STRESS GRADING SILICONE GELS IN ELECTRONIC POWER MODULES

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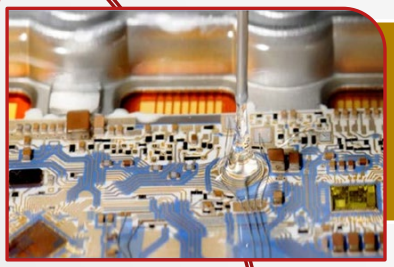
CRW engineering

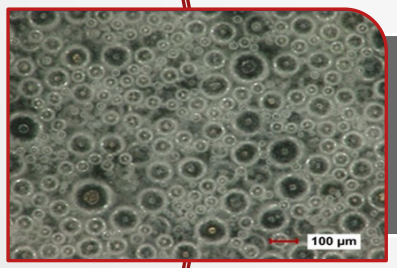
Agenda

1. Introduction to „Gel Project“
2. Nonlinear conductive silicone gels
3. Functionality of field-controlling gels
4. Summary and outlook

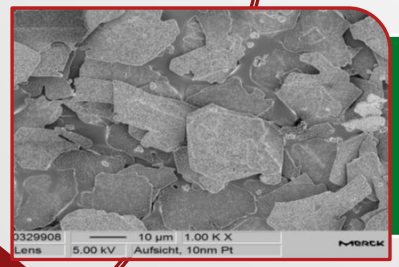
1. Introduction



Phase I (2000 – 2005):
Evaluation of the behavior of (pure) silicone gel

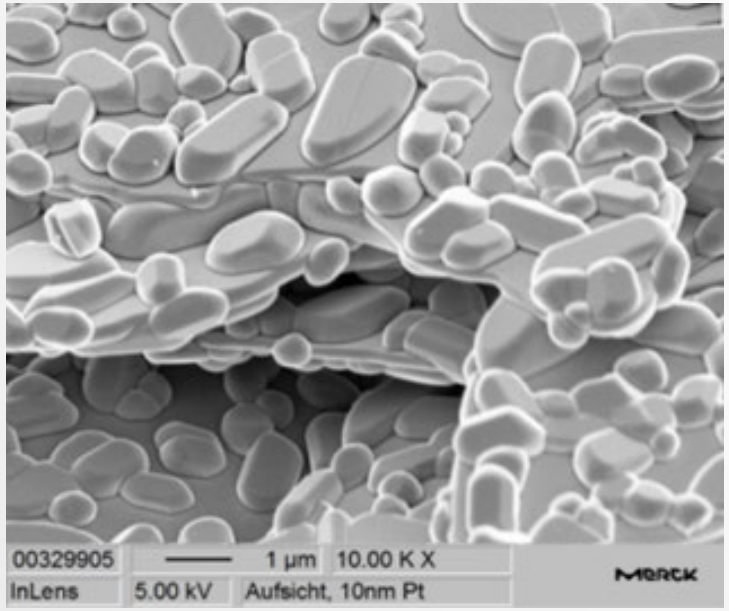


Phase II (2006 – 2010):
Investigation of hollow microsphere-filled silicone gel

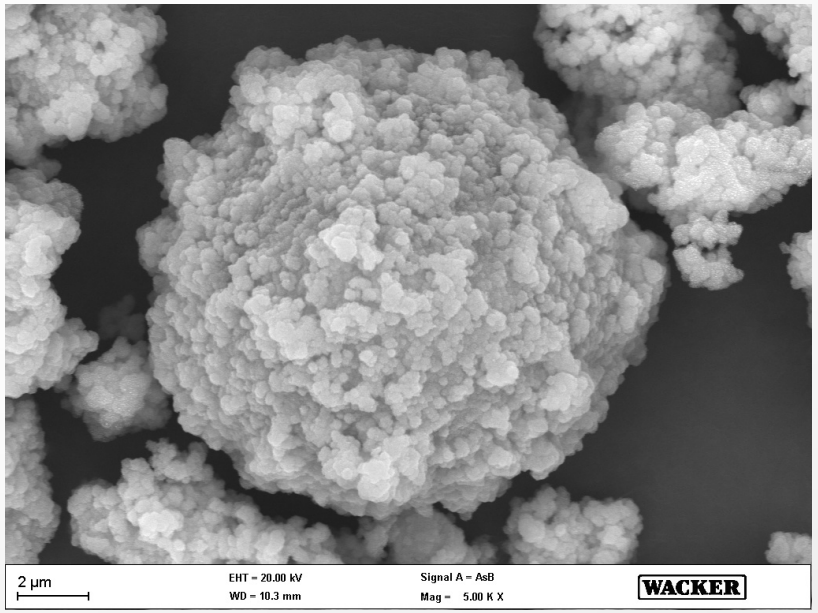


Phase III (2011 – 2021):
Field-controlling nonlinear gels: Smart Gel (NLCM)

