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Mechanochemistry: Sustainable extraction and recovery of metals

- The case of lithium silicate minerals -

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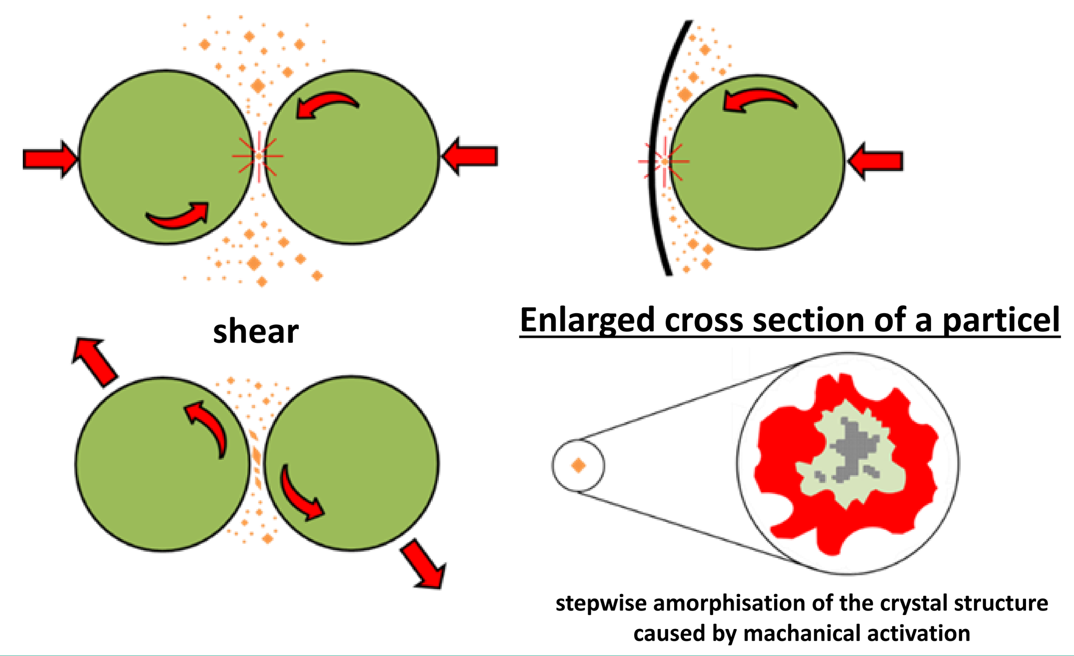
Background and Aim

With the rising demand for **Lithium-Ion batteries**, hard rock lithium ores are becoming much more important due to their higher lithium content, their worldwide deposits and their lower geopotential risks in comparison to salt-brine deposits, which are all concentrated in the south American lithium triangle [1]. **Hard rock lithium ores** consist of different lithium bearing silicate minerals such as **α-spodumene ($LiAlSi_2O_6$), petalite ($LiAlSi_4O_{10}$) or lepidolite ($(K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2)$)**, which are known to be poorly soluble at ambient conditions [1-3]. Therefore, these silicates have to be calcined in the established acid-roasting process at about 1200 °C to convert them into a more soluble high-temperature phase (β-spodumene) and treated with hot concentrated sulphuric acid (H_2SO_4) to leach out the lithium, which is energy- and cost-intensive [1-3]. **Mechanochemistry,** a physicochemical method with a wide range of applications [4], has emerged as a possible **alternative pretreatment** method for these poorly soluble lithium ores [3, 5-6]. The development presented has the potential to be an innovative and alternative process for the extraction of lithium from ores based on a combination of **mechanical activation and chemical leaching** with sodium-hydroxide solution (NaOH) in a **high energy ball mill** at ambient temperature, avoiding high temperature calcination.

