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Feasibility on a Microwave-Heating for the Volumetric Heating of Li_2TiO_3 Pebbles

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◆ Introduction on TESOMEX

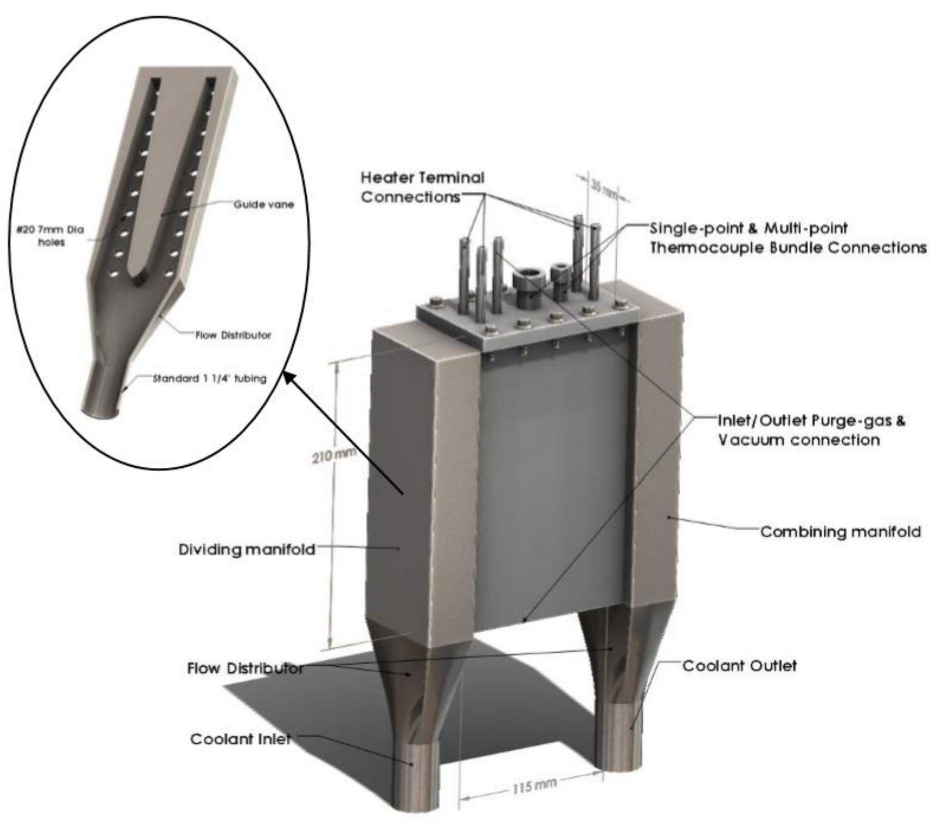
Issues we know & What we learned from the TESOMEX

Maximum operation temperature should be defined, which can be limited by the pebble's material properties.

Stress build-up in pebble bed with temperature rising and a degree of relaxation by itself, owing to creep accommodation and increased thermal conduction from larger contact area of pebbles.

BUT, irreversible deformation may occur to pebbles such as necking, sintering, cracking, permanent failure, etc.

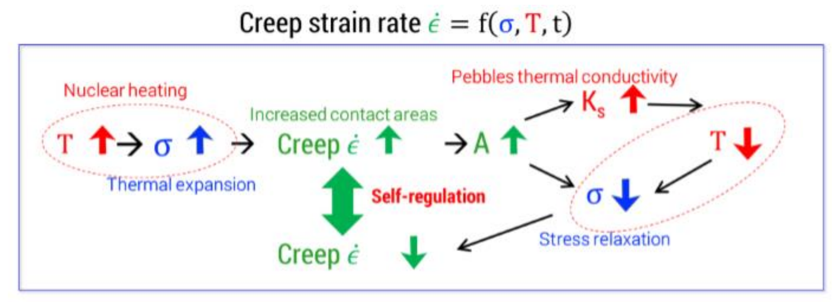
Packing of pebbles into the real structure is another big issue, with predictable problems of local void, gravity, repair or replacement in the case of pebble deformation/fracture.



