Electrical Impulse Fragmentation Pre-Treatment of Hard Rock Li-Ores

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Abstract. The need for battery grade lithium has increased continuously due to the growing demand for Lithium-Ion Batteries (LIBs), but the supply for this critical raw material remains a challenge. The main source for hard rock lithium until now has been spodumene ore, which results in a strong dependency on the import from non-european countries. The Li4Life project focuses on the evaluation of complex Li-ores such as zinnwaldite, lepidolite and petalite from underutilised european sources. Since these ores exhibit a complex microstructural composition, mineral processing poses a challenge. Hence, innovative pre-treatments such as electrical impulse fragmentation are also evaluated as potential technologies to be implemented in the mineral processing flow sheet. In this work, three different european hard rock ores (zinnwaldite, lepidolite and petalite) are characterized and their behaviour after electrical impulse fragmentation pre-treatment as single particle and multiple particle testing is evaluated. Multiple particle testing included the evaluation at two energy levels. Preliminary results show that zinnwaldite ore is more suitable for the electrical impulse fragmentation pre-treatment.

1. Introduction

The need for Lithium has increased steadily in the last years, mainly driven by the increasing demand for LIBs[1]. Alone the demand for Lithium in Europe for the battery sector is expected to grow ninefold by 2040[2].

Li resources are distributed around the world but the supply chain for Li has focused on spodumene hard rock, which beneficiation routes are well defined. Other Li-bearing ores are underutilised and have not yet been developed industrially as their Li contents are lower and have complex microstructures that pose a challenge for the mineral processing.

Within the EU Li4 Life project, potential alternative european Li sources are investigated and the entire value chain, including mineral processing and beneficiation is evaluated. The possibility of using innovative technologies, such as the high voltage electrical impulse fragmentation (EIF) as pre-treatment in the mineral processing is evaluated.

This work presents the preliminary investigations for evaluating EIF on three european Li-bearing ores. The material characterization results and the results after single and multiple particles testing with EIF are also presented in the following sections.

2. Experimental Procedure

The selected materials were characterized regarding their mineralogical composition by using the Quantitative Microstructural Analysis (QMA). The mechanical properties were determined by using a point load tester (PLT). Additionally, the Li-contents was determined by using inductively coupled plasma atomic emission spectrometry (ICP-AES).

2.1. Materials Characterization

Three european hard rock Li-ores were selected: zinnwaldite (Cinovice, CZ), lepidolite (ES) and petalite (ES).

(a)
(b)
(c)

Figure 1. Selected Li-ores: (a) zinnwaldite, (b) lepidolite, (c) petalite.

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The Li-contents was determined to range between 1518 and 4301 ppm Li for the zinnwaldite ore and between 3409 and 4462 ppm for the lepidolite ore. The results for the petalite ore are not yet available.

Furthermore, the samples were evaluated regarding their microstructural composition by using the QMA [3] and the mechanical properties, the uniaxial compressive strength (UCS) evaluated by means of Point load testing (PLT). The results are presented in Table 1.

Table 1. Materials Characterization

Ore/Varieties	Mineral Phases present	*Median grain size* [mm]	Is50, MPa	UCS, MPa
Zinnwaldite: Greisenised Granite (GCW) Greisen (GCG)	Quartz, Feldspar, Mica	Zinnw. GCW: 1,32 mm Zinnw. GCG:0,75 mm	GCW: 4,10 GCG: 2,15	GCW: 102,5 GCG: 53,8
Lepidolite Lepidolite bearing aplite (LSA) Lepidolite felspar pegmatite (LSR)	Quartz, Feldspar, Mica	Lepid. LSA: 0,10 mm Lepid. LSR: 0,25 mm	LSA: 4,59 LSR: 5,13	LSA: 114,7 LSR: 128,2
Petalite	Quartz, Feldspar, Mica, petalite	Heterogeneous Petalite up to 6 mm Quartz-feldspar mica: 0,3-0,6 mm	2,0	50

2.2. High Voltage Electrical Impulse Fragmentation

High Voltage electrical impulse fragmentation refers to the treatment of materials with high voltage electrical impulses. Although the technology has been known for several decades [4-7] and laboratory machines have found their way into geological laboratories [8], the transfer into industrial applications has not been completed. New concepts have been introduced towards the development of new machines working with high voltage electrical impulses [9-10].

Characteristic from EIF is the introduction of cracks in the microstructure of the material through the electrical impulse discharge [11-12]. The introduction of cracks in the material leads to a weakening of the material, which means less energy needed for subsequent processing. Another advantage of this process is the selectivity, which can be used for selective liberation of mineral phases of interest.

As it can be seen in **Fehler! Verweisquelle konnte nicht gefunden werden.**, several elements are needed for the EIF to function : a high voltage electrode, the material to be treated, a dielectric medium (typically water), and a ground electrode. These are the basic components in the processing area.

