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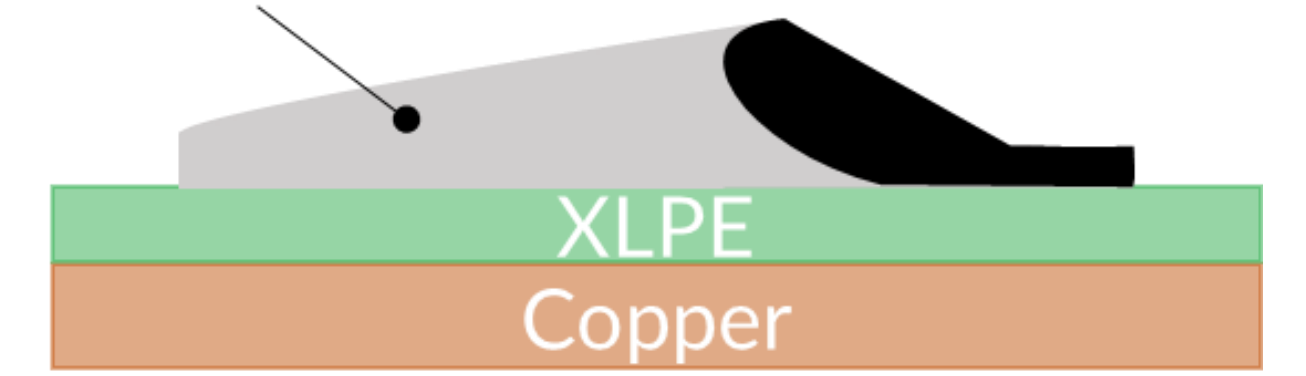
# Study of the electrical properties of HVAC EPDM and HVAC silicone rubber under DC constraint

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## Abstract

EPDM and Silicone Rubber (SiR) are elastomeric materials used in HVAC cable accessories due to their good mechanical and electrical properties. In this paper one EPDM and one SiR, are tested in DC conductivity and space charge measurements using the pulsed electroacoustic method (PEA) at different electric fields and temperatures. The electrical behaviour of silicone under DC stress is found to be largely governed by space charges while this effect is more limited for EPDM.

Elastomer stress cone



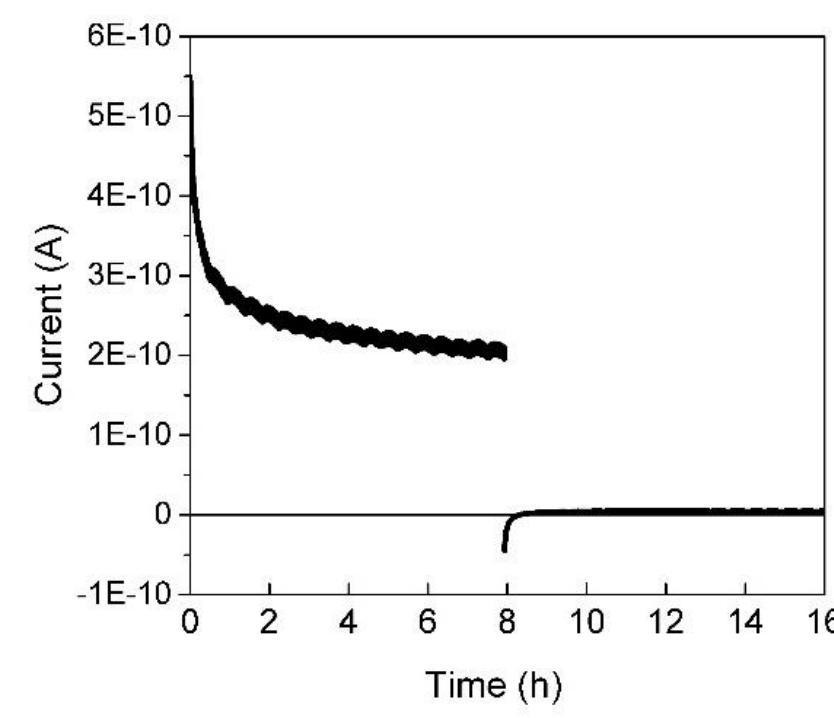
## DC conductivity



- 8 h polarisation / 8 h depolarisation
- Thickness: 1mm SiR and 2 mm EPDM
- Dry environment
- 30, 50 and 70 °C
- 1 to 25 kV/mm

