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Resonant Acoustics-Assisted Mechanochemistry Method for Li-ion Battery Recycling

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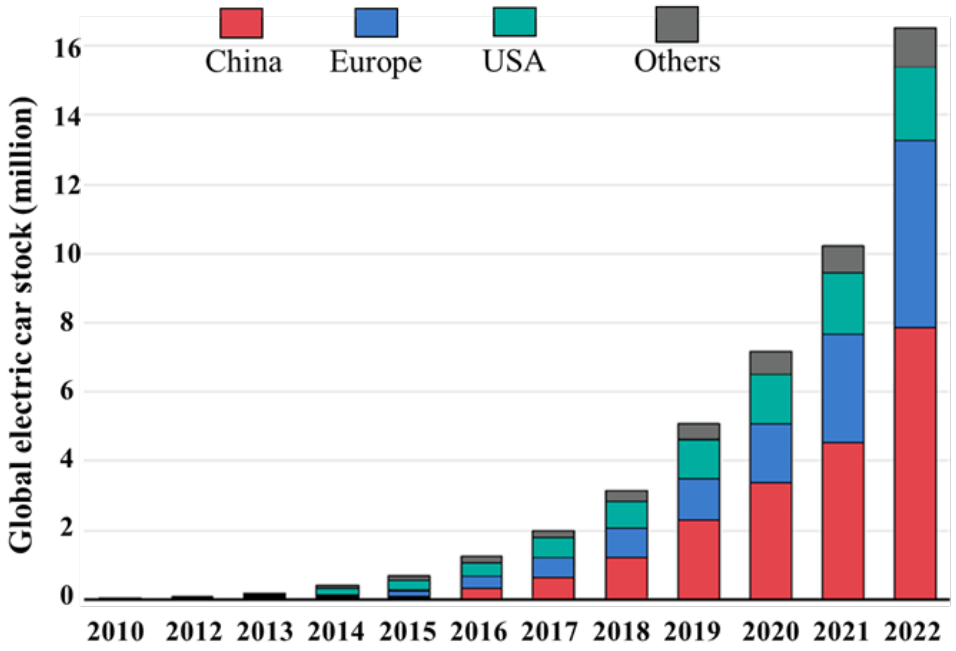
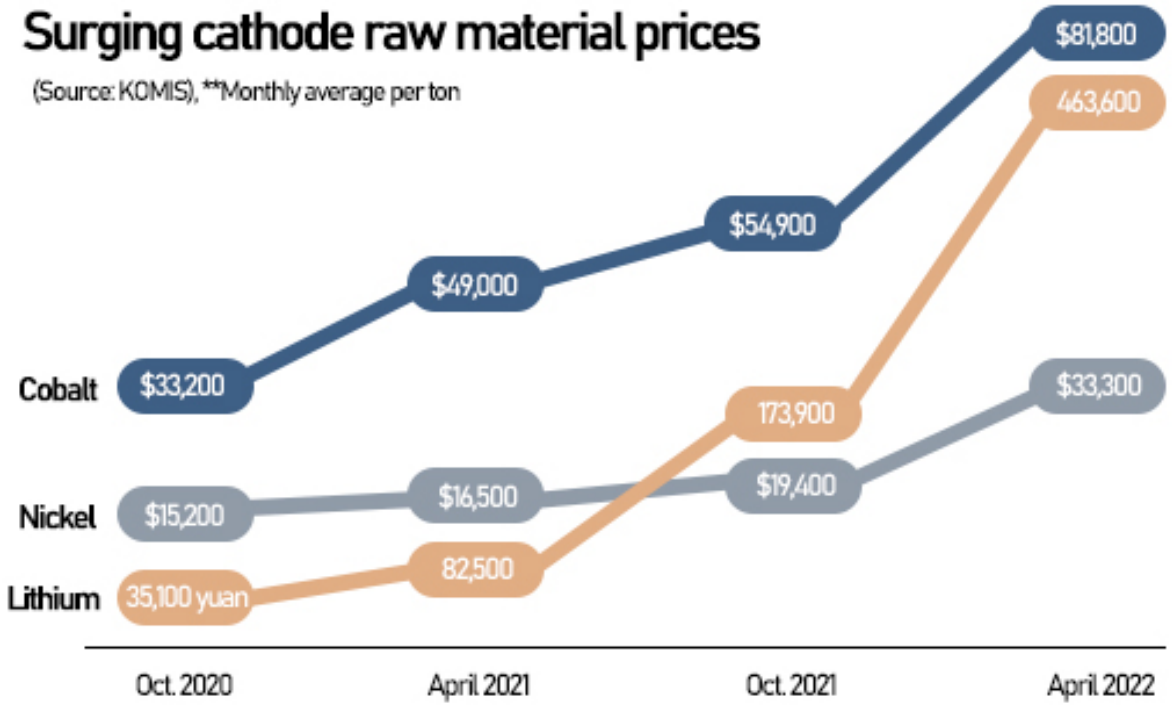
DEARBORN

