Analysis of Geometrical Aspects of a Kelvin Probe

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Introduction:

- A kelvin probe is a non-contact, non-destructive measurement technique to investigate the work function difference of materials.
- It is based on a time varying capacitor where the movable electrode consists of a material and a fixed electrode of a second material with different work functions. For electrically connected electrodes the Fermi levels are equilibrated by electrons flowing. Consequently, a contact potential difference establishes and the capacitor is charged.
- The vibration of the movable electrode results in a change of the stored electrical energy within the capacitor forcing an electrical current to flow.

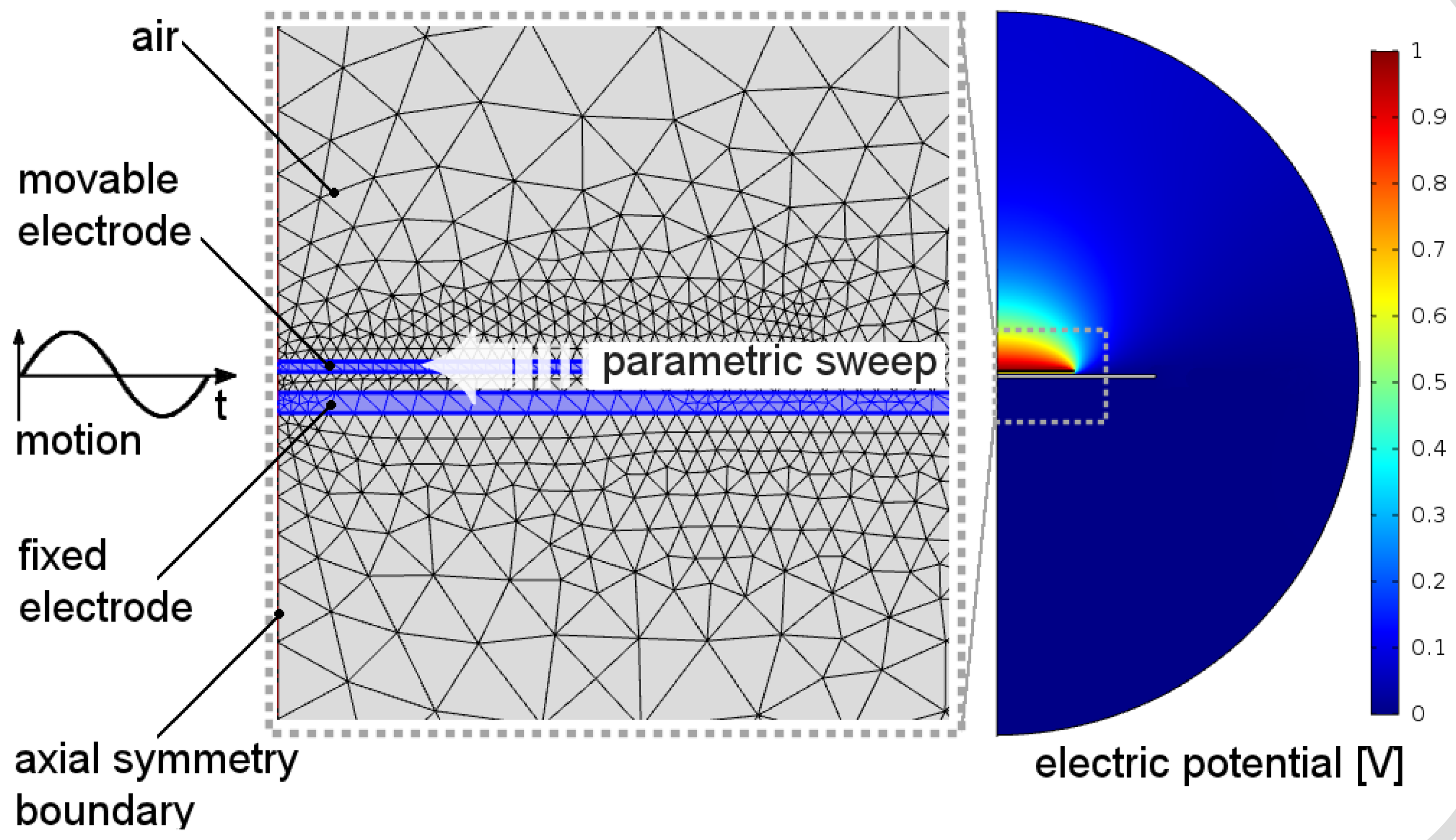


Figure: 2D axial symmetric model setup of the kelvin probe.

Transient behavior of kelvin probe:

- COMSOL (AC/DC, MEMS)
- Use of Electromechanics Interface:

$$\rho\frac{\delta^2 u}{\delta t^2} - \nabla\cdot\sigma = Fv \qquad \nabla\cdot D = \rho_v$$

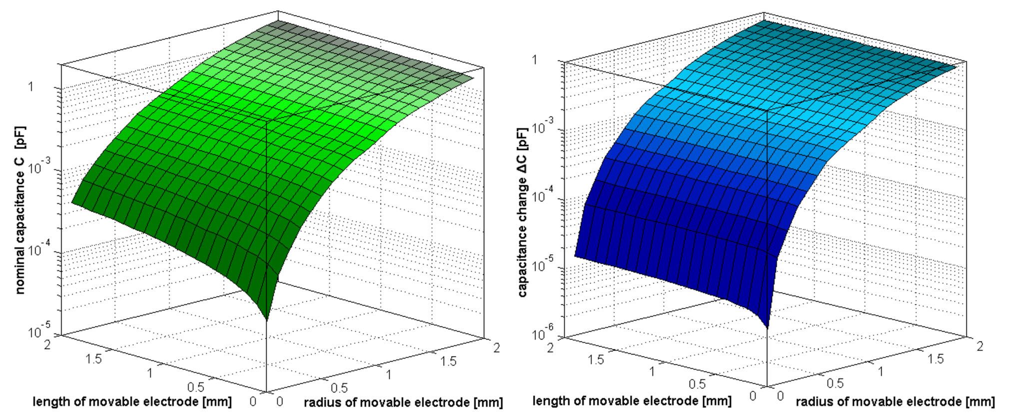


Figure: *Left:* The nominal capacitance, *right:* The capacitance change – as functions of length and radius.