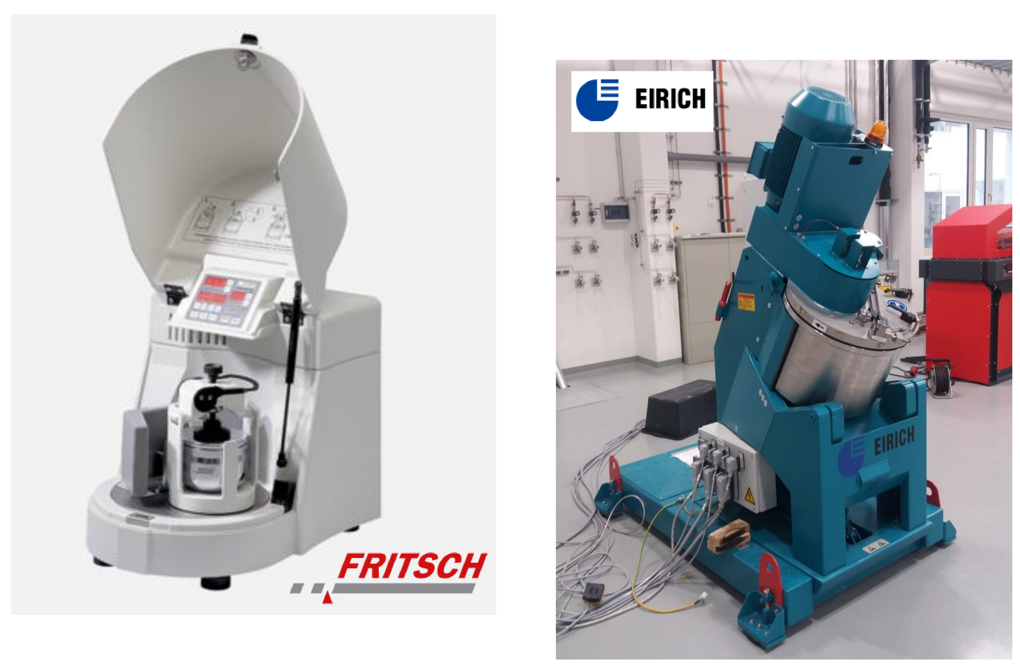
Method Mechanochemistry

grinding effects

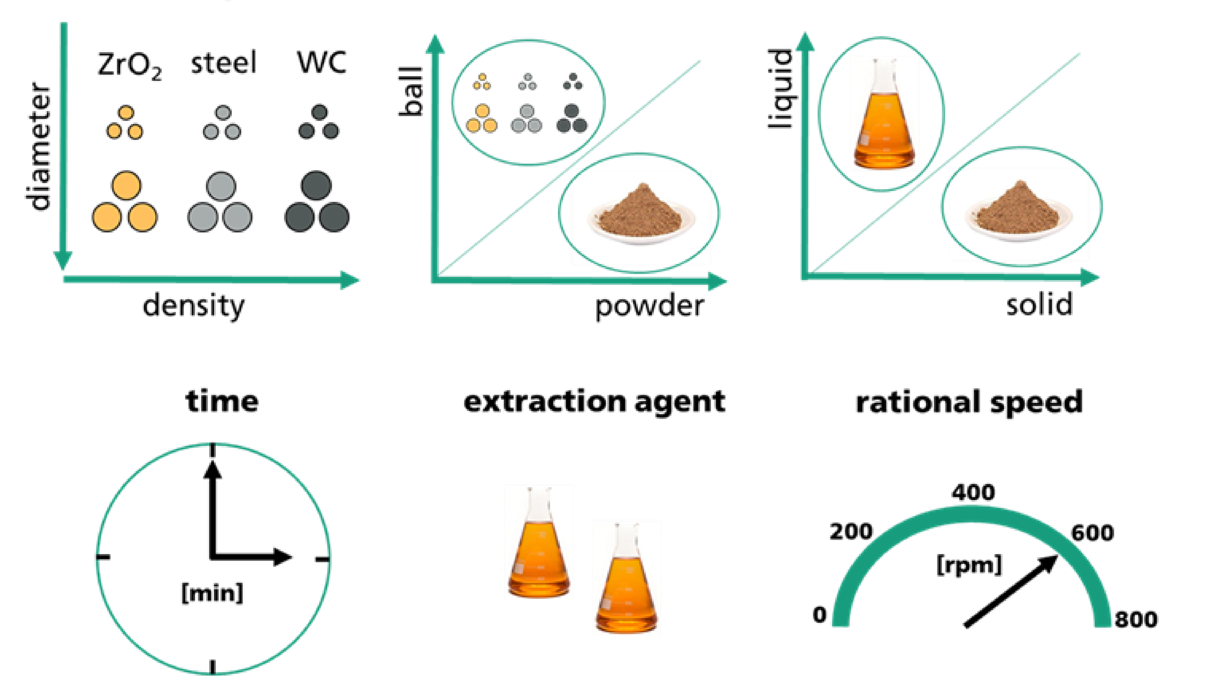


high energy ball mills

in lab and pilot scale