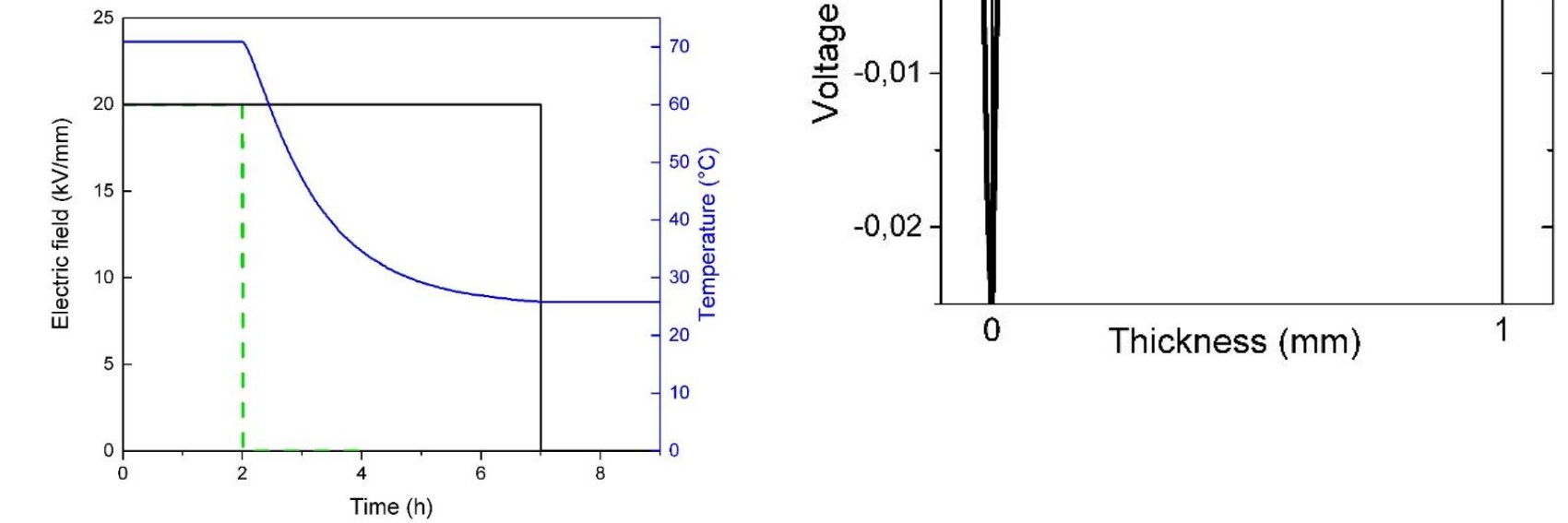
$$I_{DC} = |I_{pol} + I_{depol} - 2 \cdot I_{offset}|$$