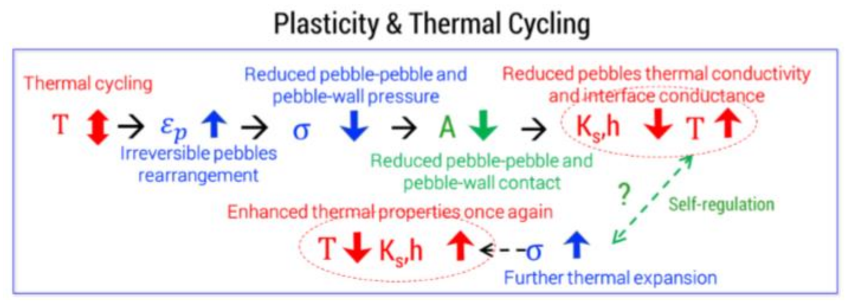
Benefits by TESOMEX

Multi-effect experimental test was performed to realize synergistic effects: self-generated stress, temperature response, self-regulate thermo-mechanical behavior, etc.

Creep strain rate $\dot{\varepsilon} = f(\sigma, T, t)$



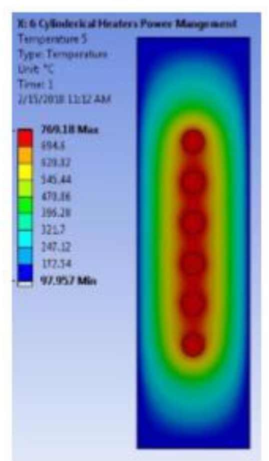
Plasticity & Thermal Cycling



Limitation of TESOMEX

- Simulated volumetric heating by using wire/rod heating elements (although it was optimized the temperature profile and enabled to induce self-generated stress)
- The measured temperature in contact with heating element is different to real temperature (the pebbles contacted with HE was observed as black, possibly heated up to about 1000C)
- HEs interfere the packing of pebbles and the interaction between pebbles at hot-zone, and additionally the chemical reaction of pebbles with HE sheath(cover-cladding) was observed.

heating element (HE)

