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Direct Extraction of Lithium from α-Spodumene

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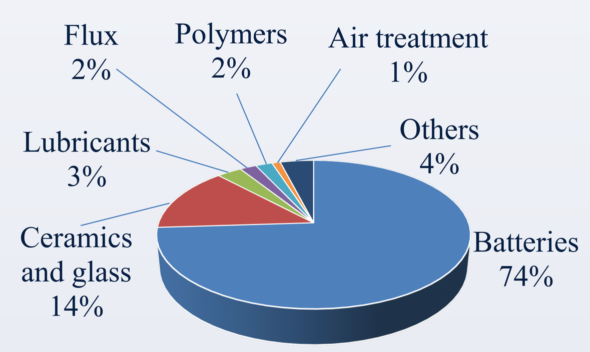
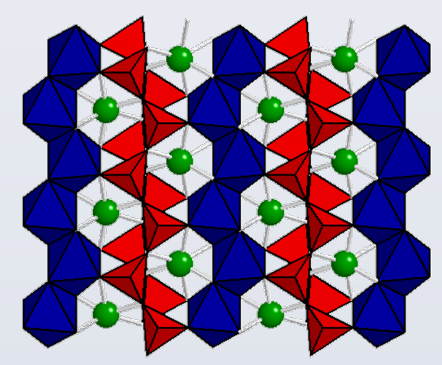
Introduction

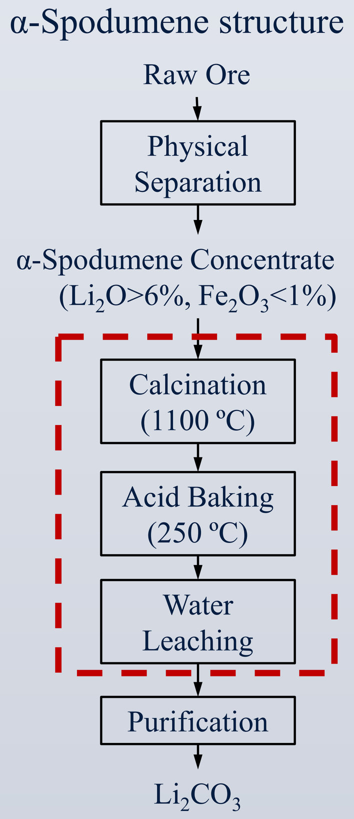
- Lithium (Li) is one of the critical elements with widespread applications in next-generation technologies.
- A steady annual demand increase of 8–11% is anticipated for Li due to its unique applications.
- Spodumene mineral is a major source of high-purity lithium with ~ 8% Li_2O.
- Spodumene naturally occurs in a compact and very low reactive α-phase, and cannot be leached for Li extraction.
- Modifying the crystalline structure of spodumene to the porous, reactive, and leachable β-spodumene using conventional heating (calcination) at 1000–1100 °C for 2 h is the current industrial practice for Li extraction.
- This calcination process is very energy-intensive and has been the bottleneck of the economic extraction of lithium from spodumene. It also significantly contributes to the high CO_2 emission (i.e., 9 tonne of CO_2 per tonne of lithium carbonate equivalent produced).



Lithium application



α-Spodumene structure



Current industrial Li extraction Flowsheet

Research Goal & Objectives

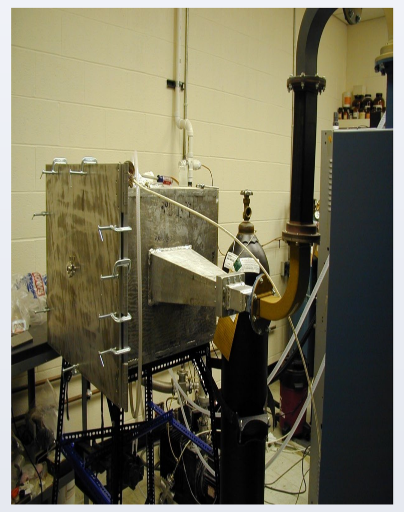
- Goal: develop alternative processes for the required high energy-consuming calcination process to extract Li from spodumene.
- Objectives
  - Study the phase transformation of spodumene via hybrid microwave (MW) heating and the effect of MW power on the leaching efficiency of lithium.
  - Find the most effective roasting reagents for phase transformation of spodumene to soluble phases for direct extraction of Li from α-spodumene.