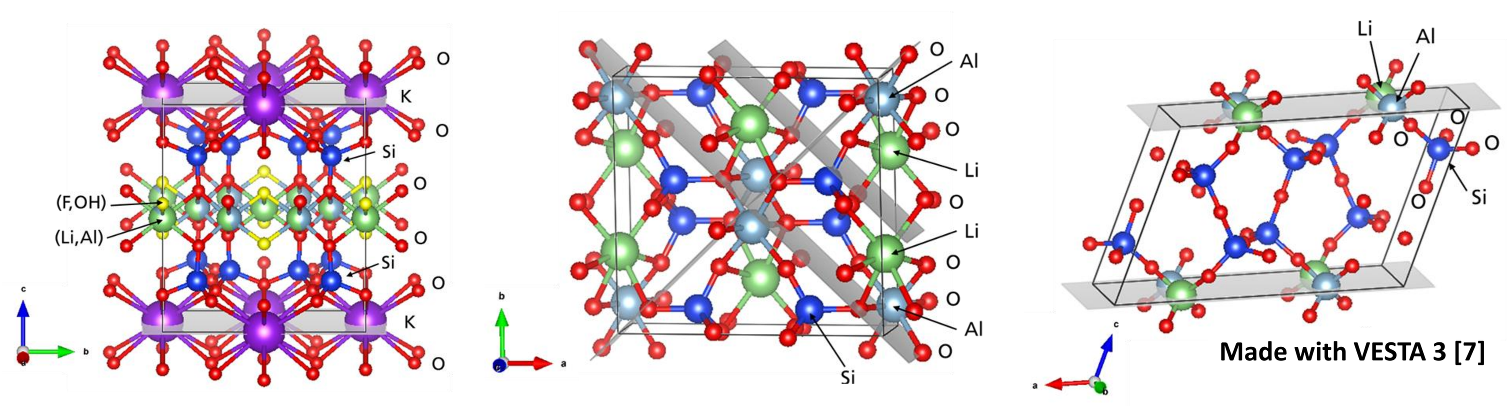
variable parameters



Mechanochemical Processes

Charakteristics of the Sample Materials

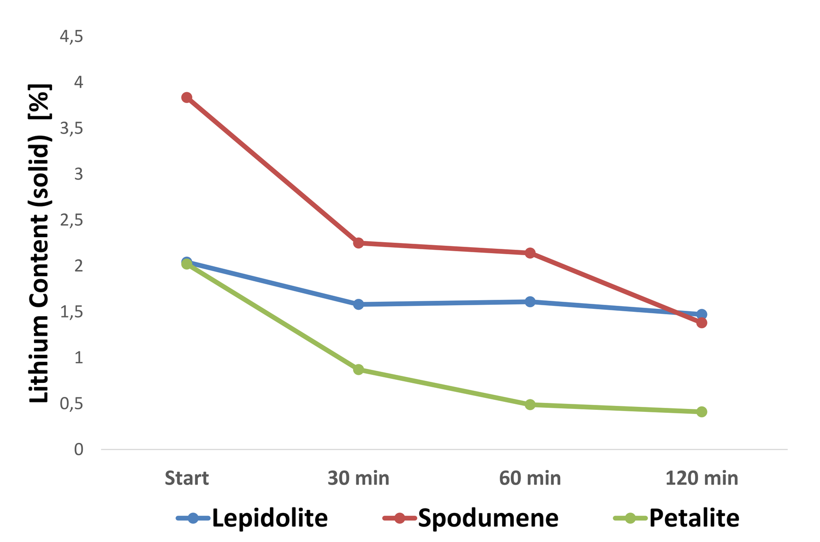
	Lepidolite	Spodumene	Petalite
