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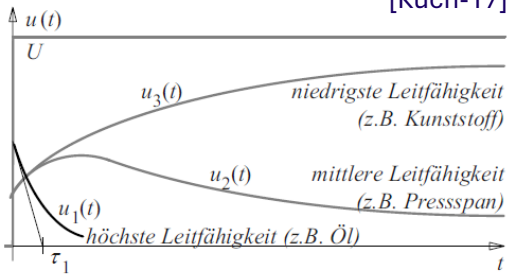
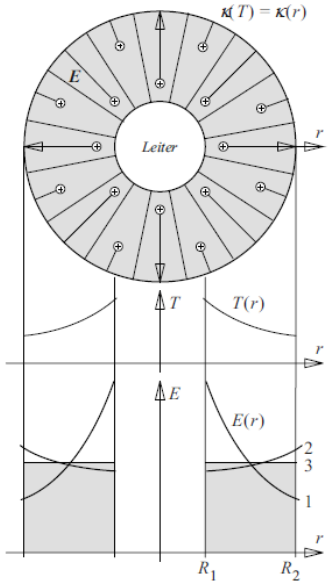
Measurement of the specific electrical volume resistivity on specimen made of LSR

Volume resistivity as a base for component development

- The specific volume resistivity is responsible for the electrical field distribution in the steady state
- Compared to AC and it‘s relative permittivity, there are a bunch of relevant differences
  - The specific resistivity of different materials might differ by some orders of magnitude
  - ➔ Some volume is stressed very low whereas other is highly (over)stressed
  - The specific volume resistivity depends strongly on the temperature
  - ➔ Load-depending field distribution with even field inversion possible
  - There is a transient process while changing stress („capacitive-resistive transition“)
  - ➔ Field inversion possible, in case of multi-dielectrics stress peaks can occur in the transition
  - ➔ Deep knowledge of the temperature- and stress-dependant volume resistivity is necessary

[Küch-17]

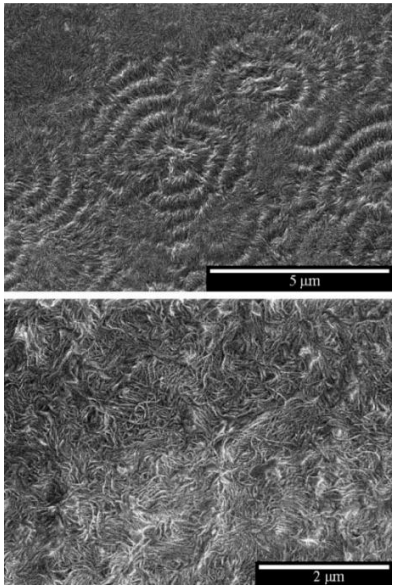




Differences between specimen and apparatus

- Measurements carried out on small specimen differ von real size mock-ups or real apparatus:
  - The surface-volume ratio changes significantly and surface effects e.g. due to release agents get a stronger influence
  - Absolute geometric deviation become bigger seen relative
  - Often, the chemical reactions in the molding / curing process differ due to the reduced material volume processed
  - Sometimes even different molding / curing processes must be used, which are less advanced and thus less clean. The manufacturing process has a huge influence on materials properties
  - Plate specimen can be cut out of bulk material. In that particular case the cutted edges and their influence must be taken into account
  - ➔ Differences between specimen and apparatus are exisiting and thus must be taken into account

[Kar-17]