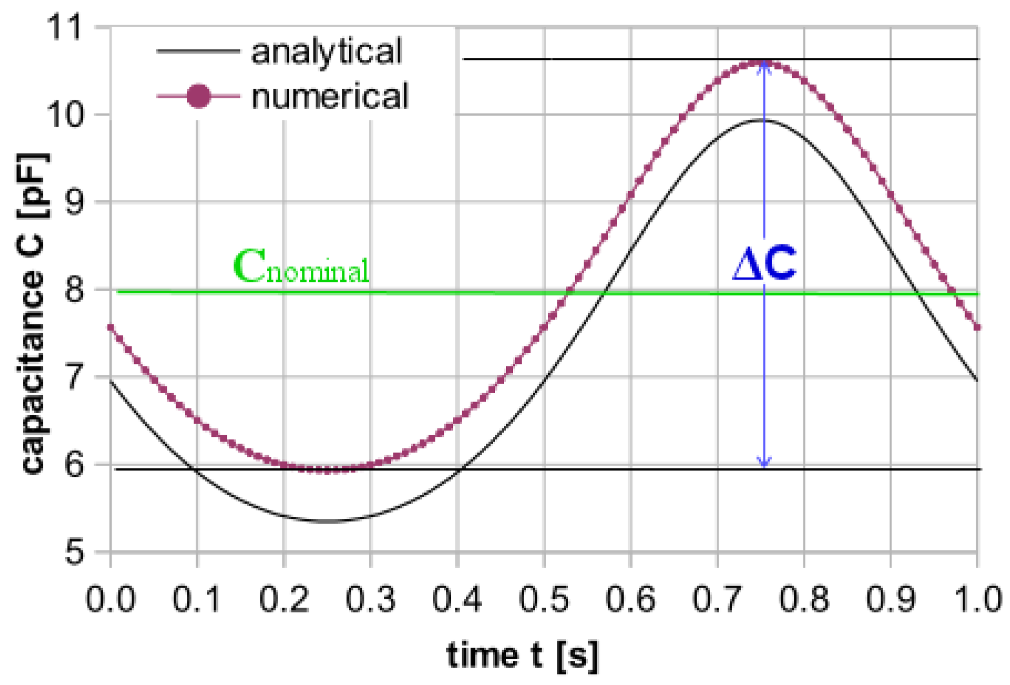


Figure: Characteristic transient capacitance behavior of the kelvin probe.

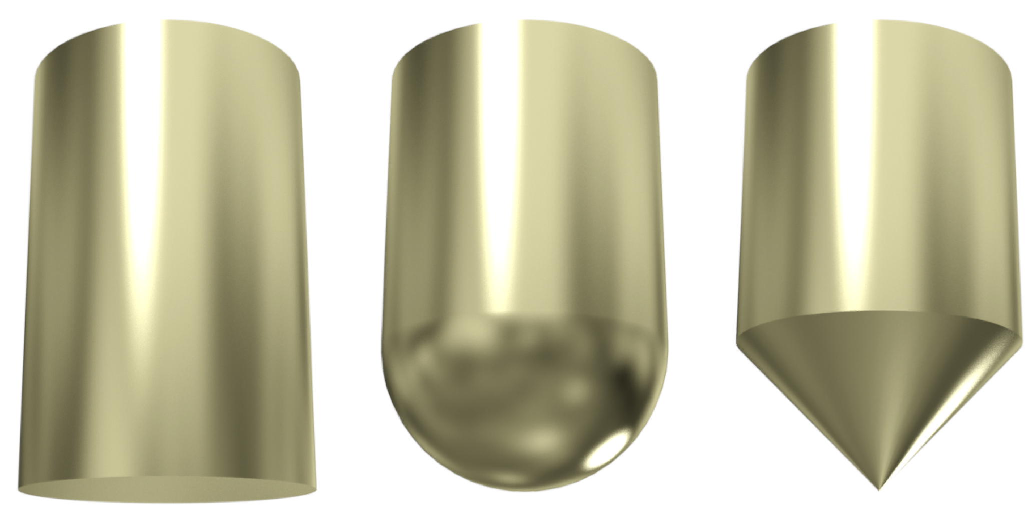


Figure: Tips: flat tip, round tip, spikey tip (45°).

Tip geometries of klevin probe

- Investigation of different probe tips: flat, round, spikey (45°)
- Shrinking of tip radius between 2mm to 50µm