$$\sigma_{DC} = \frac{I_{DC} \cdot e}{E \cdot S}$$



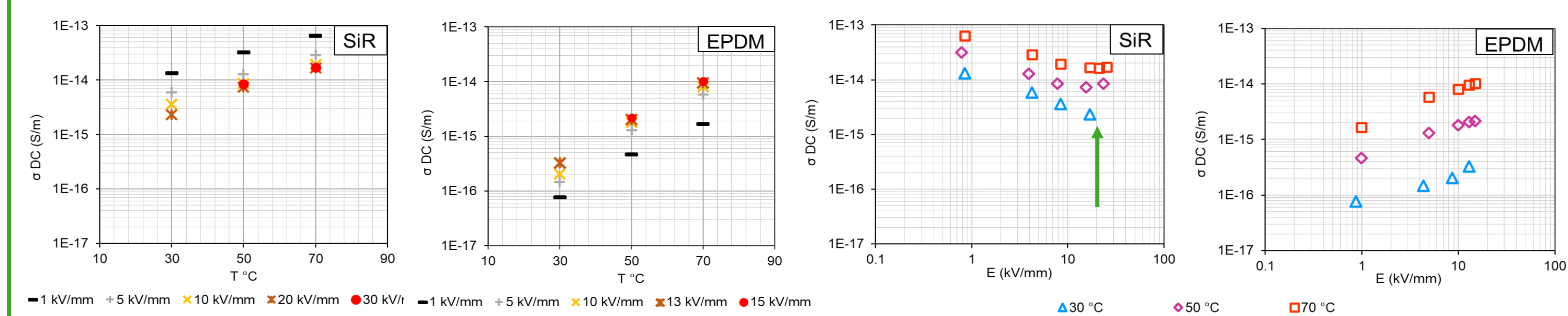
## Space charge PEA

- Polarisation at 30 and 70 °C
- Depolarisations at 25, 30 and 70 °C
- 5 or 20 kV/mm
- Thickness 1 mm



## Results

### DC conductivity



- Increase in apparent DC conductivity of SiR and EPDM as a function of temperature:  
→ Higher temperature dependency for EPDM.

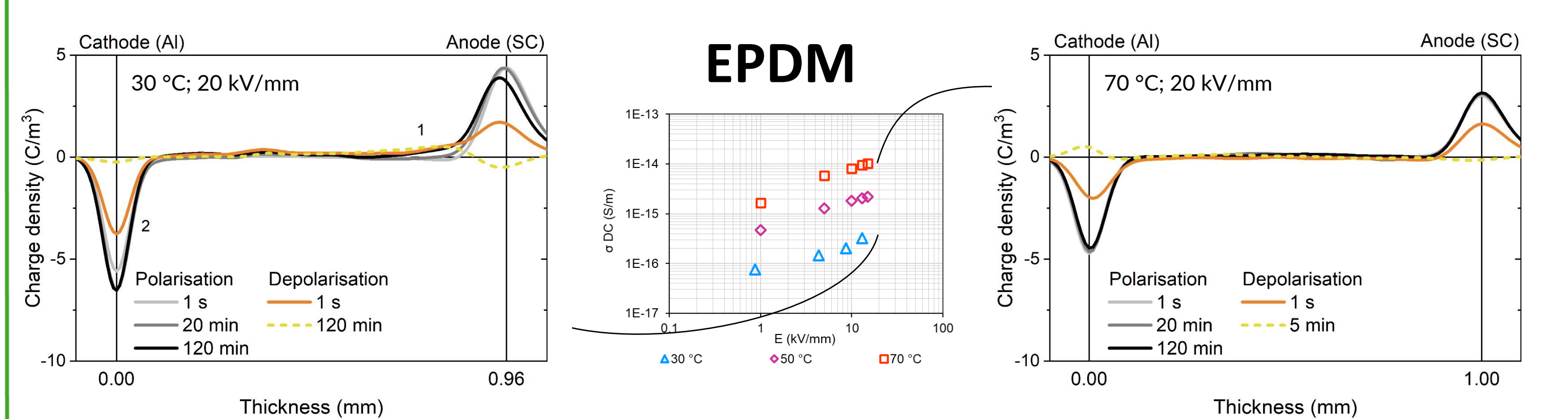
- Negative trend in SiR below the electric field threshold.
- The conductivity of EPDM increases as a function of the electric field:  
→ Injected charges contribute to the conduction for both SiR and EPDM [1].

$$\sigma_{SiR} = 1.5 \times 10^{-16} \cdot e^{0.04T - 0.14E}$$

$$\sigma_{EPDM} = 1.18 \times 10^{-17} \cdot e^{0.086T + 0.11E}$$

Below the threshold [1; 18kV/mm]  
Full range [1; 15kV/mm]