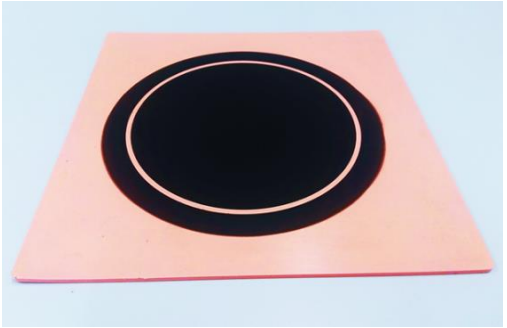


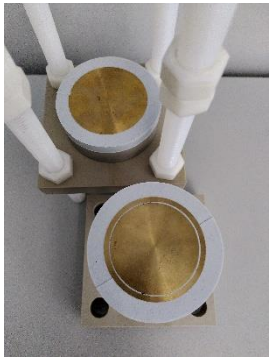
Measurement: Preconditioning

- Aim of the preconditioning is the removement of the by-products and the establishment of a certain humidity
  - No further degassing and humidity-diffusion during the long-term measurement
  - Separation of the above-mentioned diffusion processes and it‘s influence vs. the capacitive-resistive transition
- Temperature and duration must be suitable for the material
  - Degassing and drying successful
  - Undesired aging must be avoided
- After preconditioning no further handling steps shall be carried out
  - Cleaning and geometrical measurement
  - Application of surface electrodes
  - ➔ Preconditioning must be suitable for the material

Measurement: Contacting and Electrodes

- Aim is a perfect contact
  - Repeatable and even reproducible, noise-reduced measurement results
  - No feedback of the contact technique on the measurement results
- Contacts / Electrodes
  - Direct and permanent applied electrodes
    - > Painted electrodes with a conductive lacquer
    - > Sputtered gold electrodes
  - Contacting electrodes
    - > Metallic contact
    - > Polymeric, conductive contact
  - ➔ Contacting system must be suitable not only for the material under test but for the whole test setup (temperatures, duration,...)