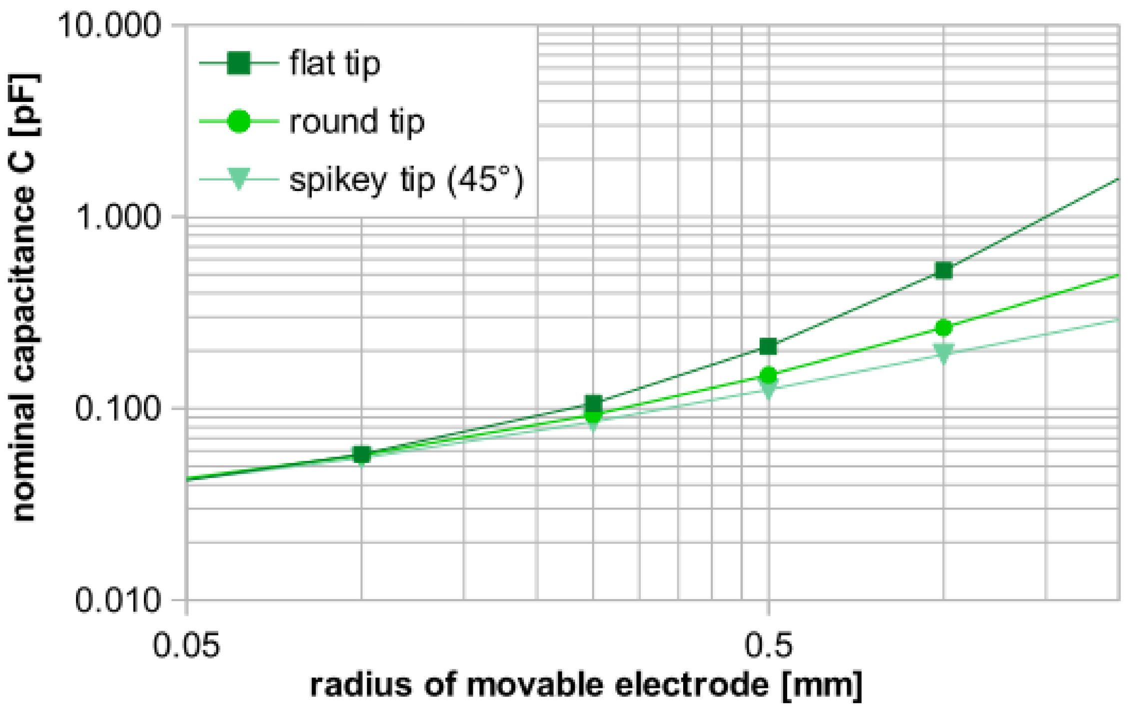


Figure: Nominal capacitance of different tips.