2. Nonlinear conductive silicone gels



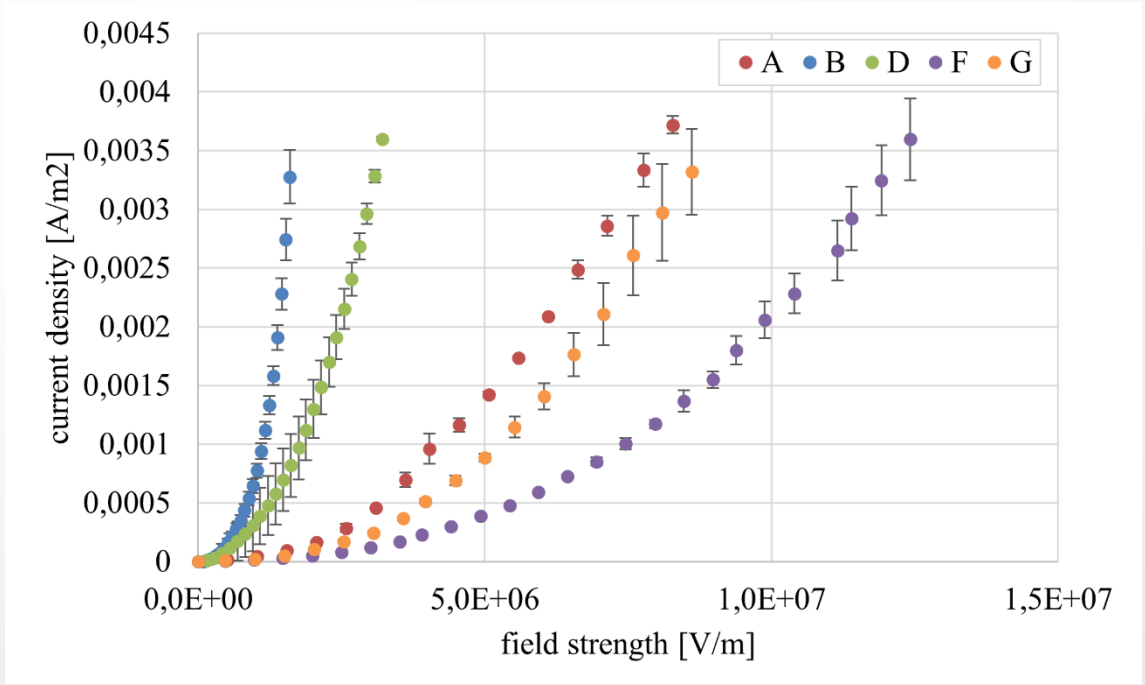
SEM Image of mica platelets with doped metal oxide coating



SEM Image of spherical substrate with doped TiO2 coating

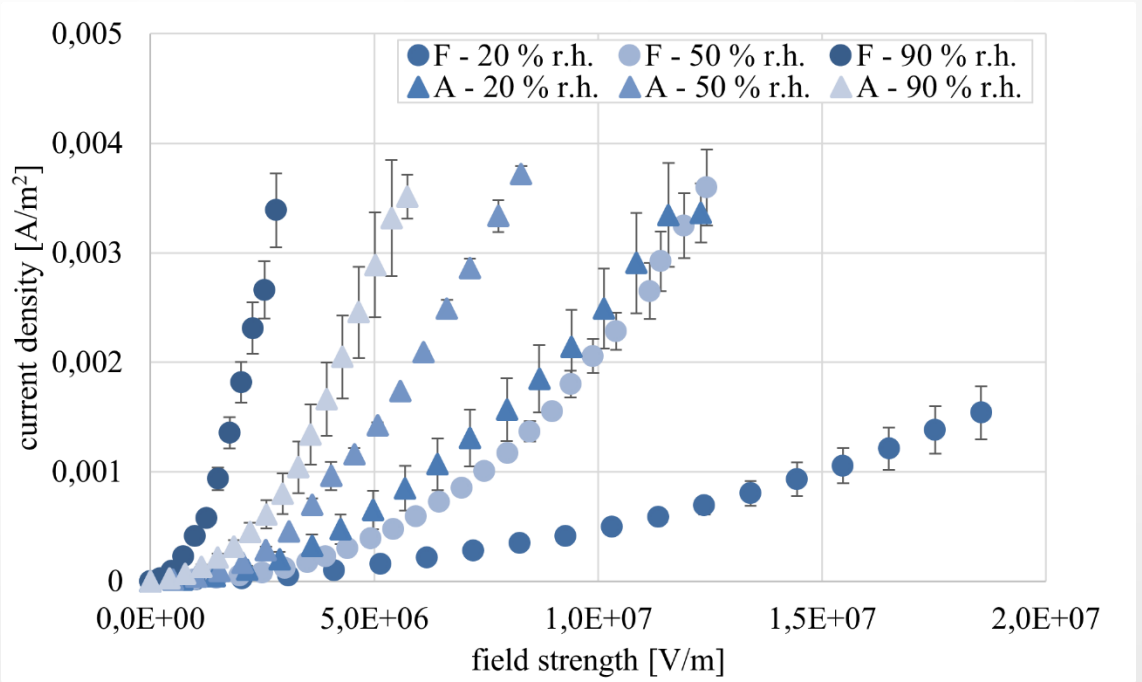
Current density – electric field strength behavior of different gel compounds

- Degree of nonlinearity determined by filling degree of additive
- Optimal material choice depending on application, operation conditions and stress level
- Operating point: 0.001 A/m²
- Tangent between operating point and x axis → reference field strength