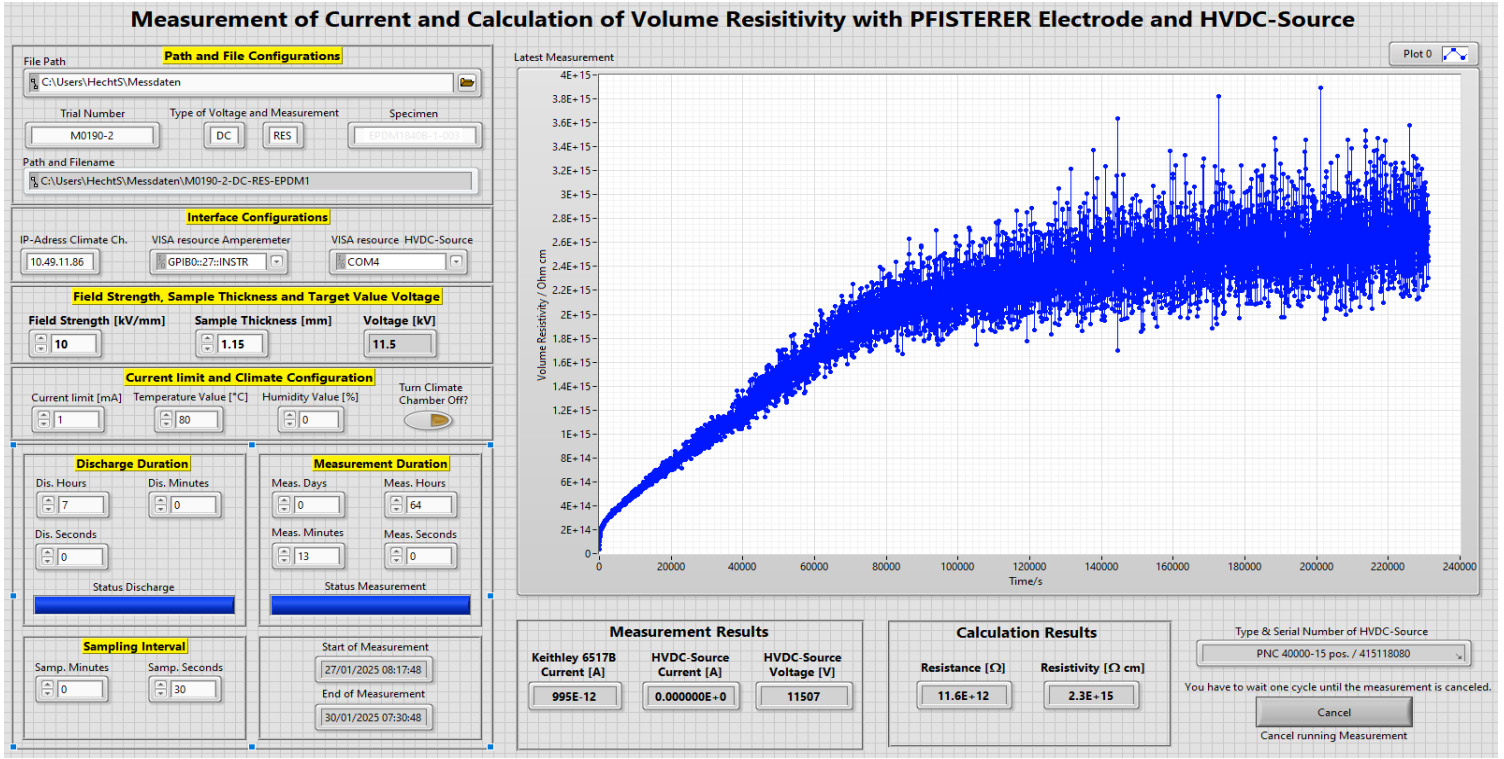




Measurement: Setup and Performance

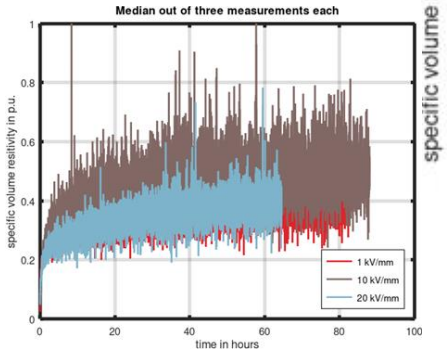
- High dielectric field strength (some kV/mm) and very low currents (Pikoampere, sometimes even femtoampere)
  - Shielding and separated ground including a transformer to reduce the noise
  - Protection of the operator from high voltage
  - Protection of the instrument in case of a breakdown
- Long-term measurement
  - Completely remote controlled by *LabVIEW*
  - Data written in CSV file
  - ➔ Longterm measurement without breakdown / data loss