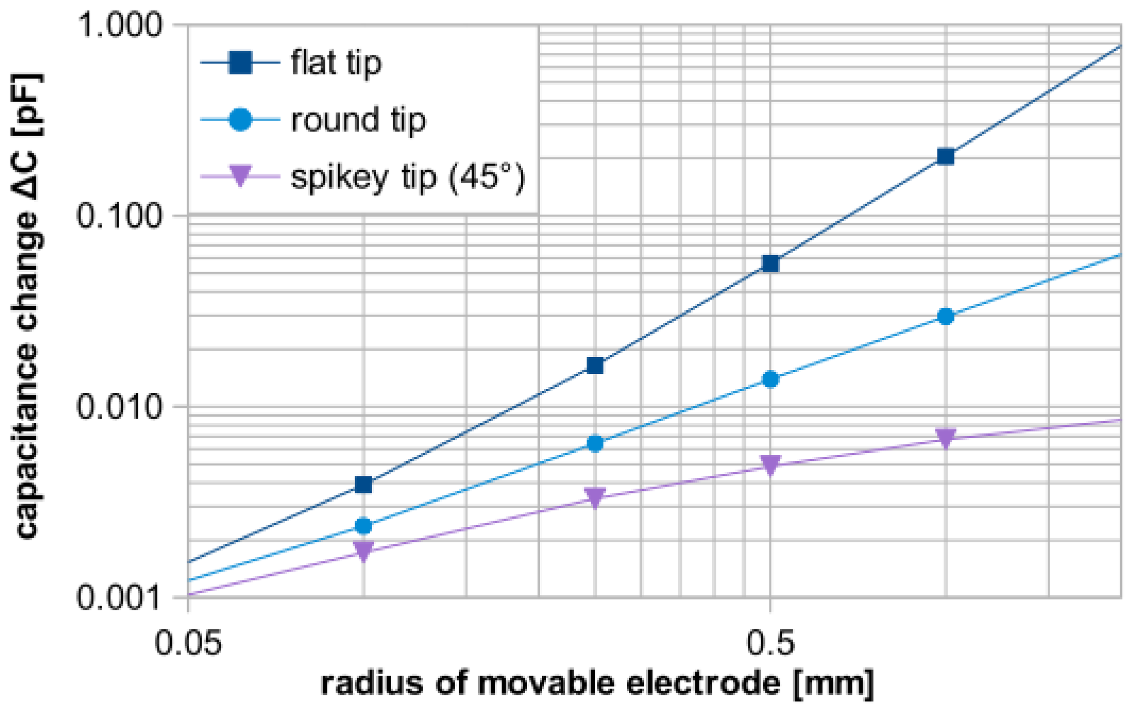


Figure: Capacitance change of different tips.

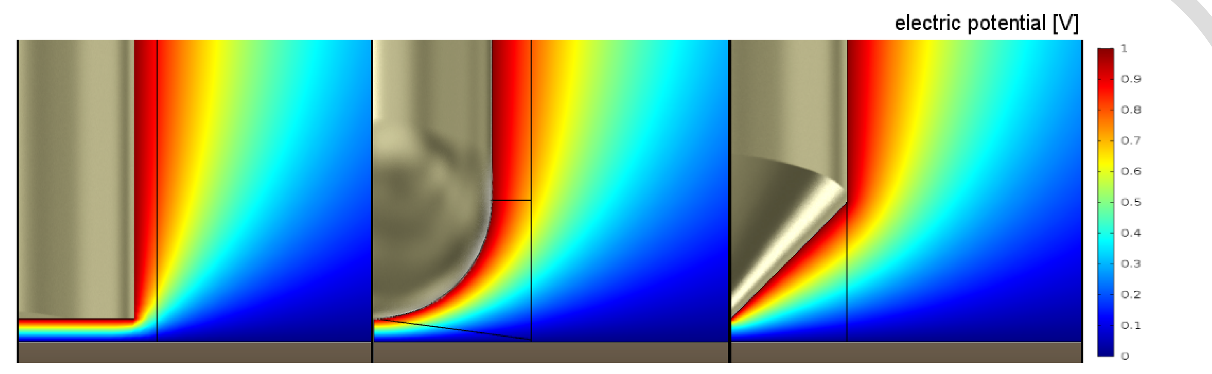