### Space charge PEA

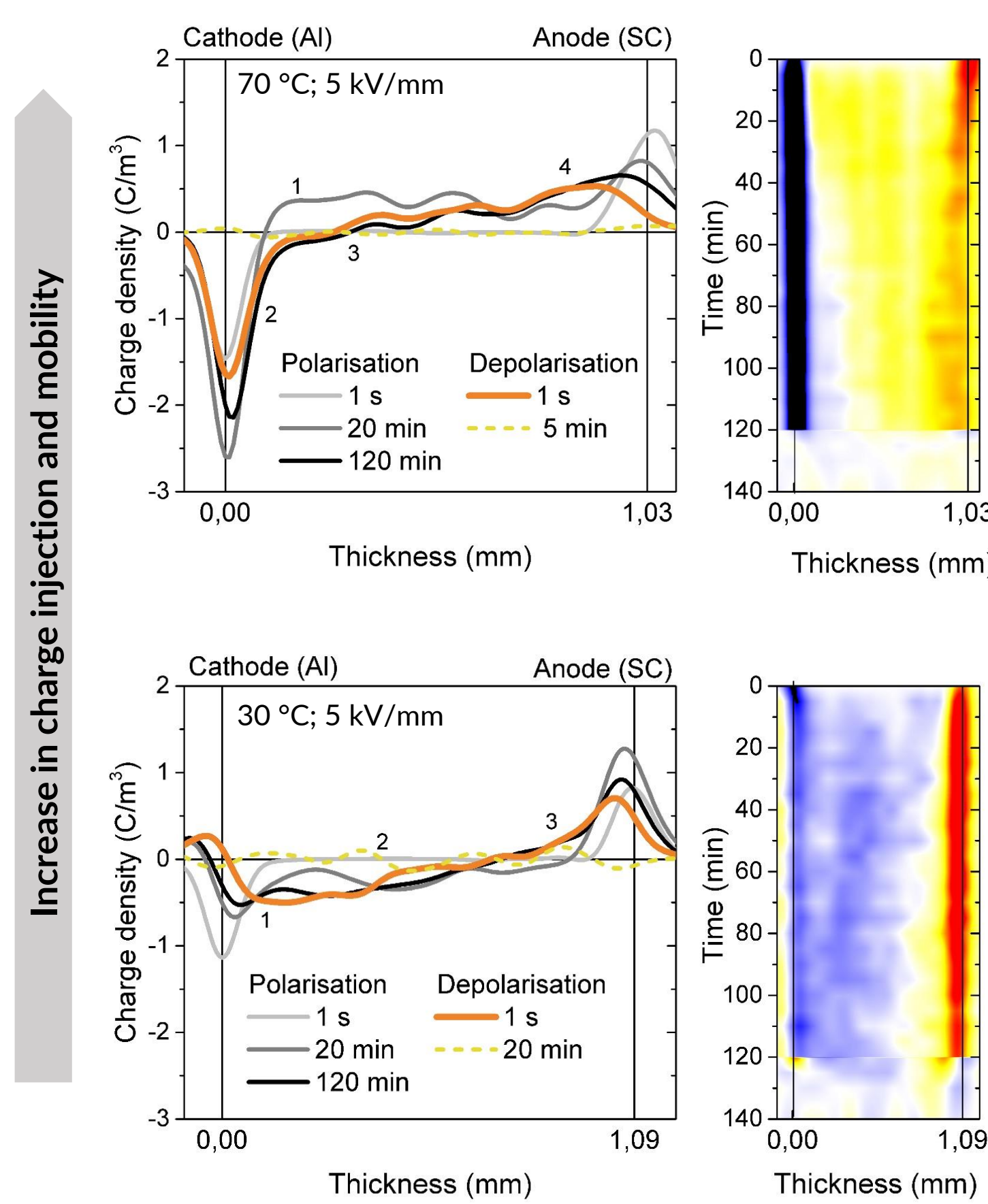


- At 30 °C positive accumulated homocharges next to the anode:  
→ The peak at the anode slightly decreases and shifts towards the bulk of the material [2].
- After 2 h of depolarisation the accumulated charges remain in the material.

- At 70 °C the charge profile is not modified during polarisation and it is assumed that injected charges contribute to the current.