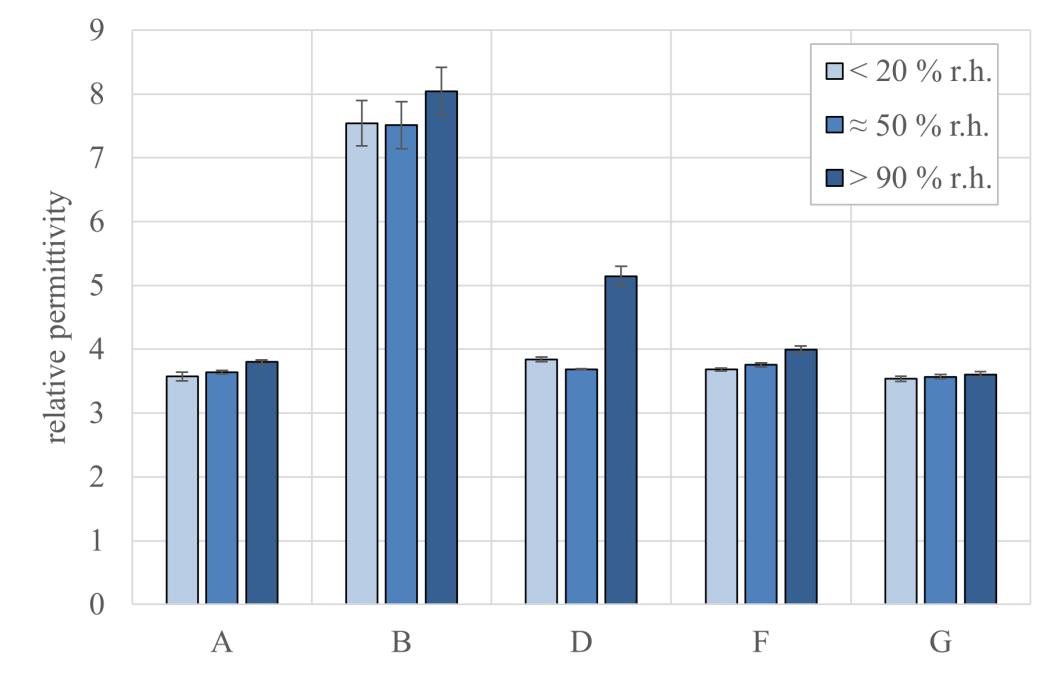
Influence of moisture on J-E characteristics

- Depending on application: ambient conditions may have influence
- Humidity has a significant influence on J-E characteristics and electrical properties
- Adding up with the inherit differences between the different compounds



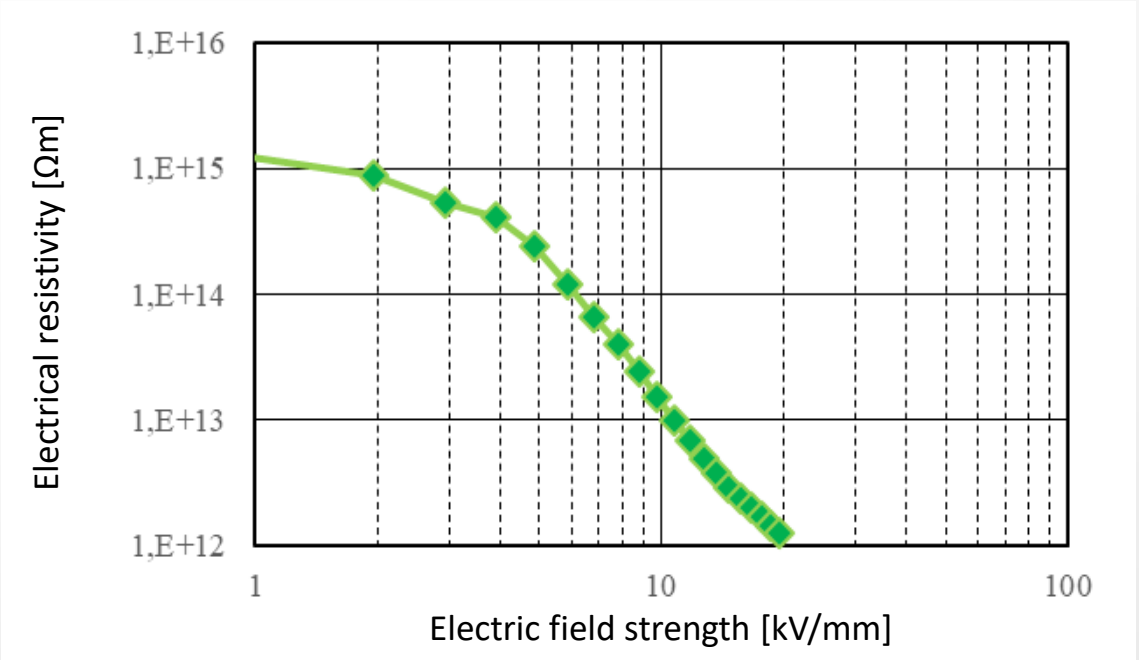
Moisture influence on electrical properties

- Relative permittivity also depending on ambient humidity
- Dopants also affect the permittivity
- Increase explained by high polarizability of water molecules stored in compound