Figure: Electric potential of three different tips: flat tip, round tip, spikey tip (45°).

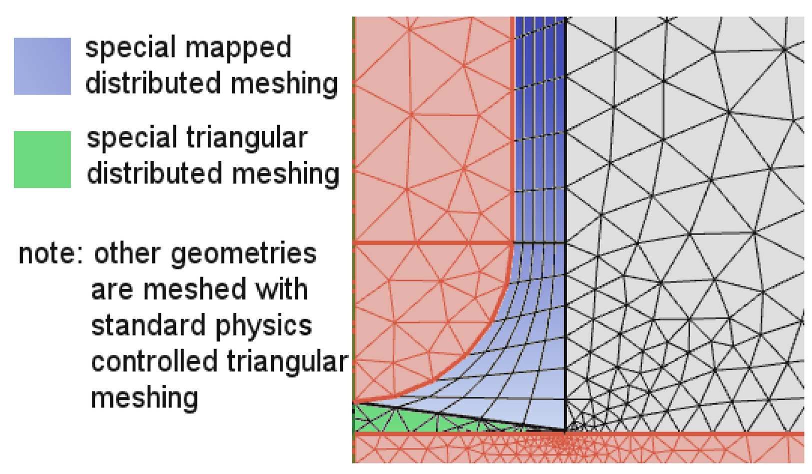
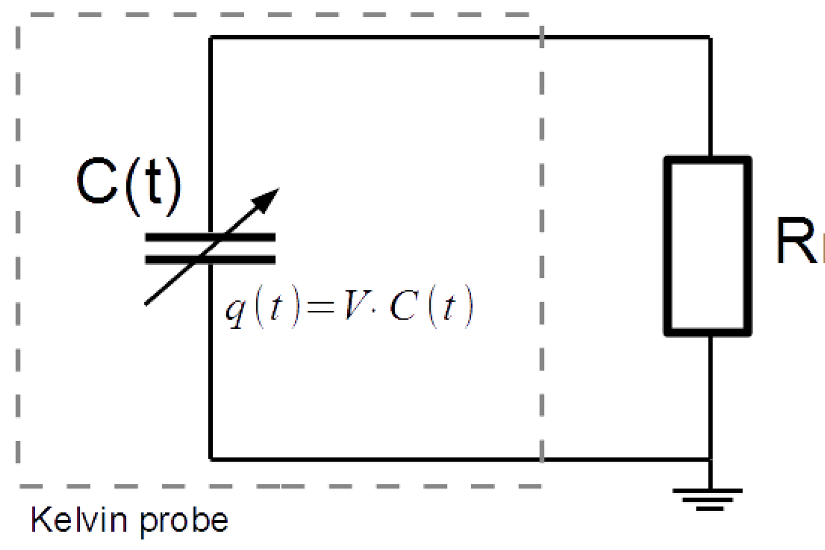