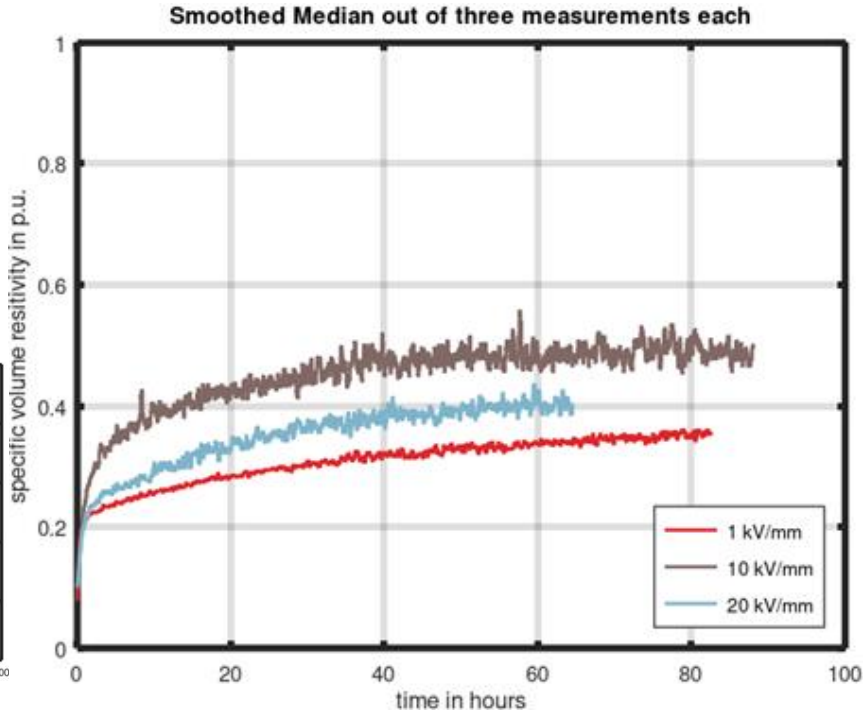
Measurement: Setup and Performance



Measurement: Data evaluation

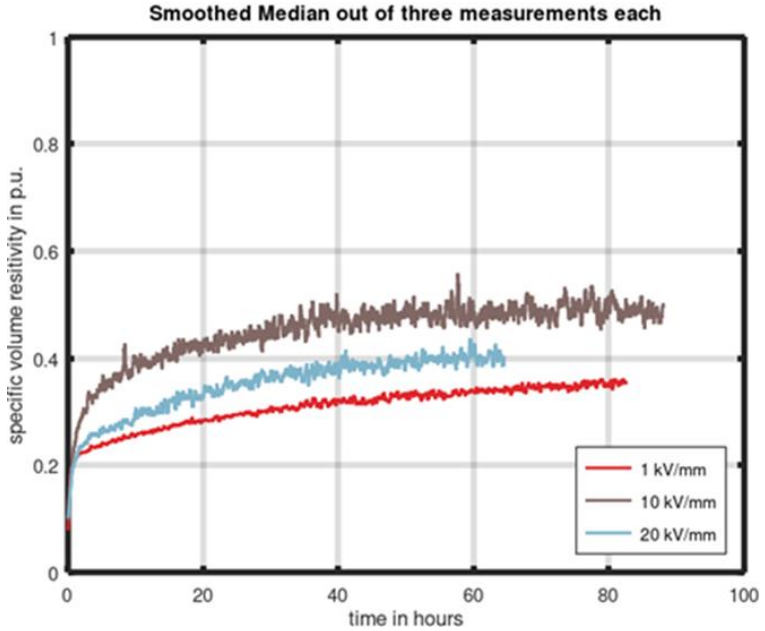
- Comparison of at least three measurements with identical set of parameters
  - For the detection of outliers and to get a median value
- Removement of noise
  - Moving median / average over one curve
  - Median / average made out of the curves with identical set of parameters