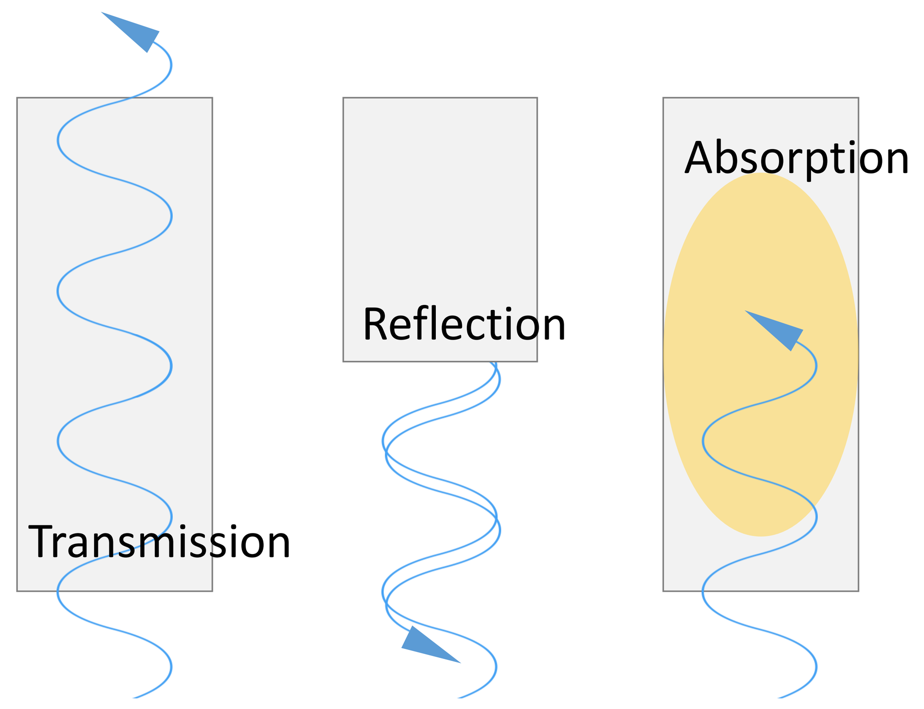


◆ Microwave for Volumetric Heating

Materials interactions to microwaves

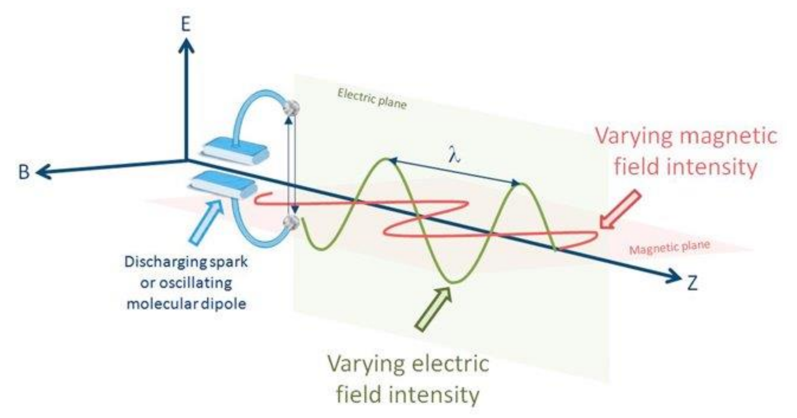
Microwave: 300 MHz – 300 GHz (2.45 GHz for heating application)

Materials interactions: transparent, opaque, absorbing



Low dielectric loss materials

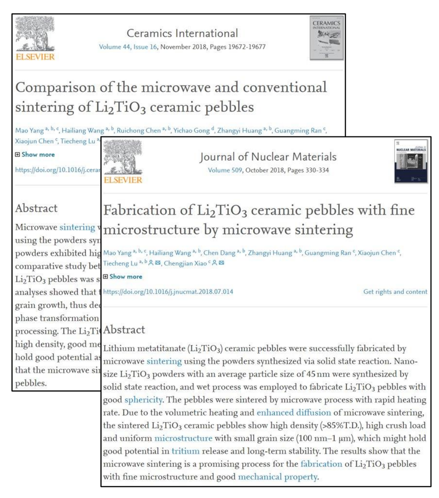
High dielectric loss materials



[Table 1. Microwave heating functionalities]

	Electric Field Component	Magnetic Field Component
Mechanism	Polarization	Conduction
Heating	Dielectric loss (ε”)	Magnetic loss (μ”)
Loss Contribution	Dipolar, Interfacial, Ionic conduction	Hysteresis, Eddy current, Residual
Materials	Ceramics	Metals, Semiconductors
Interaction Depth*	Penetration Depth	Skin Depth
	$D_p \cong \lambda_0 \sqrt{(\frac{\varepsilon'}{\varepsilon''})}$	$D_S = \frac{1}{\sqrt{(\pi f \mu \sigma)}}$

* See references D. El Khaled et al., Renew. Sustain. Energy Rev., 82 (2018) 2880-2892. and R.R. Mishura et al., Composites A, 81 (2016) 78-97.