Decarbonization: Booming Electric Vehicle Market



Global EV Outlook 2022



The rapid growth in the number of EVs would inevitably lead to a huge number of spent battery cells/packs within an 8-10 years span, estimated **21 million packs between 2015 and 2040**.

Y. Wang., et al, "Recycling end-of-life electric vehicle lithium-ion batteries," Joule, vol. 3, pp. 2622-2646, 2019.

Necessity of Battery Recycling

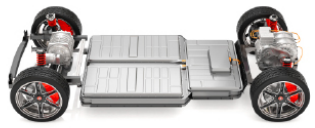
Challenges and potential issues:

- Materials shortages.
- New environmental issues from end-of-life (EOL) EVs.
- Higher GHG emission during EV manufacturing than the internal combustion engine (ICE) vehicle.

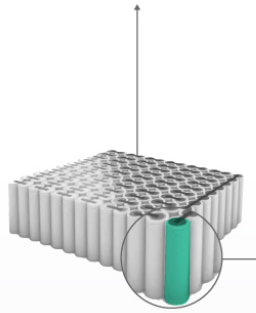
Necessity of Battery Recycling

- Recycling of cathodes is the most valuable.
- Reduction of the cost for the manufacturing and recycling processes is necessary.

Break down of the battery cell cost



EV CHASSIS



A battery pack consists of multiple interconnected modules, and each module is made up of hundreds of individual cells.

The cathode material determines the capacity and power of a battery, typically composed of lithium and other battery metals.

Lithium Nickel Cobalt Manganese

The largest EV battery **manufacturers** are all headquartered in Asia.

80% of all cell manufacturing occurs in China.

The anode is the negatively-charged electrode, typically made of graphite.

Separators prevent electric contact between the cathode and the anode.

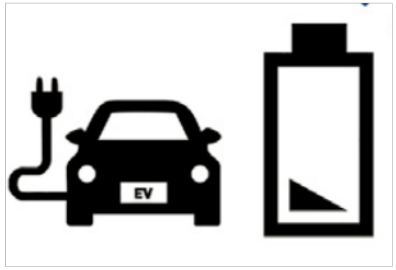
The electrolyte is the medium that transports lithium ions from the cathode to the anode.

Battery housings are cases that contain and protect battery packs, usually made of steel or aluminum.

Y. Wang., et al, "Recycling end-of-life electric vehicle lithium-ion batteries," Joule, vol. 3, pp. 2622-2646, 2019.

Traditional Battery Recycling

Traditional methods



Spent EV LIBs

Pyrometallurgical

Dismantling → Smelting → Slag → Metal alloy

Hydrometallurgical

Dismantling → Leaching → Precipitation →

New LIBs

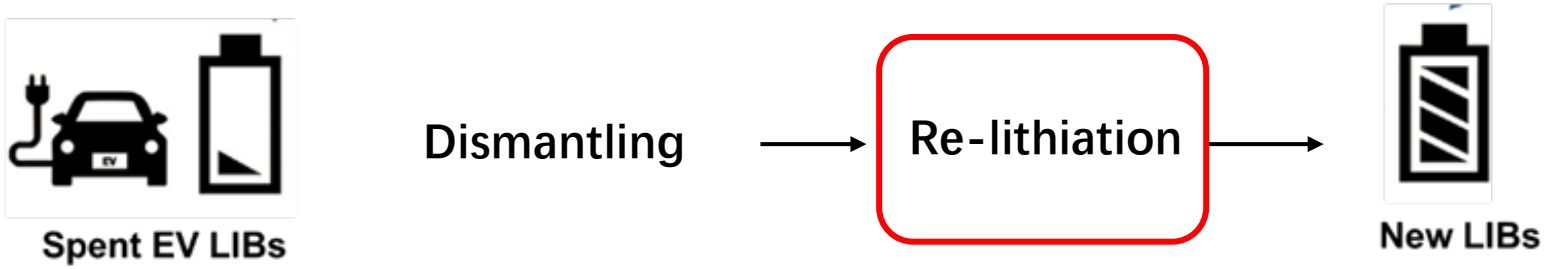
Main Drawbacks:

- Pyrometallurgical
  - High energy cost
  - GHG emission
- Hydrometallurgical
  - High water/acid waste
  - Secondary pollution

Z. Baum, et al, "Lithium-Ion Battery Recycling—Overview of Techniques and Trends," ACS Energy Letters, 2022.

Emerging Direct recycling

Z. Baum, et al, "Lithium-Ion Battery Recycling–Overview of Techniques and Trends," ACS Energy Letters, 2022.



The purpose of relithiation is to repair the surface and bulk defects of degraded materials (due to Li loss) back to their original compound structure

Liquid-synthesis methods:

- Hydrothermal process.
- Co-precipitation.
- Chemical processes.
- Electrochemical processes.

Challenges:

- Agglomeration of cathode particles.
- Necessity of additional drying step.
- Secondary chemical waste.

Resonant Acoustics-Assisted Mechanochemistry Method

Spent LIBs

Spent cathode powder

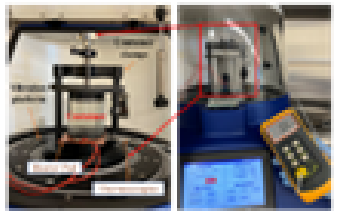
+

NiO/MnO

+

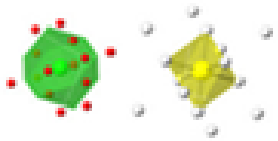
$LiOH\text{-}LiNO_3$

Resonant Acoustics-Assisted Mechanochemistry



Calcination or Sintering

New cathodes

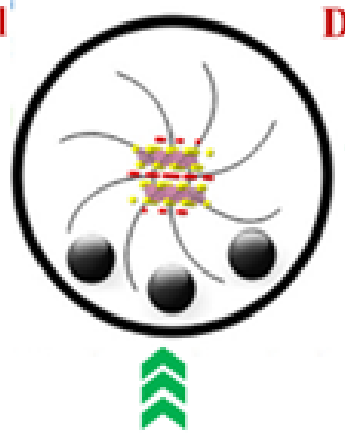


Ni-/Mn-rich single crystal

1. Accelerated mechanochemistry

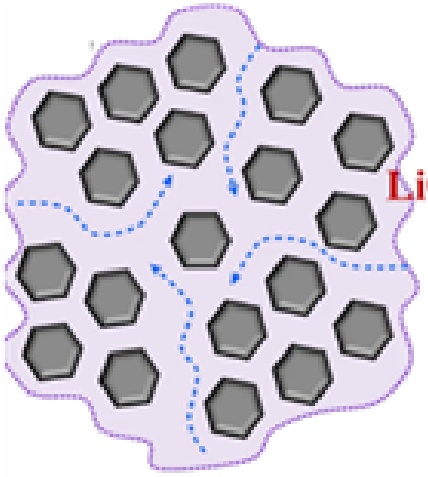
Chemical reagents

Dislocation



Resonant acoustics: high energy

2. Grain boundary corrosion

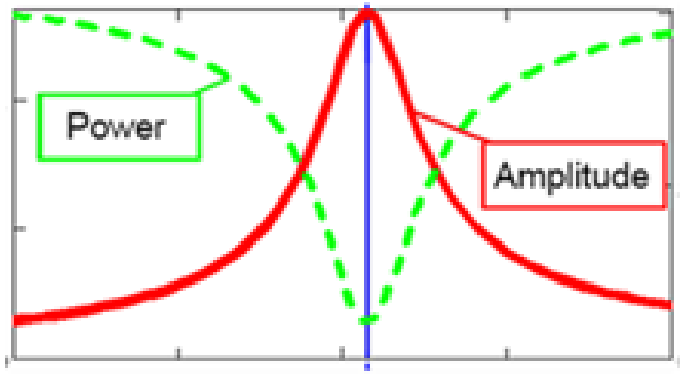


Eutectic $LiOH\text{-}LiNO_3$

Melted Li salts suspension

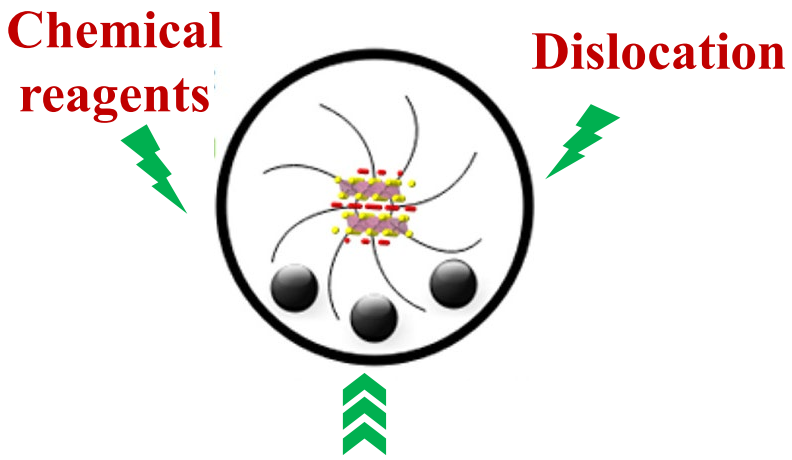
3. Scalable for industrialization

Energy efficient and simple

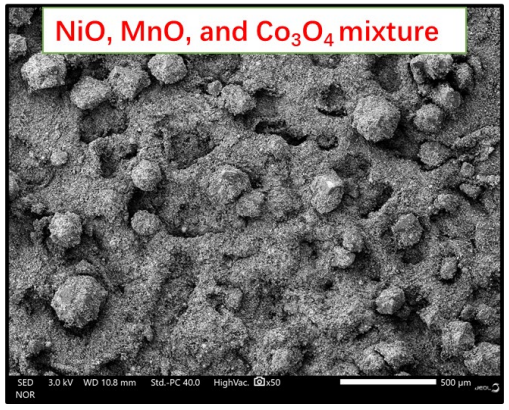


Resonance

Preliminary results: accelerated mechanochemistry

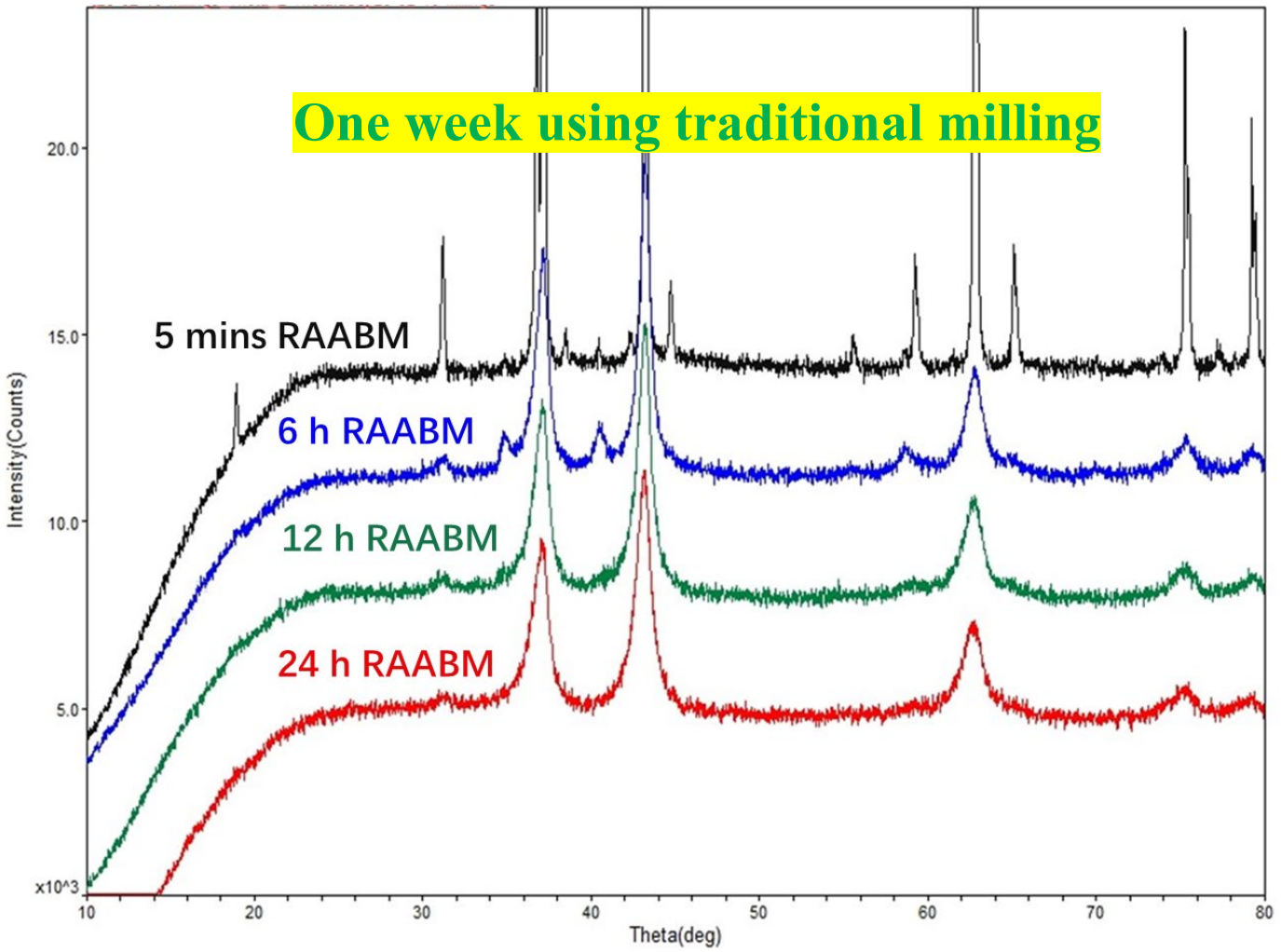


5 mins



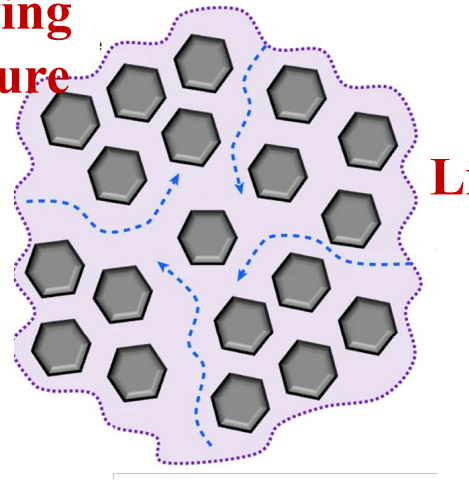
24 h

Preliminary experimental results: milling NiO, MnO, and Co_3O_4 powders in a Ni:Mn:Co =6:2:2 atomic ratio