The discharge through the material occurs when the impulse rise time, e.g. the time needed to reach the high voltage, is extremely fast, in the order of ns (usually below 500 ns) This is what is known as electrical impulse fragmentation, i.e. the high voltage discharge occurs through the solid material.

For generating the impulses, a Marx generator is used. The Marx Generator consists of several stages of capacitors. The charging of the capacitors occurs in parallel and the discharge in series, hence adding the energy of each stage in the final discharge.

The use of a Marx generator allows to regulate the amount of energy that is discharged with every impulse. Two different EIF-tests were conducted: single particle testing with individual particles ranging between 5 and 7 cm by using a 5-stages Marx Generator (max. Energy pro impulse: 90 J and max. output voltage 200 kV) and multiple particle testing (bulk) with a closed initial particle size distribution (PSD) from 20 to 25 mm by using a 12-stages Marx Generator (impulse energy: 140 J and output voltage 360 kV), see Figure 3.

The samples used for EIF single particle testing were inspected prior to the test and directly after.

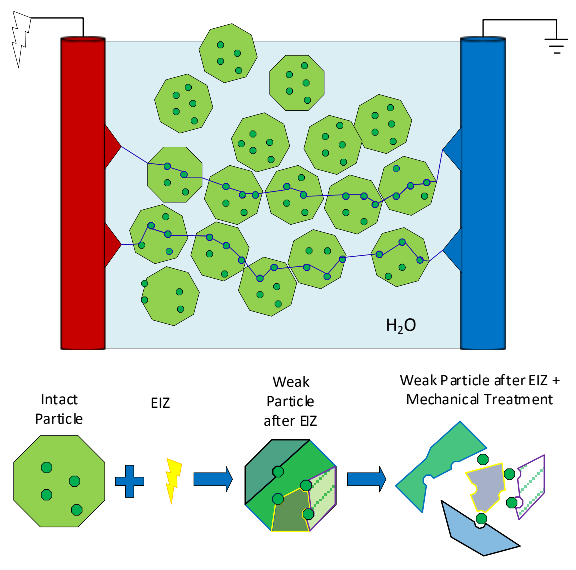
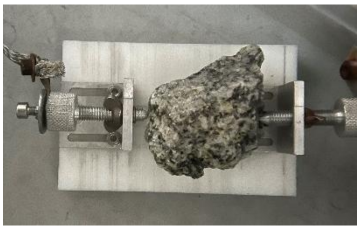


Figure 2. Electric Impulse generation and processing area (Source: M.Mezzetti/TUBAF-IART)



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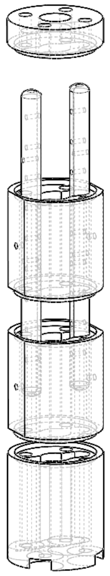

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Figure 3 (a) Set up for single particle testing (as an example zinnwaldite ore sample), (b)12-stages Marx Generator for multiple particle testing, (c) Test chamber for multiple particle testing.

3. Results

The Single particle tests were conducted by introducing initially 10 Impulses (90 J/Impulse) into the material. In the case of zinnwaldite, for most of the samples was this enough to introduce cracks into the material or break it either partially or completely.

The lepidolite samples exhibited a completely different behavior and required up to 300 impulses to exhibit cracks on the material.

The behavior of lepidolite could be described somewhere in between. For the petalite sample, some of the samples reuired only 10 impulses, but some others required more than 100 impulses for introducing cracks into the material.

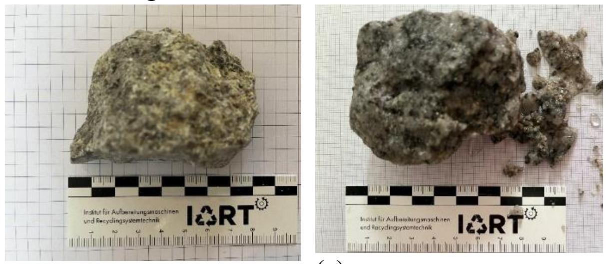
An example of the evaluation of the samples after single particle testing can be observed in Figure 4.

Based on the observations and results gathered after single particle testing, testing with bulk material with initial particle size in the fraction 20-25 mm was evaluated.

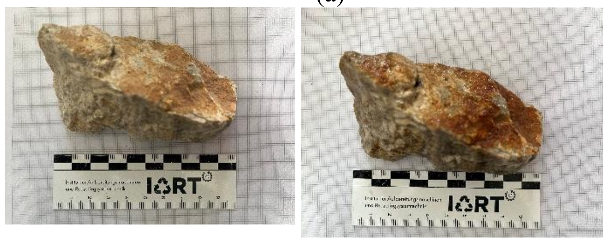
As zinnwaldite ore seem to be more suitable for the EIF pre-treatment, several energy levels were evaluated, namely 1,16 kWh/t, 3,1 kWh/t and 6,1 kWh/t.

