Laboratory SIP-investigation on unconsolidated mineral-sand-mixtures

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The BMBF (German Federal Ministry of Education and Research) funded project ROBEHA aims at investigating abandoned mine dumps with regard to the potential reuse of the dumped mineral resources. Different geophysical methods (geoelectric, radar, SIP, magnetic) were applied on a typical mining dump in the Harz mining area to study the dumps structure and extension. In order to evaluate the SIP signals obtained in the field, laboratory measurements were carried out on samples comprising those minerals typically expected in the abandoned mine dumps (pyrite, galenite, sphalerite).

For these laboratory measurements we created different synthetic unconsolidated mineral-sand-mixtures. For each of the three above mentioned minerals we investigated three different concentrations (volume percent of 0.5, 2 and 6 %) with three different grain size fractions (fine ≤ 63 µm, middle = 112 – 200 µm and coarse = 630 – 1000 µm). For these mineral-sand-mixtures a new measuring cell was constructed. This cell enabled to measure SIP and saturation simultaneously and the embedded samples can also be used for NMR-measurements. Each mineral fraction (e.g. pyrite, 2 %, coarse) was homogenised with quartz sand (density 1.5 g cm^{-3}) after DIN 19747 (2009) and fully saturated with tap water ($\rho \sim 13.6$ Ωm). To provide constant temperature the measurements were conducted in a climate chamber using the SIP-measurement device from Zimmermann et al. (2008).

Figure 1 shows the results for the saturated 6 % pyrite-sand-mixtures with different grain sizes. The resistivity of the coarse and the fine/middle fraction differ significantly (Fig. 1, left) With decreasing grain sizes the phase amplitudes increase. Also the frequency of the phase maximum increase (Fig. 1, right). The peak of the finest fraction is at a very high frequency (15 kHz). Due to the accurate measurement device and the new measuring cell, the errors are very small.

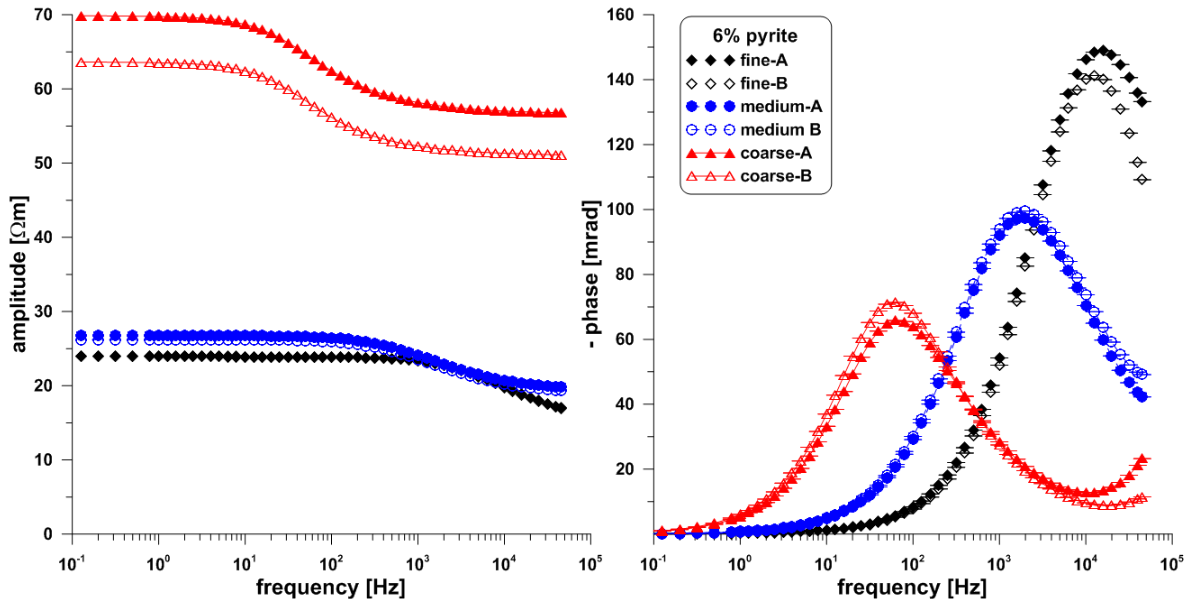

Fig. 1: Results of the saturated pyrite-sand-mixtures. The pyrite grain size changed from <63 µm (fine) to 112 – 200 µm (medium) up to 630 – 1000 µm (coarse). Significant differences are visible in phase amplitude and in the frequency of the phase maximum. The error bars are very small.