Preliminary results: grain boundary corrosion

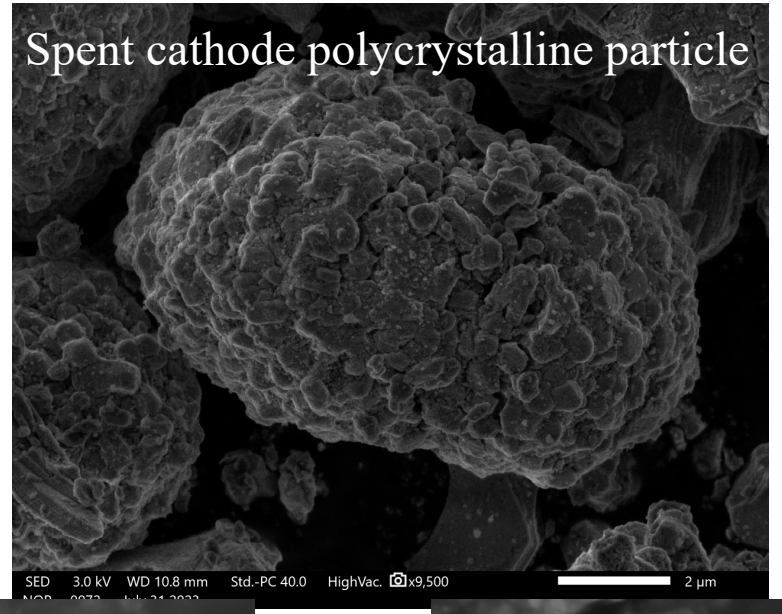
Low melting temperature

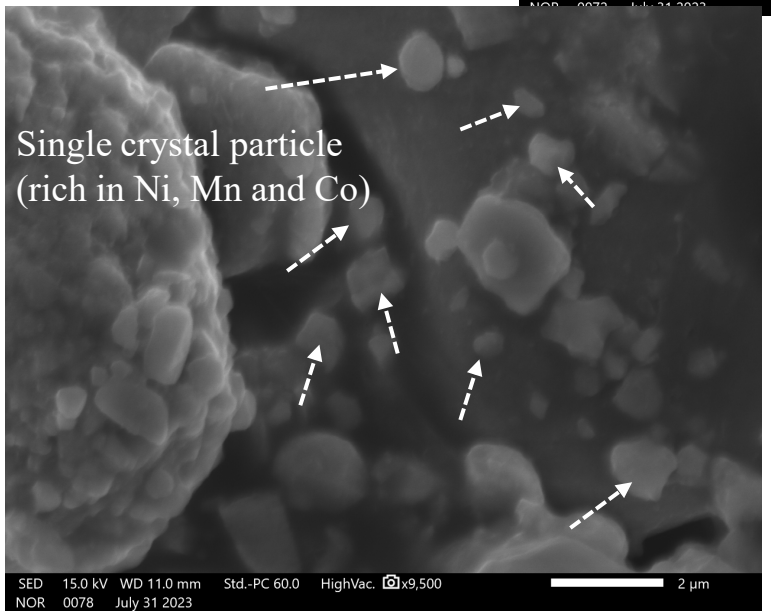


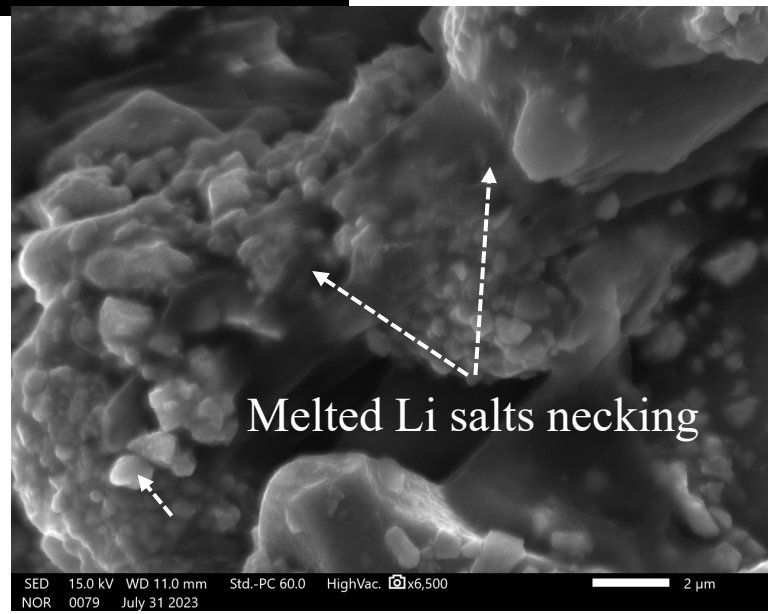
Eutectic $LiOH\text{-}LiNO_3$

Melted Li salts suspension

Single crystal

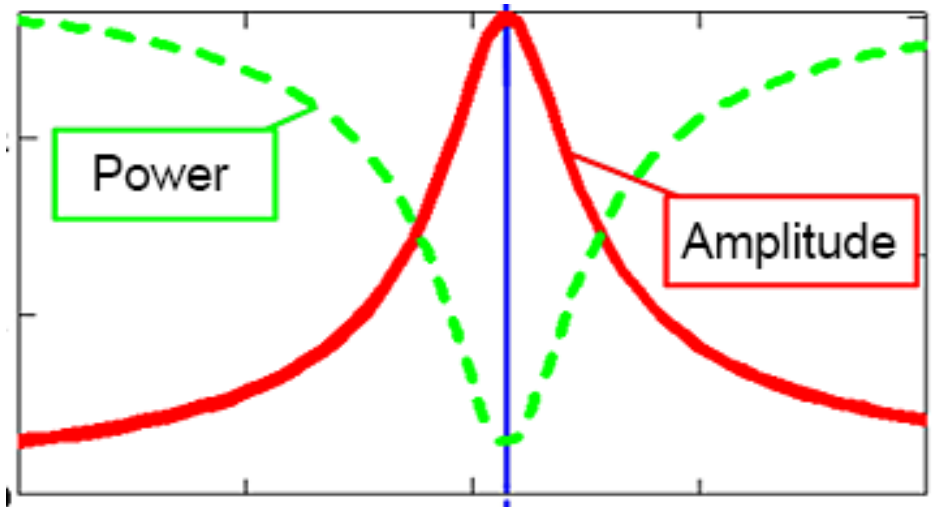






Scalable for industrialization

Energy efficient and simple



Resonance

1.1 lb, Lab scale

80 lb, Pilot scale

924 lb， Industrial scale

Key Takeaways

- All-dry synthesis
- Energy efficient and pollution-free
- Potential toward single crystal
- Scalable for industrialization
- Battery collection, sorting and dismantling is equally important