### General observation

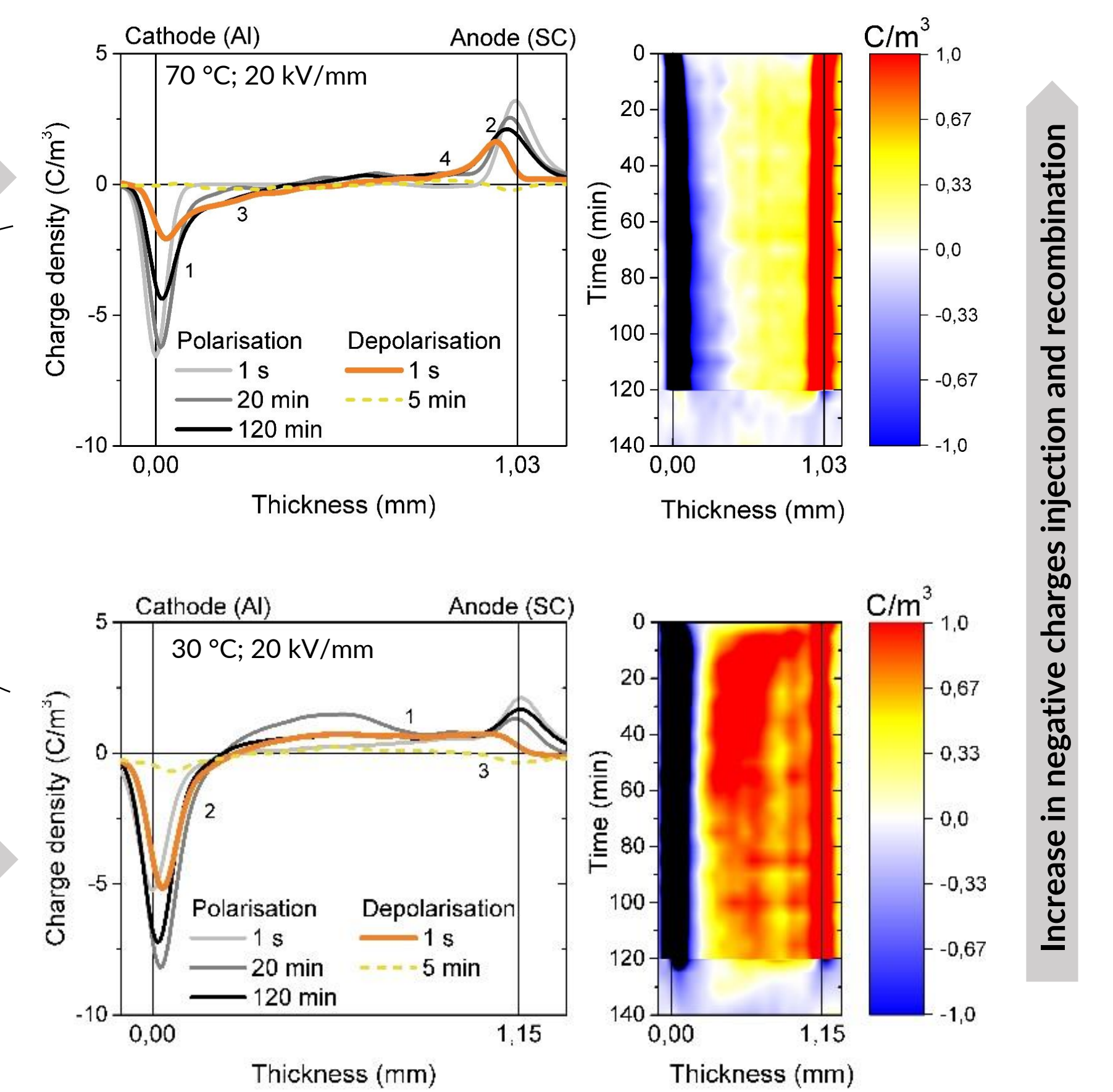
- Accumulated homocharges in all conditions:  
→ Strong decrease and shift of the electrode peak towards the bulk of the material.  
→ Local decrease in electric field.  
→ Decrease in further injection "blocking electrode effect".  
→ Limitation of conduction current resulting from injected charges [3].
- Homocharges are injected in SiR:  
→ Observed at both electrodes.  
→ Trapped at the injecting electrode as homocharges.  
→ Accumulated at the opposite electrode as heterocharges.
- Positive and negative homocharges can recombine during polarisation and can be evacuated during depolarisation.
- Full discharge observed in all conditions after maximum 20 minutes of depolarisation.
- High temperature and electric field accelerate the charge injection, mobility and recombination dynamics.