Figure: Additional airspace meshing of the round tip model.

Equivalent electrical circuit of kelvin probe:

- Use of Electric Circuit Interface
- Simple electrical measurement circuit: Load Resistor
- Comparison:
  COMSOL vs. Spice

Figure: Equivalent electrical circuit of kelvin probe with simple voltage measurement application.



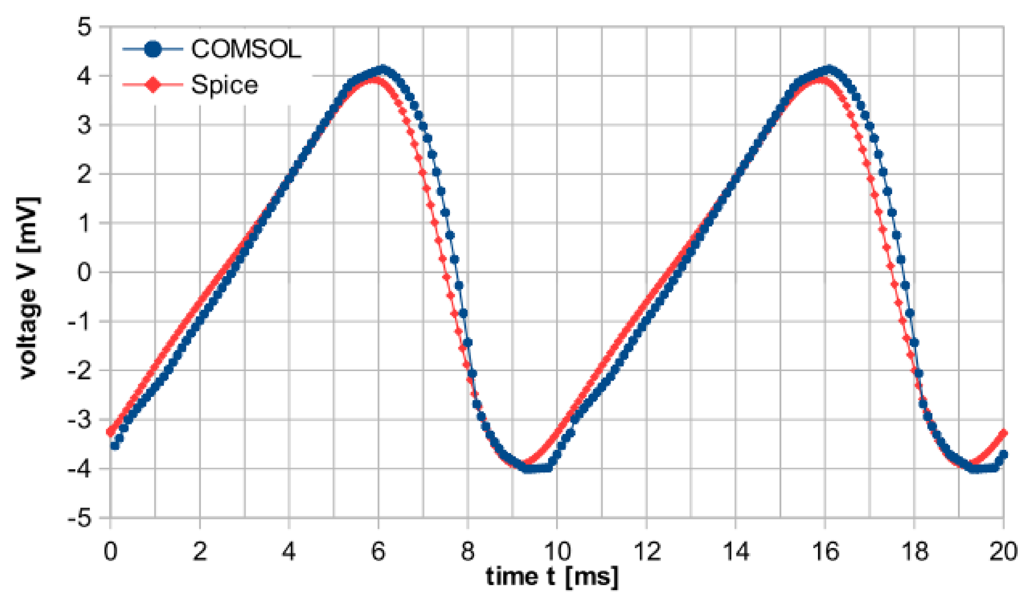


Figure: Characteristic transient voltage drop over load resistor.

Conclusion: A COMSOL model of a kelvin probe was successfully established and different probe geometries were investigated. Moreover, the model was expanded by a simple electrical measurement circuitry to demonstrate a complete kelvin probe setup.

References:

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