

Semester / Master Thesis

Investigation of permittivity probes for ice content measurement in icy regolith

theoretical / numerical thesis

Start date: As soon as possible

Topic:

The Professorship of Lunar and Planetary Exploration develops instruments for future lunar missions (Gscheidle et al. 2024) and performs research in fundamental planetary science. Of particular interest is the extraction of water at the Moon's south pole, where icy regolith deposits hold the potential to support future human exploration. In preparation of these missions, high-quality icy regolith simulants are crucial for conducting lab experiments that replicate lunar conditions. The utilized icy regolith simulants need to be characterized for different properties to interpret the experimental results. One critical parameter is the ice content inside the sample.

Our research group is actively investigating geo-electrical measurement methods to determine ice content. In geophysics, methods such as low-frequency impedance measurements are already established and have demonstrated the ability to resolve ice-content in permafrost (Stillman et al. 2010, Grimm et al. 2008). Here, the electrical properties (such as conductivity or permittivity) of the mixture are measured using electrodes (Nurge 2012). The proposed thesis shall investigate different electrode designs to adapt these methods to our applications and maximize the sensitivity of the instrument to measure minimal ice content. Besides the bulk ice content, the distribution of the ice within the regolith is of interest. The goal of this thesis is to establish a multi-physical model of the instrument and investigate different electrode arrangements in the sample using the COMSOL software package.

Tasks:

- Literature research into ice content measurement
- Building a simulation model of the electrodes and the regolith sample in COMSOL
- Investigating different electrode arrangements for instrument sensitivity and spatial resolution
- (*optional*) Design and building of an experimental setup
- (*optional*) Testing and analysis of a sensor prototype

Requirements:

- Basic knowledge and interest in lunar exploration
- Basic knowledge of electromagnetics
- Knowledge of data analysis (e.g. Python, MATLAB, Julia, etc.)
- Ideally, previous knowledge of COMSOL or comparable simulation software
- Ideally, previous experience with experimental lab work

Recommended Literature:

- Gscheidle, C. et al. (2024): *Permittivity sensor development for lunar and planetary surface exploration*. Front. Space Technol. 4, DOI: 10.3389/frspt.2023.1303180
- Mudler, J. et al. (2022): *Broadband spectral induced polarization for the detection of Permafrost and an approach to ice content estimation – a case study from Yakutia, Russia*. The Cryosphere 16, DOI: 10.5194/tc-16-4727-2022
- Nurge, M. (2012): *In situ dielectric spectroscopy for water detection on the lunar surface*. Planetary and Space Science 65, DOI: 10.1016/j.pss.2012.01.010
- Stillman, C. et al. (2010): *Low-Frequency Electrical Properties of Ice-Silicate Mixtures*. The Journal of Physical Chemistry B 114, DOI: 10.1021/jp9070778
- Grimm, R. et al. (2008): *Low-Frequency Electrical Properties of Polycrystalline Saline Ice and Salt Hydrates*. The Journal of Physical Chemistry B 112, DOI: 10.1021/jp8055366

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