Specific electrical resistance as function of the field strength

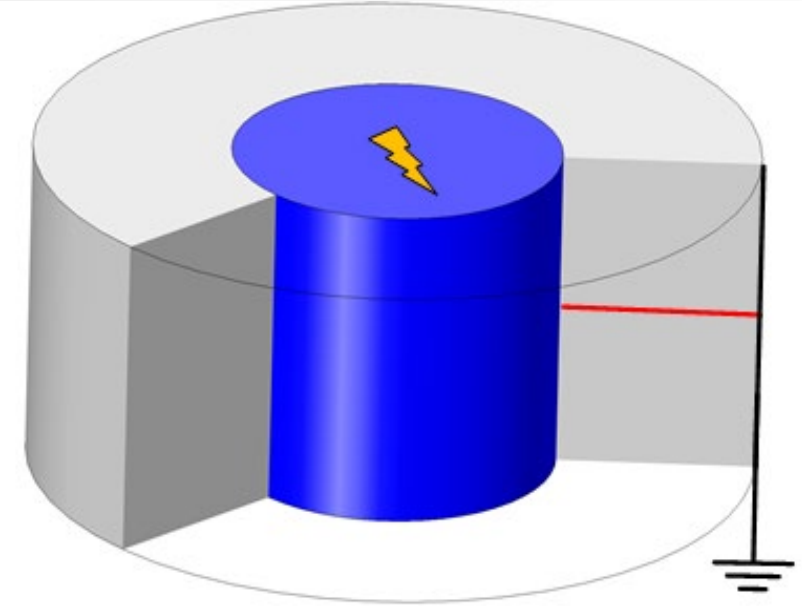
- Compound with spherical additive
- Alternative display of nonlinear behavior
- Only local field strength increase inside dielectric material