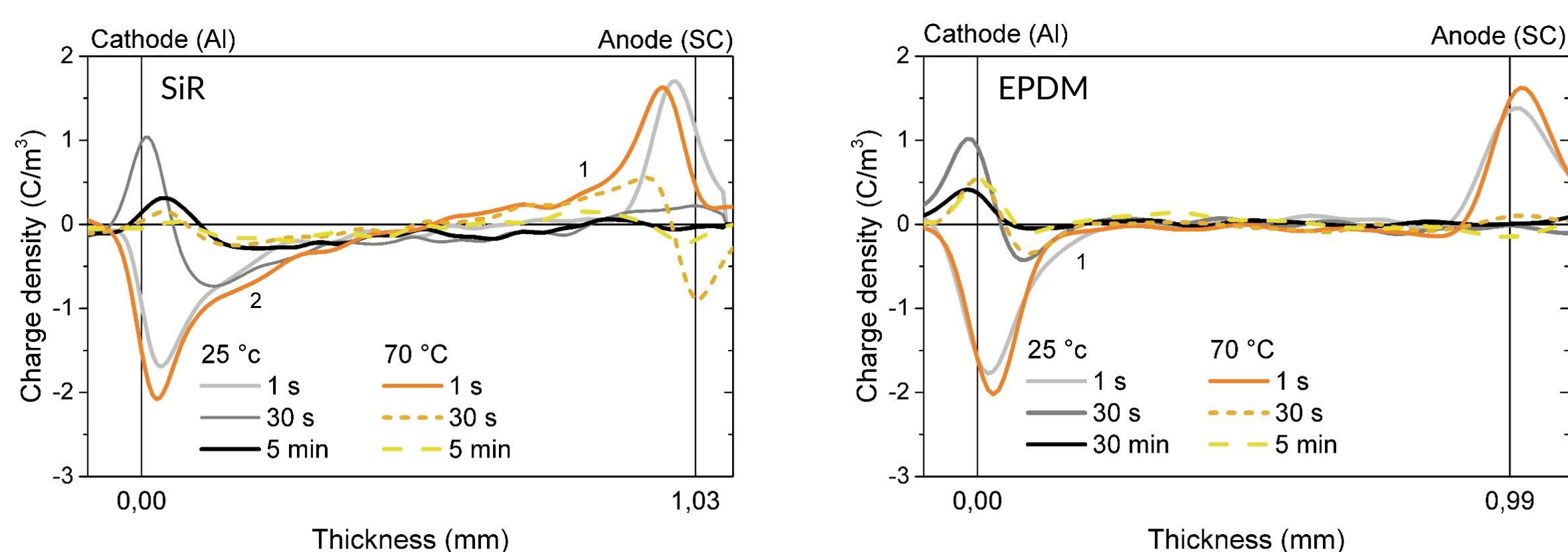
### SiR

Increase in negative charges injection and recombination

Increase in charge injection and mobility leading to higher charge density in the bulk



### Temperature during depolarisation



- Positive homocharges are injected in SiR during the temperature decrease.
- Discharge of both materials:  
→ Increased with temperature.  
→ Charge dynamic seems to be a reversible phenomenon.

- Space charge profiles confirm that injection occurs on the whole measurement range for both materials.
- The injected charges move freely in the material in the case of EPDM:  
→ Conductivity increases as a function of the electric field.
- The injected charges are accumulated in the material in the case of SiR. The presence of homocharges close to the electrodes decrease the electric field locally therefore limiting the injection of additional charges acting as a blocking electrode [3]:  
→ Conductivity decreases as a function of the electric field below the threshold.

## Conclusion

- Both EPDM and SiR have a low charge injection threshold.
- Injected charges have a significant impact on the apparent conductivity of both elastomers.
- Charge dynamics in SiR depends on temperature and electric field.
- Injected charges can accumulate in the materials, but are easily evacuated (except for a limited number of charges in EPDM) and therefore the charges are considered to be in shallow traps and the accumulation is a reversible phenomenon rather than a consequence of a material degradation.

[1] G. C. Montanari and P. H. F. Morshuis, "Space charge phenomenology in polymeric insulating materials," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 12, no. 4, pp. 754-767, 2005.

[2] W. Wang, Y. Tanaka, T. Fujitomi, T. Takada, and S. Li, "Study on conduction current and space charge accumulation simultaneously in Ethylene Propylene Diene Monomer film," *ICEMPE 2017 - 1st Int. Conf. Electr. Mater. Power Equip.*, no. January 2018, pp. 464-467, 2017.

[3] D. H. NGUYEN, "Etude des propriétés électriques des élastomères silicones utilisés pour l'isolation électrique," 2005.