Silicate typ	Phyllosilicate	Inosilicate	Phyllosilicate
Li-Content	2,04 [wt%]	3,7 [wt%]	2,02 [wt%]



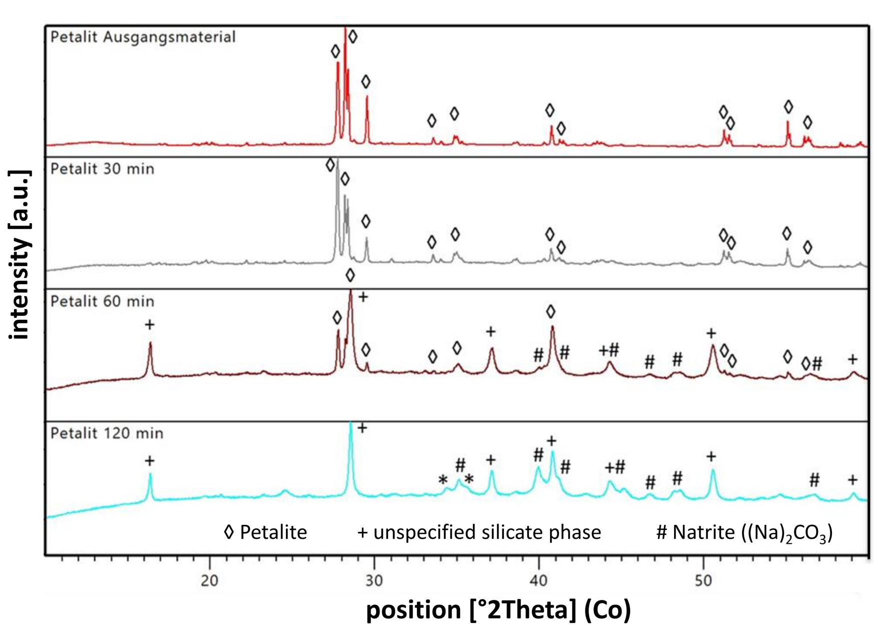
Results from the Mechanochemical Treatment with NaOH