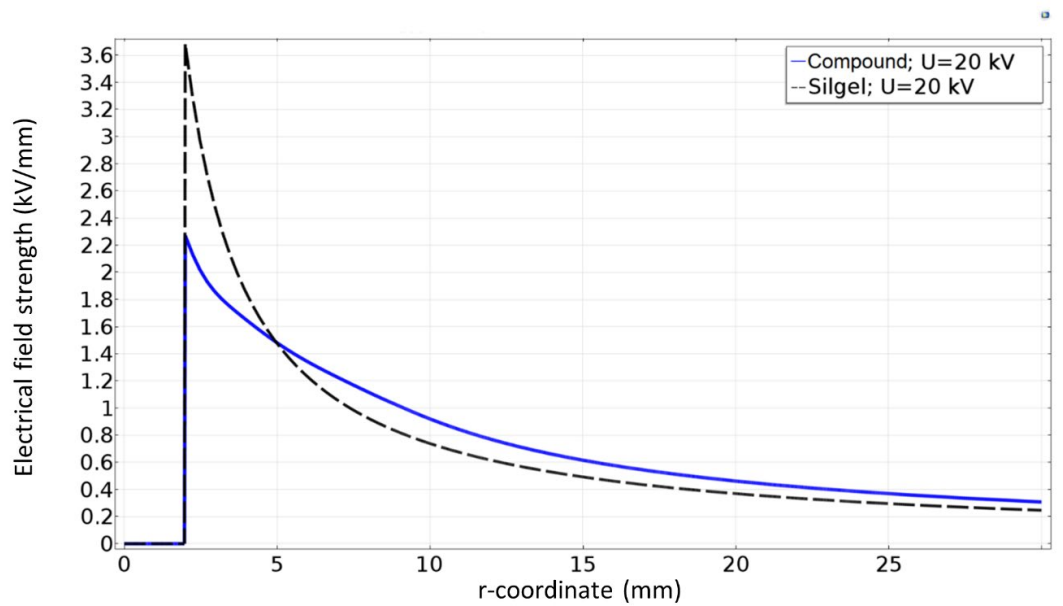


3. Functionality of field-controlling gels - simulation

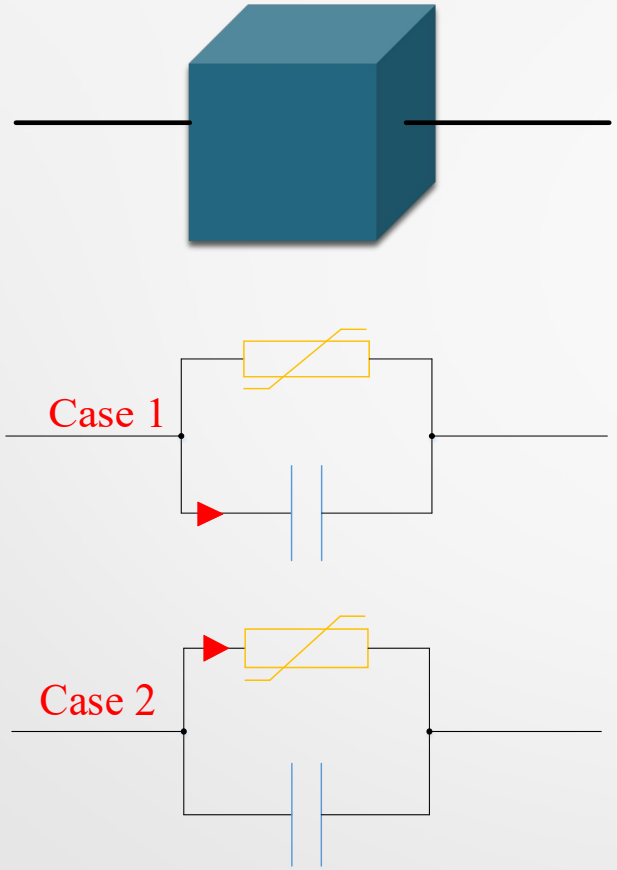
Coaxial arrangement

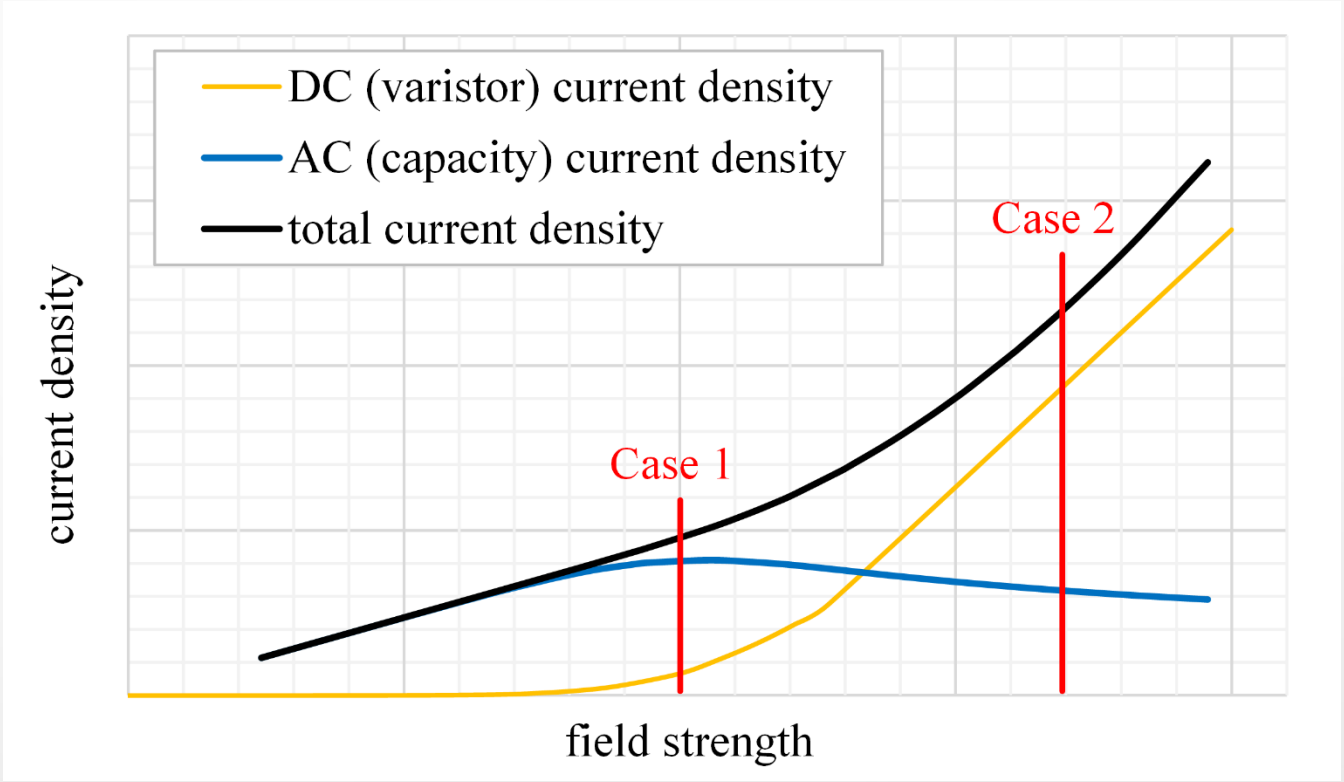
$$E(r) = \frac{U}{\ln\left(\frac{r_2}{r_1}\right)} \cdot \frac{1}{r}$$