Responses of Li_2TiO_3 to microwaves (applicability)

Anisotropy in the crystal lattice structure

Sintering experiences (2.45 GHz, 2 kW)

Quality factor: 15,000 – 63,000 GHz

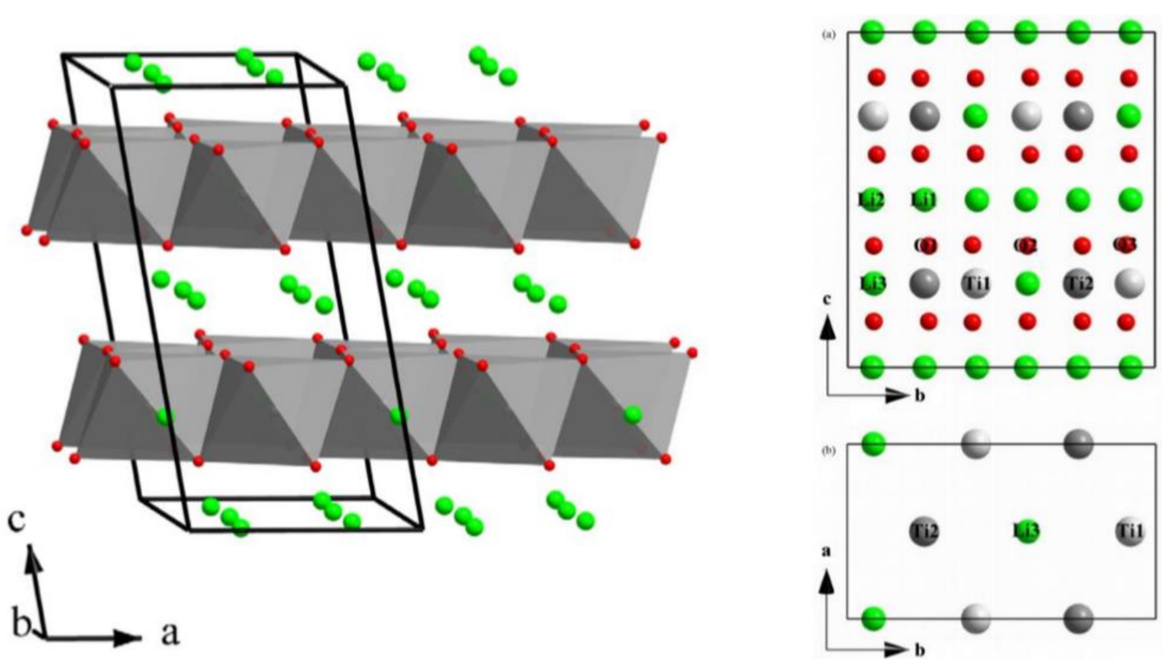
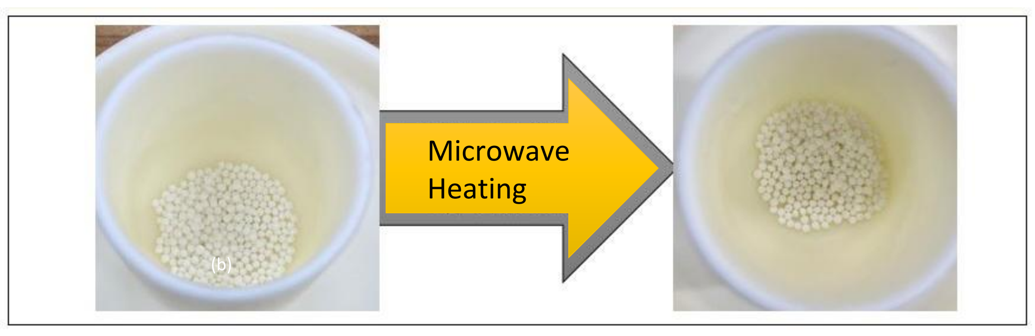
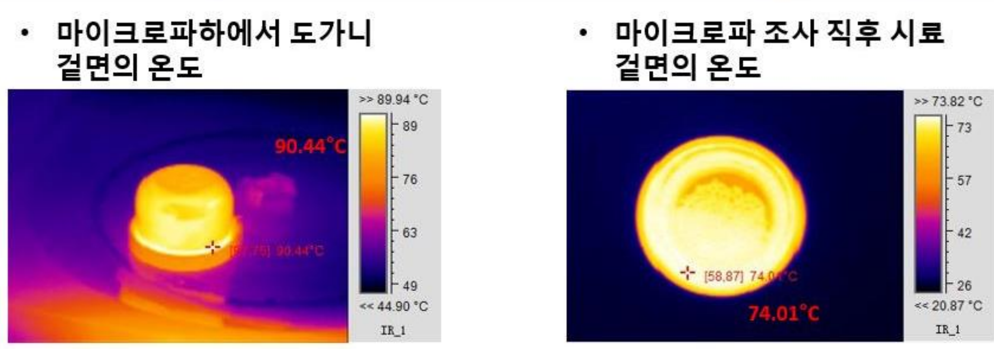