Materials & Methods

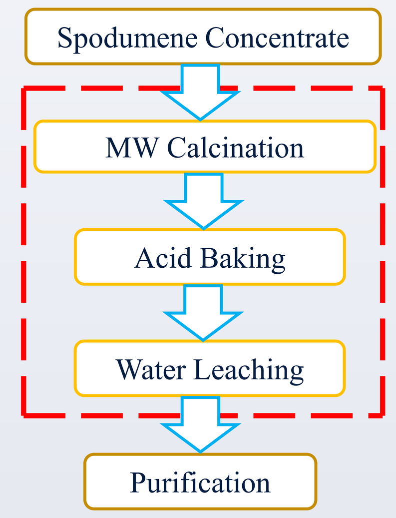
- Sample: The spodumene sample was provided by Piedmont Lithium Inc., from the Carolina Tin-Spodumene Belt near Kings Mountain, NC. The spodumene was concentrated by physical separation at Minerals Research Laboratory, North Carolina State University.

Chemical composition obtained by ICP-AES (%)							Mineral composition (%)	
Li_2O	Al_2O_3	SiO_2	Fe_2O_3	Na_2O	CaO	Total	α-Spodumene	Quartz
5.64	25.10	65.70	0.73	1.06	0.66	98.90	92	8

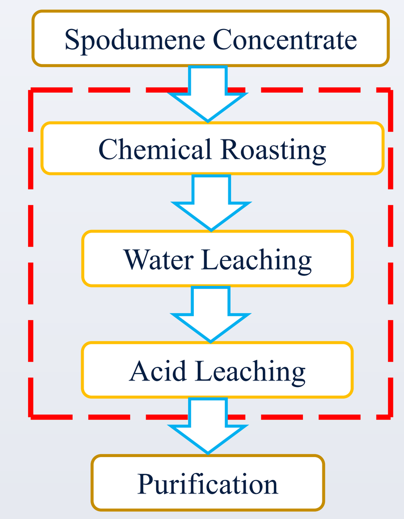
- Methods



Multimode MW System 2.45 GHz



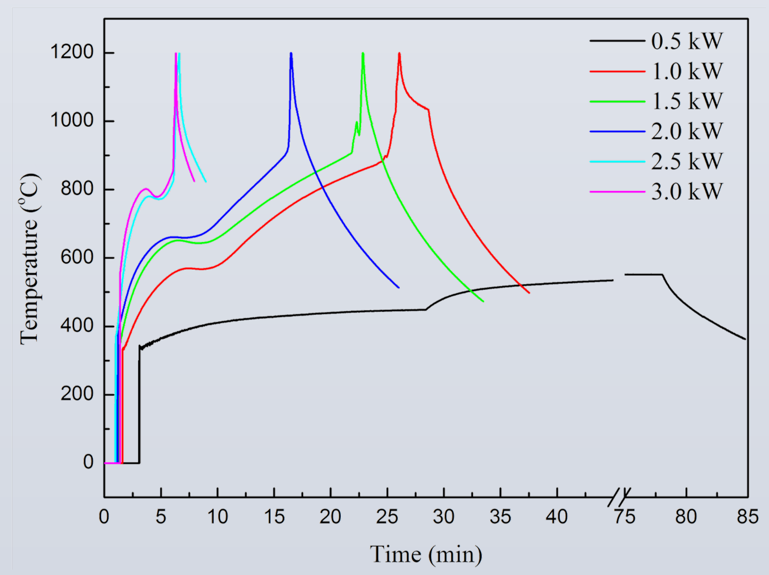
MW-assisted calcination



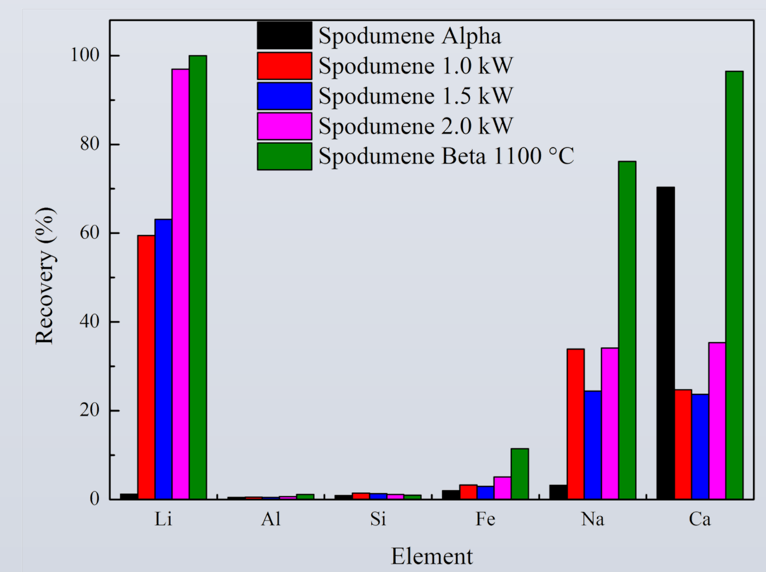
Chemical roasting

Results & Discussion

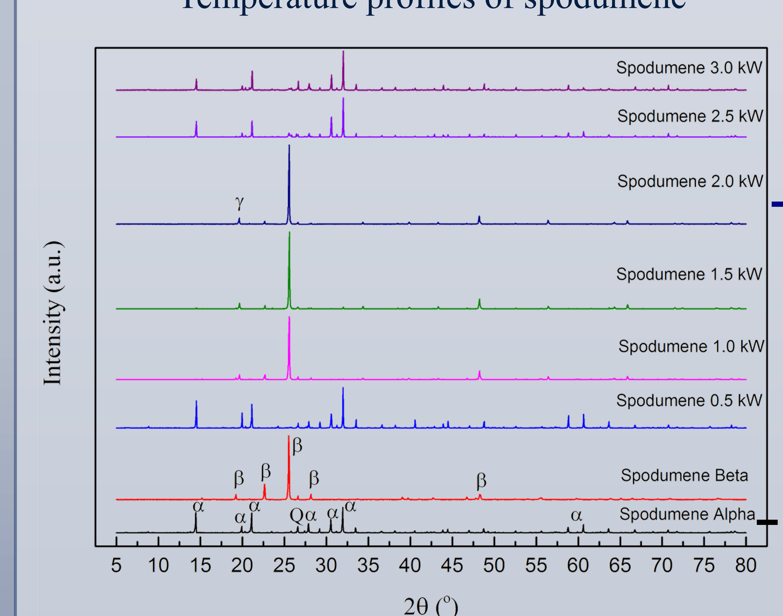
- MW-assisted calcination



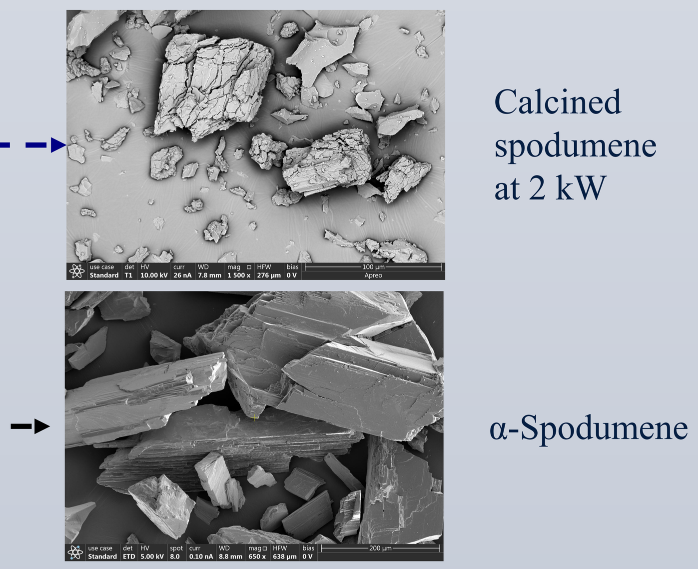
Temperature profiles of spodumene



Leaching recovery of major elements



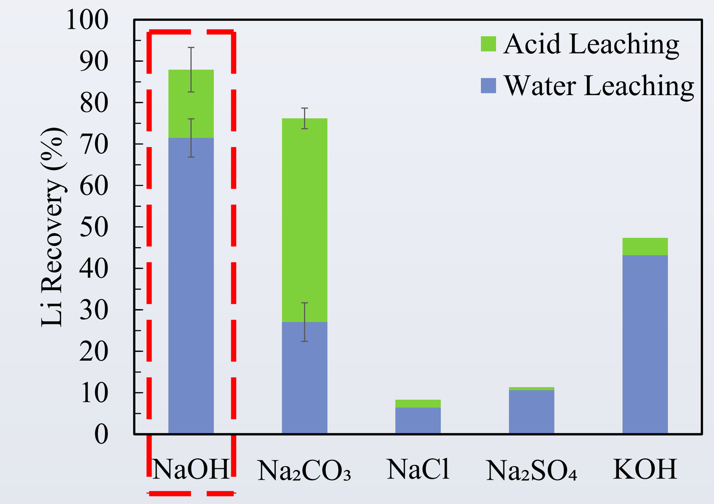
XRD patterns of spodumene samples