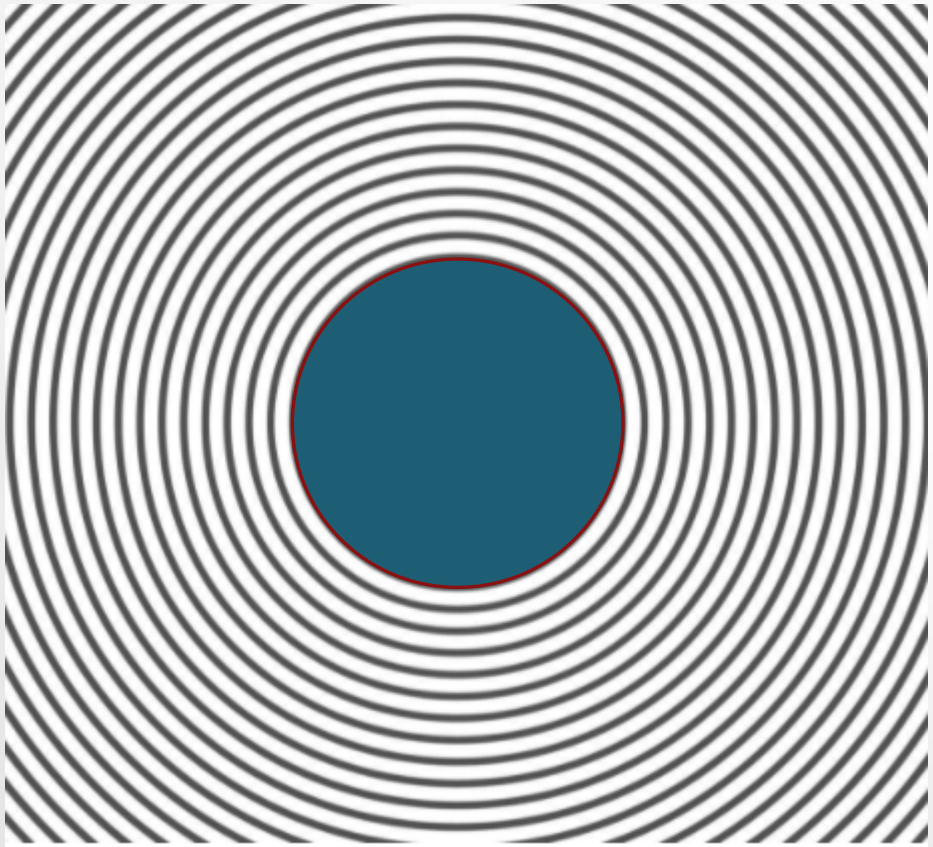


Equivalent circuit diagram of a volume element and current density for two different field strengths





Equivalent circuit diagram of coaxial arrangement



- ECD for each ring element
- Resistive behavior on inner elements
- Capacitive behavior on outer elements must be ensured

