Advanced Blending for Next-Gen Batteries

ResonantAcoustic® Mixing for Advanced Cathode Development

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OVERVIEW

The race to build better lithium-ion batteries—longer-lasting, higher-performing, and capable of meeting the demands of electric vehicles and grid-scale energy storage—has led researchers to a key optimization: the mixing process. Scientists at the Politecnico di Torino, in collaboration with research partners, achieved a significant advancement with a novel blended cathode combining lithium nickel manganese oxide (LNMO) and lithium iron phosphate (LFP). The result is a cathode that delivers capacity retention exceeding 80% after 1,000 cycles vs pure LNMO, a benchmark that has long eluded high-voltage cathode chemistry. [1]

ResonantAcoustic® Mixing was central to this breakthrough. Researchers demonstrated that RAM technology produced a measurably more uniform distribution of LFP across LNMO particle surfaces than conventional mixing, directly improving electrochemical performance and cycle life.

Solution

- ResonantAcoustic® Technology
- Homogeneous LNMO/LFP Cathode Blending
- Next-Generation Li-ion Battery Cathodes
- Scalable, Low-Energy Mixing Process

Achievement

- >80% Capacity Retention After 1,000 Cycles
- ~30% Improvement Over Pure LNMO Cathodes
- Superior LFP Particle Distribution
- Enhanced Performance

CHALLENGES

High-voltage cathode materials like LNMO are among the most promising candidates for next-generation lithium-ion batteries, offering high energy density and excellent rate capability. However, LNMO has a well-documented weakness: rapid capacity fade during cycling. As lithium is consumed during repeated charge-discharge cycles, performance degrades. This has frustrated researchers and battery manufacturers alike for years. [2]

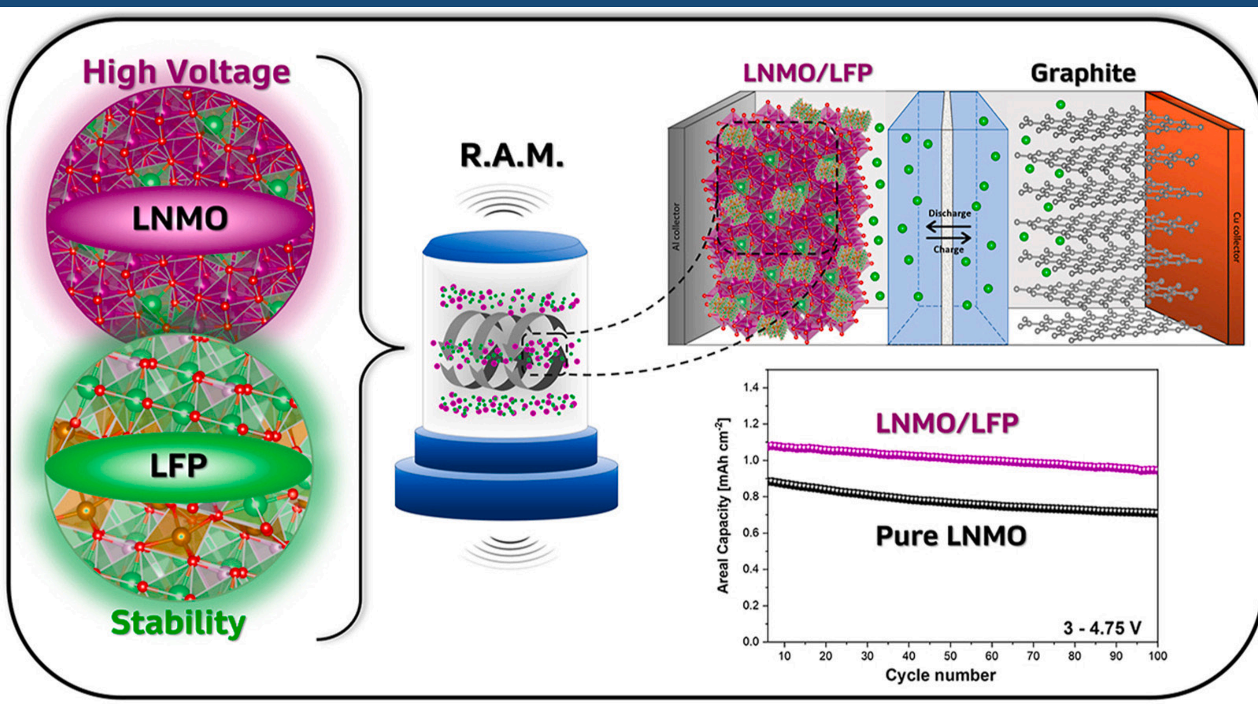
One emerging solution is blending LNMO with LFP, a stable cathode material that can act as a lithium donor to compensate for losses during cycling. In theory, the combination addresses LNMO's core weakness. RAM is critically important to bringing the LMNO and LFP particles close enough together for the exchange to occur. This is due to the uniquely efficient distribution of mixing energy throughout the entire mixing vessel. This ensures unmatched homogeneity at record speed, and is ultimately results in enhanced material performance.