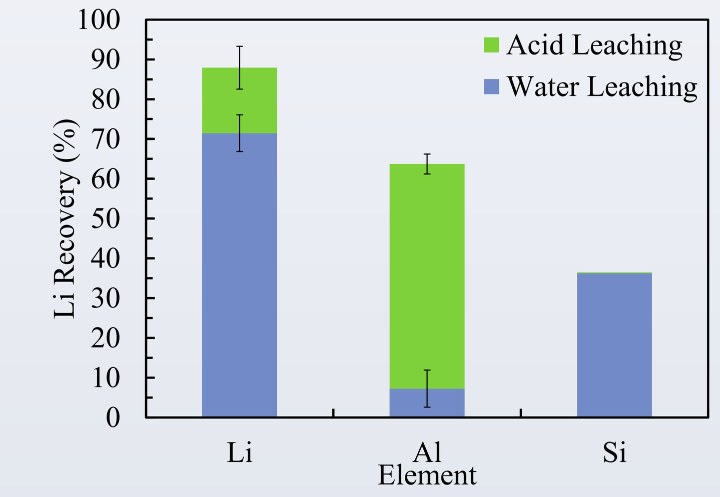
SEM images of spodumene samples

- The critical temperature for α-spodumene was around 570 °C, after which spodumene started to absorb MW.
- MW power has a significant influence on the temperature profiles, phase transformation, and leachability of spodumene.
- The optimum MW power was 2 kW, above which the sintering time was not enough for phase transformation of spodumene. Below this value, the α-spodumene was only partially converted to γ+β phases.
- At this optimum power, a Li recovery of 97% was obtained, which was comparable with that of conventional heating.
- The MW-assisted calcination resulted in lower amounts of impurities (i.e., Fe, Na, and Ca) in the leachate, which is an advantage in downstream purification processes.

- Chemical roasting
  - The spodumene concentrate was roasted with various reagents at their melting points (e.g., 320 °C for NaOH).



The recovery of Li by chemical roasting

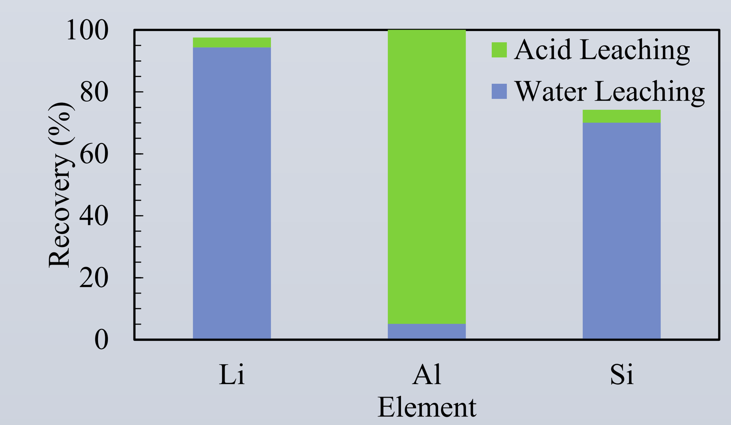


Elemental recovery by NaOH roasting

  - NaOH was found as the most effective roasting reagent for the phase transformation of α-spodumene to water-soluble phases, resulting in more than 70% Li recovery in water leaching in nonoptimized conditions.
  - The reactions of NaOH roasting with α-spodumene calculated by FactSage:

$$3\alpha\text{−}LiAlSi_2O_6 + 14NaOH \longrightarrow 3NaAlO_2 + 5Na_2SiO_3 + Li_3NaSiO_4 + 7H_2O$$
$$SiO_2 + 2NaOH \longrightarrow Na_2SiO_3 + H_2O$$
$$Na_2SiO_3 + 2NaOH \longrightarrow Na_4SiO_4 + H_2O$$

- MW-assisted NaOH roasting
  - MW-assisted NaOH roasting resulted in about 95% Li recovery in water leaching.



Elemental recovery by MW-assisted NaOH roasting

Conclusions

- MW calcination-acid baking-water leaching process reached 97% Li recovery, comparable with that of conventional heating
- MW-assisted NaOH roasting resulted in 95% recovery of Li directly from α-spodumene.

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