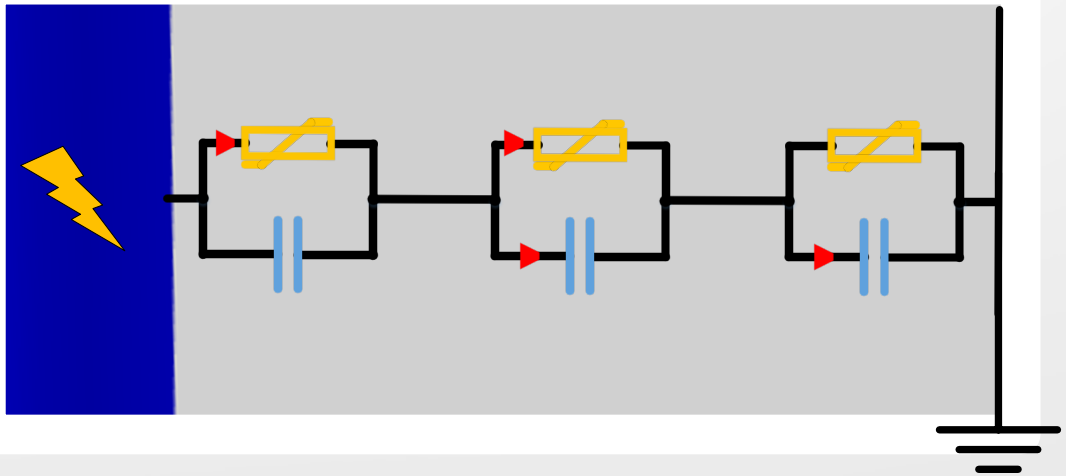
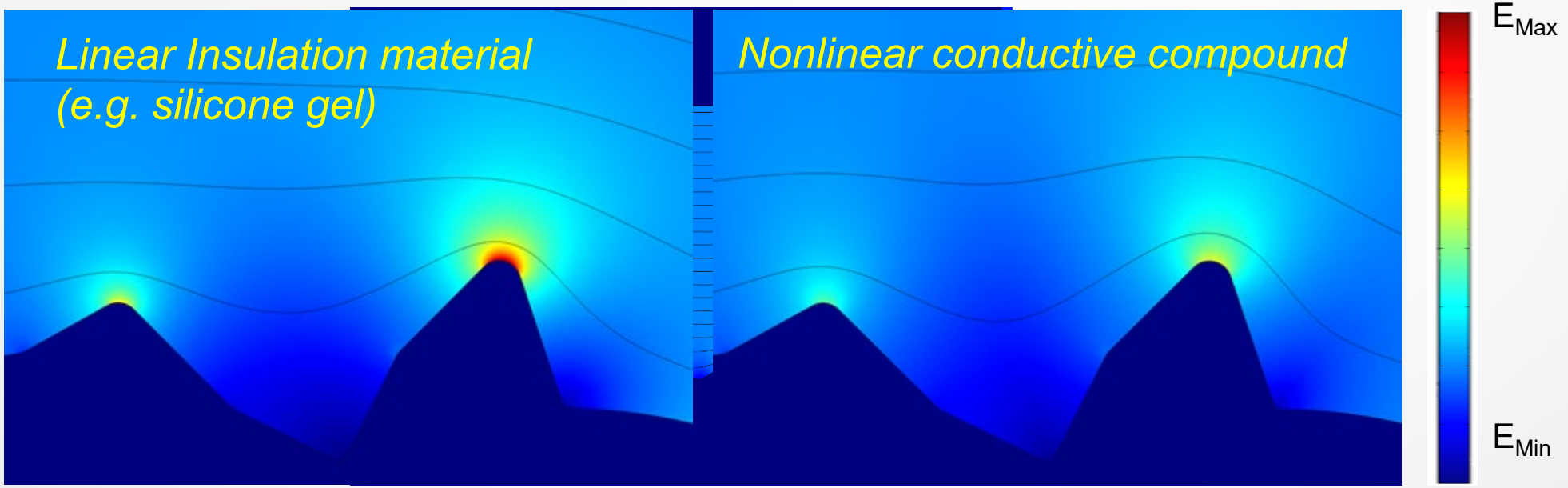
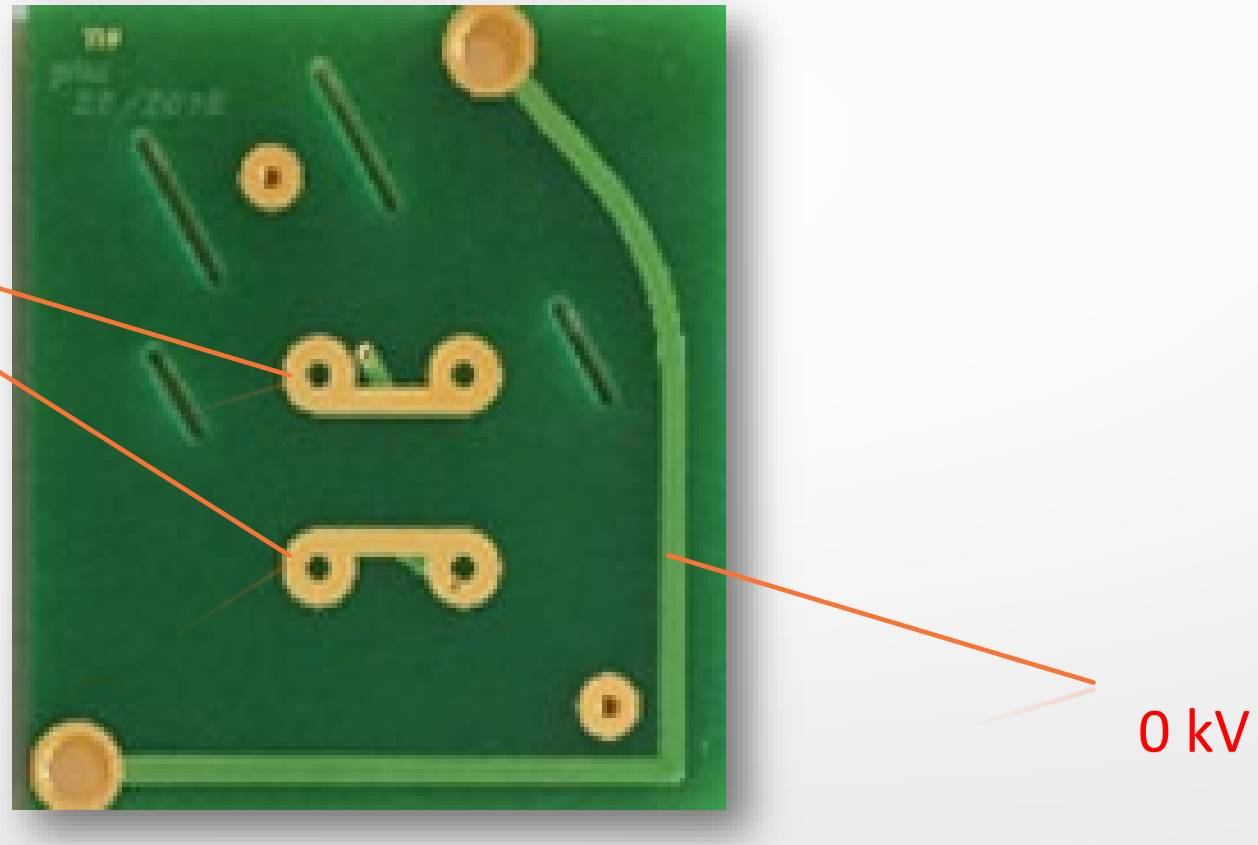