For lepidolite and petalite, the evaluation was conducted on meterial without pre-treatment and the highest energy level from 6,1 kWh/t.

The samples of material were dried after testing and the resulting PSD was evaluated. The results can be observed in Figure 5.



(a)



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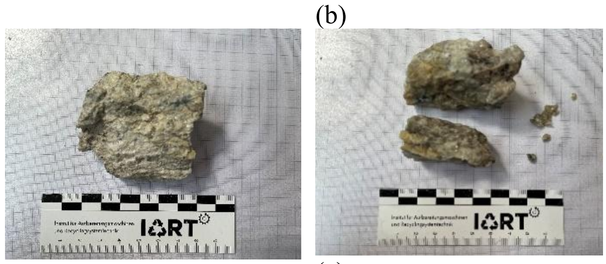

(c)

Figure 4 Single particle testing (left: before the test, right: after the test). Tests on (a)zinnwaldite ore (10 Imp-90J) (b) lepidolite ore (150 Imp-90J) and (c) petalite ore (15Imp -90 J).

4. Conclusions

Three different Li-bearing ores have been evaluated regarding their suitability to EIF pre-treatment. Through the initial single particle testing it was possible to assess the susceptibility. The preliminary results showed that the zinnwaldite ore had the better response and only a few impulses, meaning low energy, was needed to introduce cracks into the material.

The bulk testing results confirmed the positive response from the zinnwaldite ore, resulting in the finer PSD when comparing testing among the three ores at the same energy level (6,1 kWh/t). The least susceptible material after bulk testing on this fraction was the petalite.

The difference in the response to EIF is presumably related to the microstructural features. The differences can be seen for example in the median grain size of the mineral phases present as well as in the mechanical properties. While zinnwaldite exhibits a relatively coarse microstructure (median grain size up to 1,32 mm), the lepidolite exhibits a much finer median grain size with only 0,1-0,22 mm.

The heterogeneous microstructure of petalite was also reflected on the single particle testing. In the bulk testing, petalite showed the less susceptibility.

Further investigations include the evaluation of the mineral liberation, the correlation to the microstructural features as well as the crack propagation behavior.

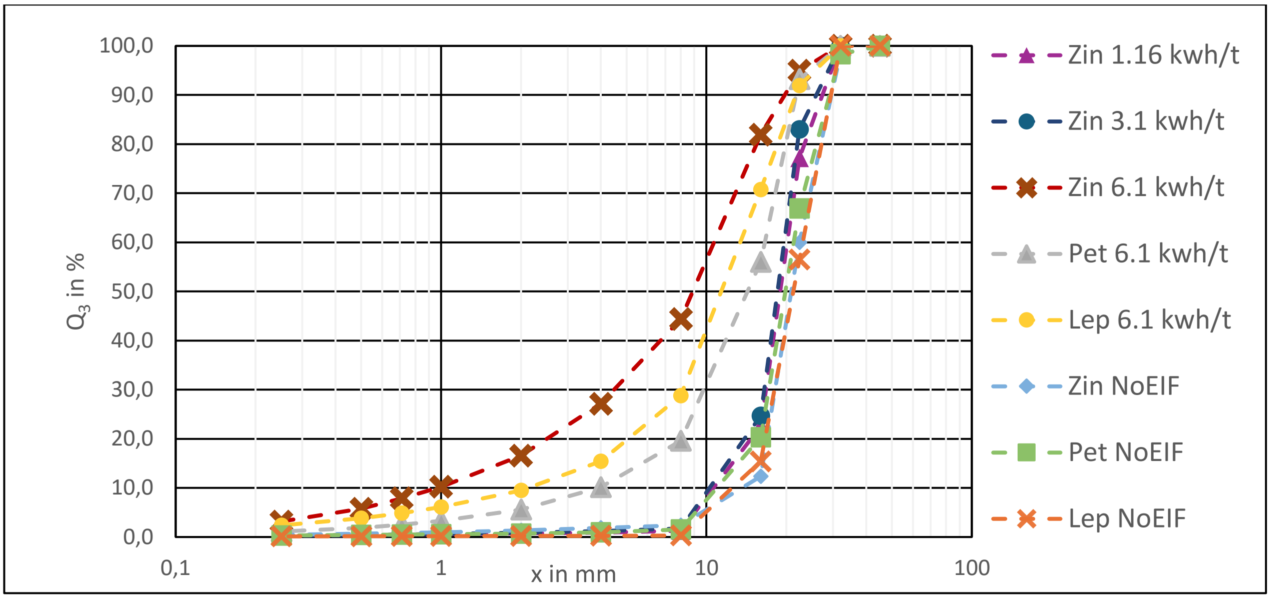

Figure 5. Particle size distribution of test materials after bulk EIF-testing.

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Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor CINEA can be held responsible for them.

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