Figure 2 left shows conductivities and phases of the coarse pyrite fraction for different concentrations. With increasing concentration the phase amplitude increases whereas the frequency of the phase maximum changes only slightly (from 60 Hz (6 %) to 120 Hz (0.5 %)).

The relationship between concentration and imaginary part of conductivity is pictured for all measured pyrite samples in Fig. 2 right. Both, the coarse and middle fraction as well as the fine pyrite fraction show a linear relationship. With increasing concentration the imaginary part of conductivity increases.

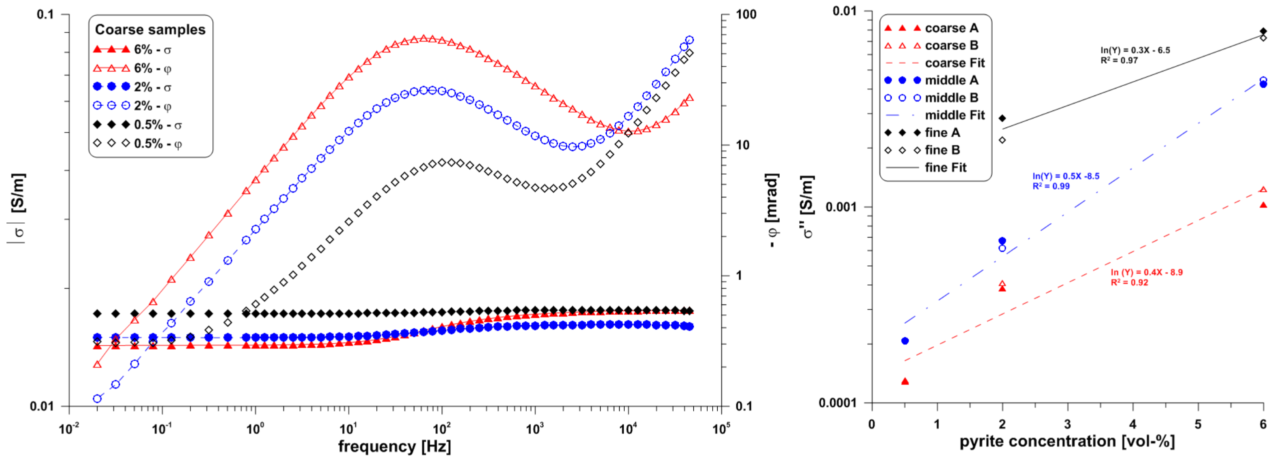

Fig. 2: Left: Comparison of saturated coarse pyrite-sand-mixtures with different pyrite concentrations. With decreasing concentration the phase maximum decreases. The frequency of the phase maximum is changing only slightly. Right: Pyrite concentration versus imaginary part of conductivity for all measured pyrite samples.

In summary we observed the following effects in our pyrite investigations:

- With increasing pyrite concentration the phase effect/imaginary part of conductivity increases.
- With decreasing grain size the phase amplitude/chargeability increases.
- With decreasing grain size the frequency of the phase maximum increases (decreasing of the relaxation time).
- No systematic relationship between conductivity and pyrite concentration is observed. Samples with the coarse pyrite show the highest conductivity with the lowest pyrite concentration (0.5 % vol.), samples with middle pyrite show the highest conductivity with 6 % vol. pyrite concentration and the samples with fine pyrite show the highest conductivity with 2 % vol. pyrite.

The results back the hypothesis that the minerals cause the polarisation effect and the effect increases with the mineral amount. The data seem to confirm that the size of the pyrite fraction and therefore the changing specific surface area influenced the polarisation in the mineral-sand-mixture (analogue to Slater et al. 2006).

Our results show a very significant relationship between mineral concentration/grain sizes and SIP-signature. So, at least in a laboratory environment SIP measurements can clarify the valuable mineral concentration. In field application this differentiation is much more complicated and could not be shown yet.

References

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