	Lepidolite	Spodumene	Petalite
Extraction rate	28 %	64 %	77 %

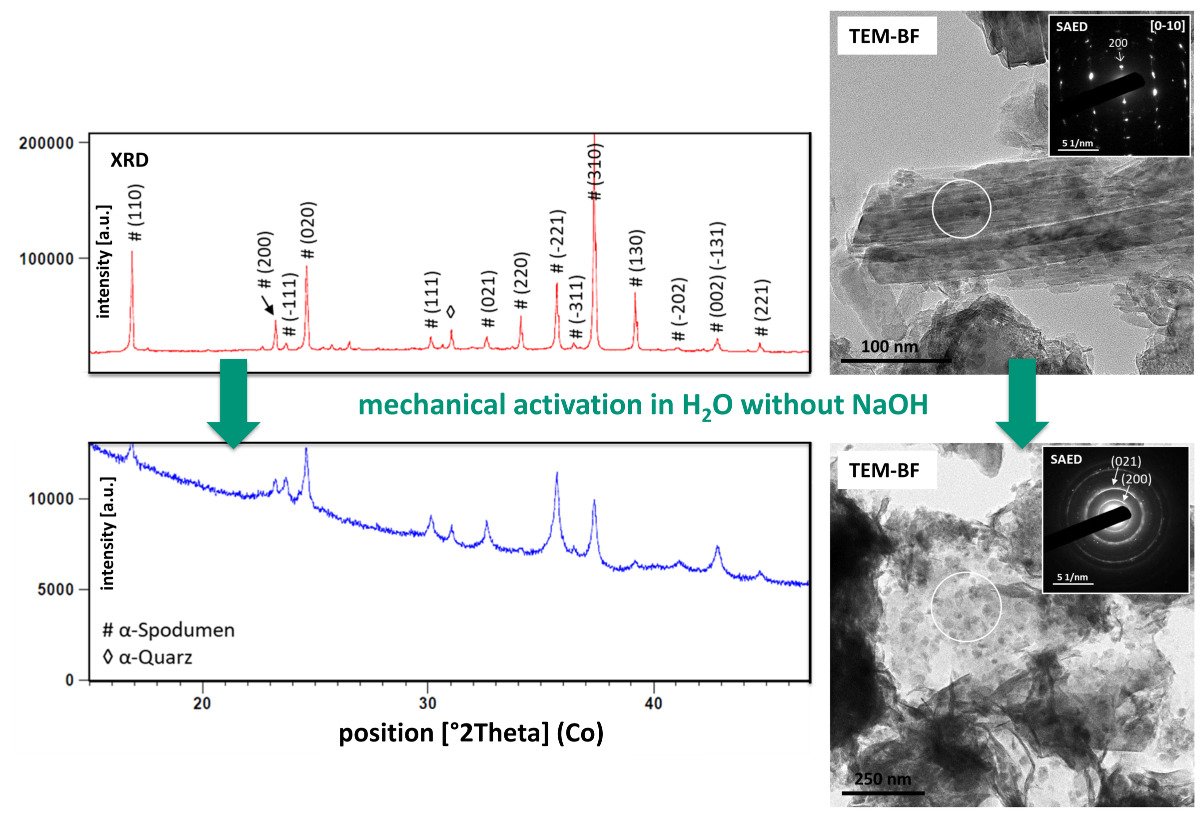
ICP-OES results



XRD results (treatment of petalite)



Crystallite size reduction and amorphisation (in case of spodumene)



- **XRD**: well orderd source material
- **TEM-BF:** single crystal of spodumene with lamellar like cleavage
- **SAED:** single crystal pattern of spodumene [0-10]

- **XRD:** peak broadening due to crystallite size reduction and amorphisation
- **TEM-BF:** fine grained masses of spodumene
- **SAED**: (nano)polcrystalline pattern of spodumene

Conclusion and Outlook

Mechanochemical leaching of **lithium-silicate minerals** with NaOH leads to promising extraction rates for spodumene (64 %) and petalite (77 %) and much lower values for lepidolite (28 %). These results correlate well with the bonds to be broken for a release of lithium and with the accessibility of lithium due to the formation of cleavage planes in the investigated minerals as a result of the mechanical activation in the ball mill. However, for industrial application, the extraction rates need to be increased by adjusting the parameters.

At **Fraunhofer IWKS, mechanochemistry** is established as a method for the **recovery of valuable metals** and for the **removal of pollutants**, which were demonstrated for several recycling issues like the separation of heavy metals from blast furnace sludge **(several industrial projects)**, the extraction of Scandium from red mud, a byproduct of the aluminum industry **(SCALE)** and for the recovery of Rare Earth Elements from optical glasses **(MinSEM).**

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