Plate-Plate arrangement with surface imperfections

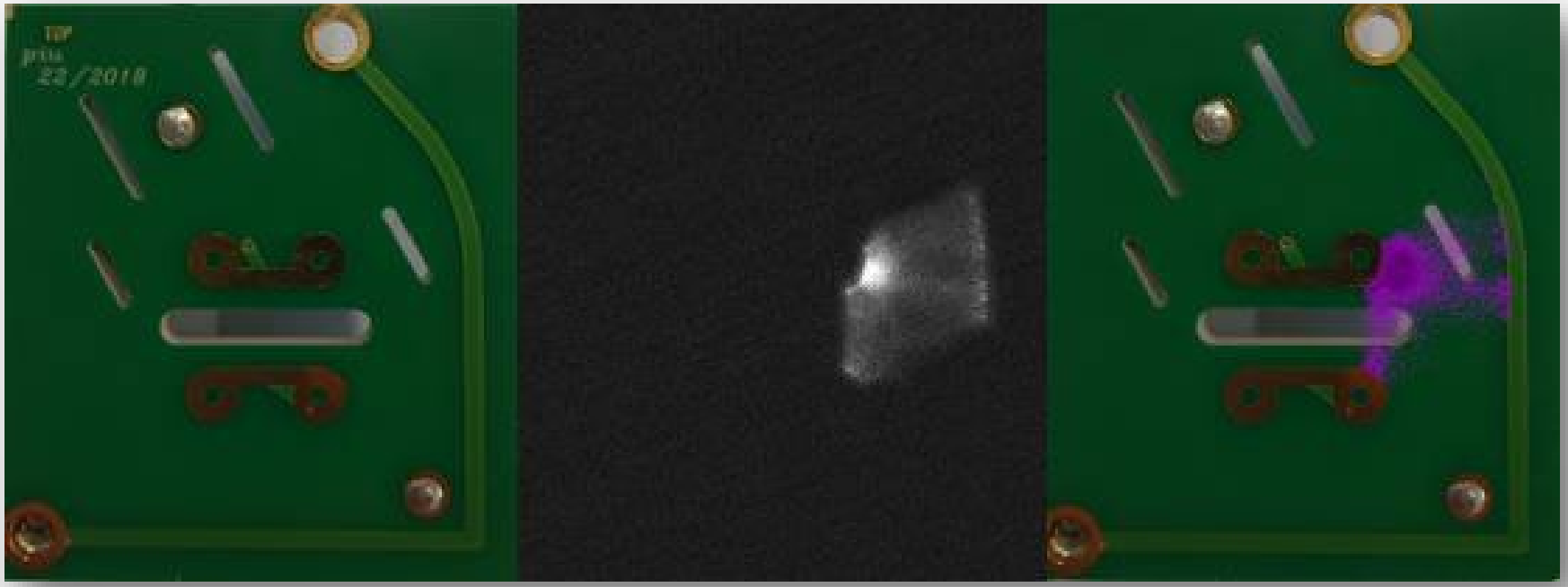


- Main advantage of nonlinear conductive gels (NLCM)
- Influence of surface imperfections decreased due to field-controlling effect, compared to linear material
- Reduced field strength peaks on edges
- Material can be used as coating

Application examples: circuit board of a semiconductor module



Application examples: Circuit board of a semiconductor module



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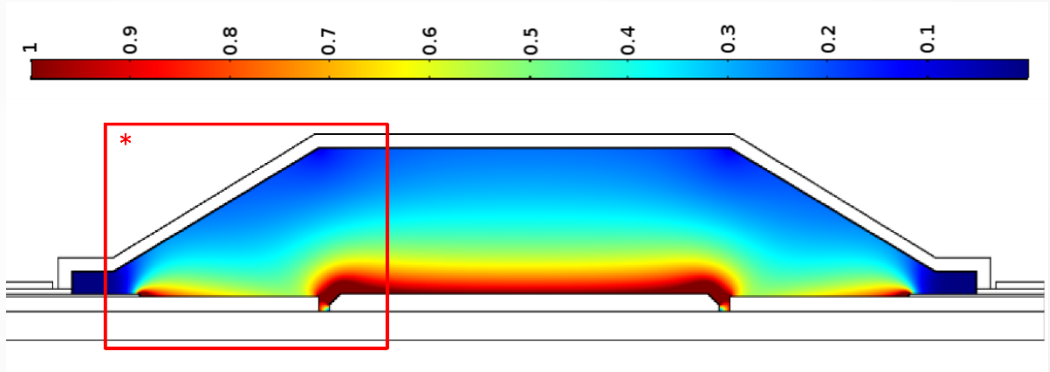
Standard image

UV image

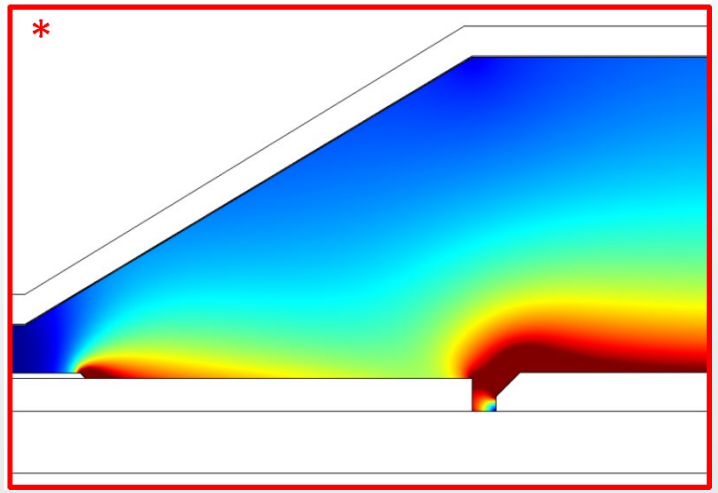
Combined standard + UV overlay with color indicator

Application examples: cable joint geometry

- Investigation of NLCM for MV application
- Reference field strength of 1kV/mm
- Working scale of compound in red areas



- Reduced specific volume resistance on edges
- Simulation results promising



Application examples: cable joint geometry prototype

- 3D printed housing
- Mounted and tested with standard MV-cable and connector
- Compound with nonlinear additive and hollow microspheres (HMS)
- HMS compensate the thermal expansion of silicone gel
- Tested according to DIN VDE 0278-629-1
- All tests passed → NLCM applicable for MV applications

Acknowledgments: Project Silicone gel

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Thank you for your attention
CitroGel 110
WaldGel 131
HimGel 122