Figure II.5. Lattice structure of Li_2TiO_3 (monoclinic phase) [4]

◆ Feasibility Test of Microwave Heating

Heating up to 1000°C was possible; however, power density needs to be defined for TESOMEX





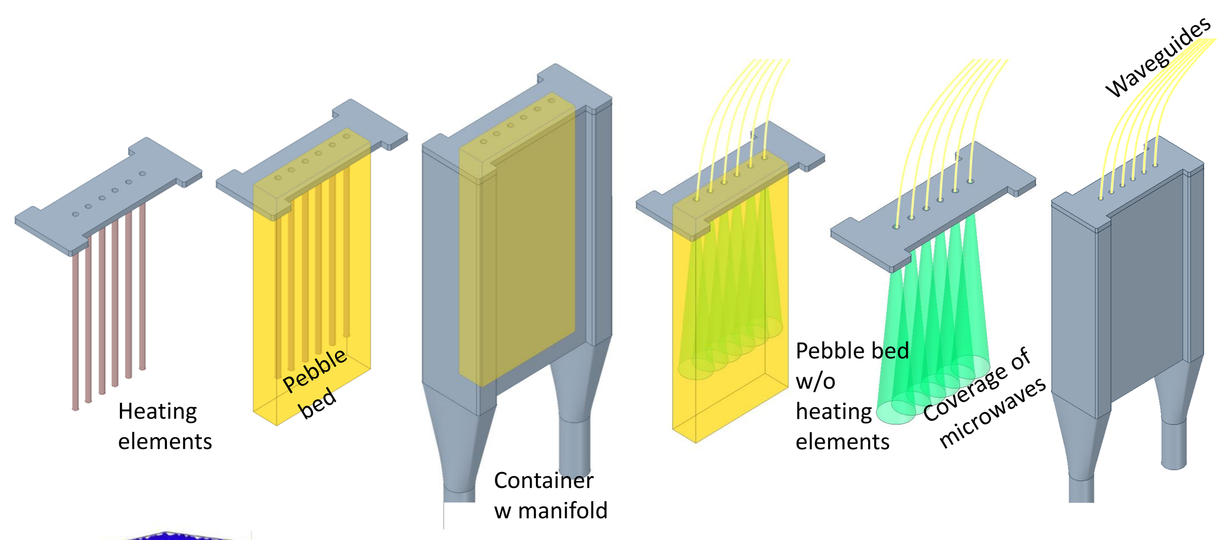
Low Power Microwave

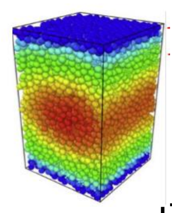
- Microwave: 700W (exposure for 1.5 h)
- Temperature of crucible reached to 90°C during heating, and the pebble was 74°C (pebble temperature was measured after turning off the microwave and opening the chamber)

- Microwave: 2.5 kW and 5 kW (exposure time: >10 min)
- Heating to 800°C, 900°C, 1000°C was possible (But, it is unclear the effect of alumina crucible)
- At 1000°C, sintering was occurred. At 800-900°C, pebble was intact

◆ TESOMEX Next-Step

Schematic design of TESOMEX with microwaves





No unwanted interaction with heating elements

The coverage of microwave should be examined to determine how may ports will be needed

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