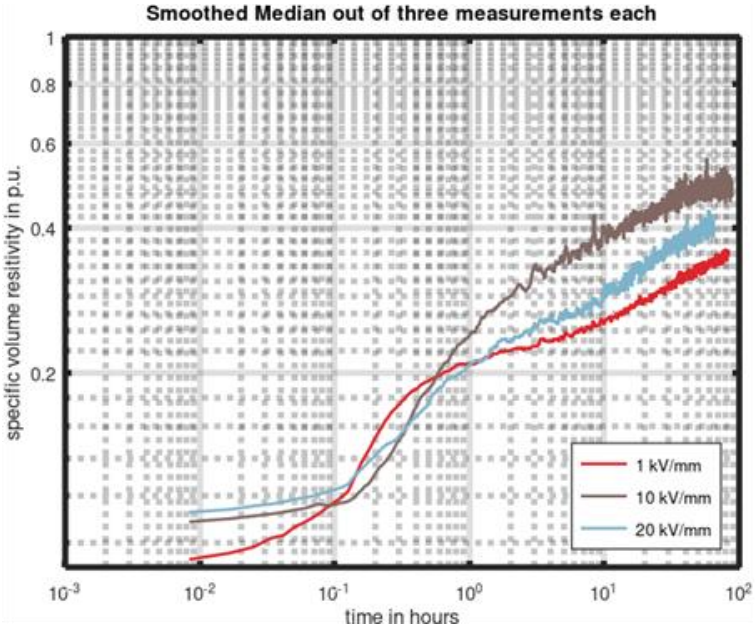




Measurement: Data evaluation

- Representation in double logarithmic form is common

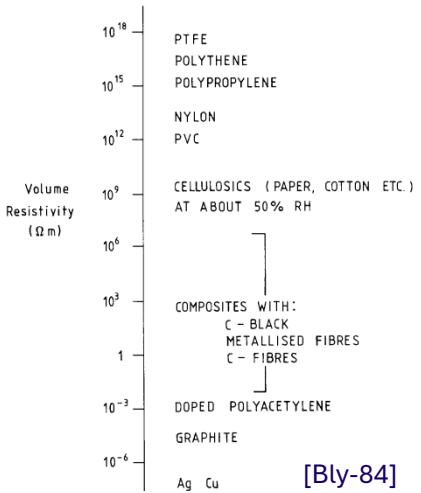




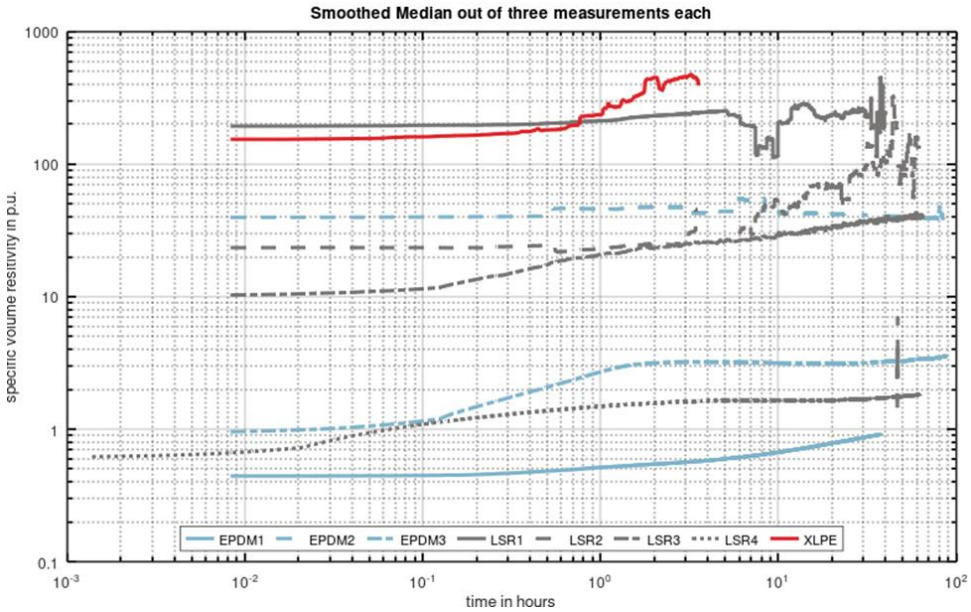
Total overview

- Earlier times: Ranking of the families of material
- Today: Spreading of the material family across several orders of magnitude

  ➔ Material modification allow certain, well defined specific volume resisitivities



[Bly-84]



Outlook

- Refinement of the filter algorithm
- Measurement on different test stands
  - Longterm measurement
  - Influence of grease on the material
  - Stacked dielectrics

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THANK YOU

for your attention.

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Sources

[Küch-17]: Küchler, Andreas „*Hochspannungstechnik Grundlagen · Technologie · Anwendungen*“, 4. Auflage

[Kar-17]: M. Karlsson, X. Xu, K. Gaska, H. Hillborg, S. Gubanski und U. Gedde, *„DC conductivity measurements of LDPE: Influence of specimen preparation method and polymer morphology“,* in Proceedings of the Nordic Insulation Symposium, 2017, Västerås, 2017.

[Bly-84]: A. Blythe, *„Electrical resistivity measurements of polymer materials“,* Polymer Testing, Bd. 4, Nr. 2-4, pp. 195-209, 1984