes injection from anode than electrons from cathode ;
- Each charge type increases with time at both interfaces ;
- Low trapping and transport mechanisms in the bulk with time ;

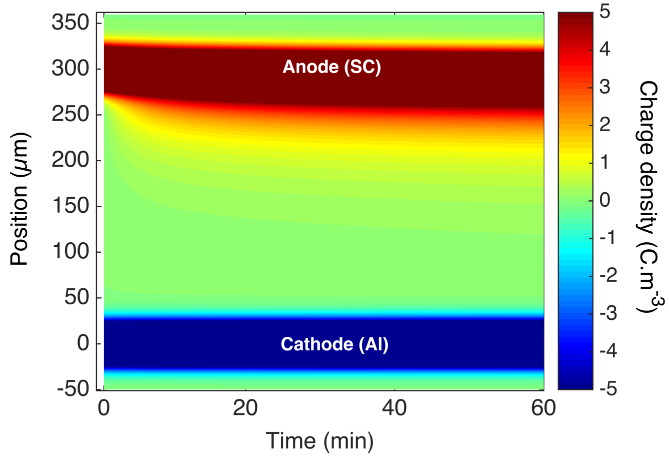
The nature and distribution of injected charges has a significant impact on partial discharge risk at triple points.



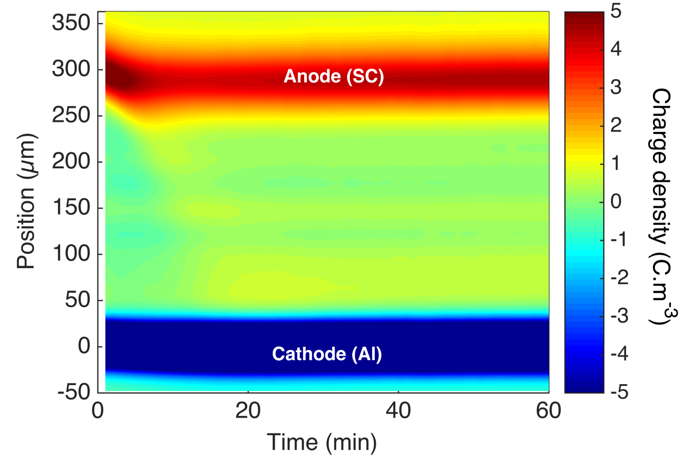


Simulated Model giving well agreement with experimental measurements for LDPE material

Simulation



Measurement



Confrontation with PTFE experimental measurements

Use of Powerful Comsol® solver to compute the model more quickly than Fortran® source code

THANK YOU FOR YOUR ATTENTION