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2024

Document Version: Publisher's PDF, also known as Version of record

Link to publication

Citation for published version (APA): Martin, T., & Weller, A. (2024). *Superposition of IP signals measured on pyrite–sand mixtures.* Poster session presented at 7th International IP workshop, Lund, Sweden.

Total number of authors: 2

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on pyrite-sand mixtures

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Introduction

- IP is a valuable tool in ore exploration to get insights into the material properties of ores, slags, and other processing residuals.
- Most studies have been focused on **single fractions** of metallic particles with varying grain size (Fig. 1) or varying volume percentage (VP).
- The chargeability has been accepted as a

Material

- 11 unconsolidated **pyrite sand mixtures**, measured with SIP-ZEL (Tab. 1)
- 6 samples consisting of a single pyrite grain radius mixed with sand (E - samples) with a pyrite content of **2.75 VP**
- 5 samples containing **two different grain radii** within the sand (Z – samples) with a pyrite content of **5.5 VP**



Fig. 1: Spectra of the E-samples with a single pyrite grain radius: a) resistivity amplitude, b) phase shift.

- proxy for the metal content and the relaxation time for the particle size.
- We investigate whether mixtures with **two fractions** of different grain size and the same VP (Fig. 2) can be presented by an additive superposition of the spectra measured with single grain size fractions.
- The measured spectra are fitted to Peltonmodels and processed by a Debye decomposition to get the relaxation time distribution (RTD).
- We compare the resulting values of chargeability and the spectra of imaginary conductivity, phase shift, and RTD.



Sample	First pyrite grain radius [µm]	Second pyrite grain radius [µm]	Mean pyrite grain radius r _{gm} [μm]	Pyrite content p _v [VP]
E 01	31 - 56	-	42	2.75
E 02	56 - 100	-	75	2.75
E 03	100 - 177	-	133	2.75
E 04	177 - 315	-	236	2.75
E 05	315 - 500	-	397	2.75
E 06	500 - 1000	-	707	2.75
Z 01	31 - 56	500 - 1000	172	5.50
Z 02	56 - 100	500 - 1000	230	5.50
Z 03	100 - 177	500 - 1000	307	5.50
Z 04	177 - 315	500 - 1000	409	5.50
Z 05	315 - 500	500 - 1000	530	5.50

Tab. 1: Overview about the measured samples with a single pyrite grain radius (Esamples) and two different pyrite grain radii (Z- samples).



Fig. 2: Spectra of Z-samples with two pyrite grain radii: a) resistivity and b) phase shift.



Results

- E-samples (Fig. 1): An increase in resistivity (ρ), a decrease in chargeability (*m*), and a decrease in the peak frequency (f_{peak}) is observed with increasing pyrite grain radius.
- Although equal in VP, the fraction with the lowest grain size indicates the strongest IP effect.
- Z-samples (Fig. 2): An increase in ρ , a decrease in m and a decrease in f_{peak} is observed with increasing radius of the **fraction of smaller pyrite grains**. The spectra become wider for an increasing radii difference between the two pyrite grain fractions.
- **Phase spectra** indicates a good agreement between the measured (red line) and mathematically predicted (orange line) additive superposition (Fig. 3, middle column).
- The mathematical superposition underestimates the measured superposition of **spectra of imaginary conductivity** (Fig. 3, left column).
- The agreement becomes better for fractions with similar grain size (see sample Z 05, lowermost row in Fig. 3).
- Although equal in VP, chargeabilities m_a , m_P , and m_t decrease with increasing grain size (Figs. 4, 5). Mathematical superposition overestimate the values determined from the measured spectra.





Fig. 3: Superposition of spectra of samples with different pyrite grain radii for the imaginary conductivity, phase shift, and the RTD from Debye decomposition. Consider that the τ -axis is scaled in inverse direction (from larger to lower values).

Fig 4: Superposition of different chargeabilities (m_a , m_p and m_t) versus grain size r_{gm} (E-samples) or for the smallest grain size fraction $r_{gm s}$ (Zsamples). Sum (red crosses) corresponds to the mathematical superposition via addition. (a) Approximate chargeability m_{av} (b) chargeability of the Pelton model m_P and (c) total chargeability resulting from the Debye decomposition m_r .

100

r_{gm} resp. r_{gm_s} [μm]



Fig 5: Chargeability versus grain size for E- and Z-samples. The solid lines are the calculated chargeability values for VP according to Gurin et al. 2015 (2.75 VP - blue, resp. 5.5 VP - orange).

Conclusions

- Mathematical superposition of spectra of σ' , phase shift, and RTD provides a useful approximation.
- Although equal in VP, chargeability and RTD-amplitude decrease with increasing grain size.

 r_{gm} resp. r_{gm_S} [μ m]

RTD amplitude does not reflect the VP of a certain grain radius.

Sum

Chargeability is not a suitable proxy for the **volumetric metal content** (for particles r_{gm} < 500 μ m).

Reference: Gurin, G., Titov, K., Ilyin, Y. & Tarasov, A., 2015. Induced polarization of disseminated electronically conductive minerals: a semi-empirical model, Geophys. J. Int., 200(3), 1555-1565.

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Poster presented at the 7th International IP workshop 2024

 r_{gm} resp. r_{gm_S} [μ m]