The research team at Politecnico di Torino wanted to know if solving the mixing problem would ultimately lead to solving the chemistry problem. They discovered the two are inseparably connected, with mix quality directly correlating to cathode performance.

Creating the Perfect Hybrid Material

Lithium-ion batteries rely on cathode materials to store and release energy during charge and discharge cycles. LNMO ($LiNi_{0\text{-}5}Mn_{1\text{-}5}O_4$) is a high-voltage spinel cathode offering excellent energy density, but it loses capacity over time as lithium is consumed. LFP ($LiFePO_4$) is a chemically stable cathode known for long cycle life.

Blending the two materials combines LNMO's high-energy performance with LFP's stabilizing role as a lithium reservoir — compensating for lithium loss and extending overall cathode life. Achieving the full benefit of this blend requires LFP to be distributed uniformly across LNMO particles at a fine scale.

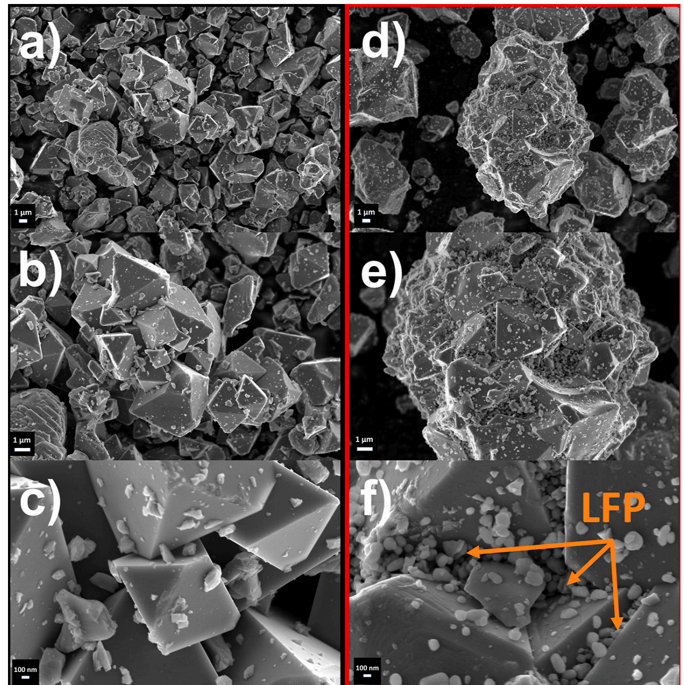


SOLUTION

ResonantAcoustic® Mixing technology, pioneered by Resodyn Acoustic Mixers, uses low-frequency, high-intensity acoustic energy to homogeneously mix powders, pastes, and viscous materials without blades or impellers. In this study, RAM was applied specifically to the powder preparation stage: blending LNMO and LFP powders prior to electrode fabrication, with the goal of achieving a high level of particle-surface distribution.

The research team at Politecnico di Torino designed a systematic investigation to isolate the effect of both LFP loading level and mixing method on cathode performance. Two blend ratios were evaluated: 2 wt% and 10 wt% LFP relative to LNMO. Each was prepared using RAM and assessed against baseline samples. Morphological analysis was conducted to characterize how LFP particles distributed across LNMO surfaces under each condition, providing a direct visual and quantitative basis for comparing mixing quality. This morphological data was then correlated with electrochemical performance, establishing a clear link between particle distribution and battery behavior.

Electrochemical testing was conducted in both half-cell and full-cell configurations. Half-cell testing, in which they paired the blended cathode against a lithium metal counter electrode, allowed the team to evaluate intrinsic cathode performance under controlled conditions across extended cycling at 1C rate. Full-cell testing then validated those findings in a configuration closer to real-world application, using a graphite anode to assess how the blended cathode performed as part of a complete electrochemical system. Rate capability testing was also performed to understand how the blended cathodes responded across different charge and discharge rates. This is a critical consideration for applications like electric vehicles where fast-charge performance matters alongside cycle life.



LFP distributed evenly throughout the LNMO particles to act as lithium donors.

The mechanism behind the improvement is well-defined: LFP acts as a lithium donor during cycling, compensating for the irreversible lithium loss that causes LNMO capacity to fade over time. For this mechanism to function effectively, LFP must be in close proximity to LNMO particles throughout the electrode—precisely the condition that RAM blends achieved. The 2 wt% LFP formulation proved particularly significant. At that loading level, the performance benefit was realized without meaningfully diluting the high-energy contribution of LNMO, preserving the energy density advantage that makes LNMO attractive in the first place.

FINAL RESULTS

The results were both impressive and significant to understanding the link between material performance and its manufacture:

- Highly uniform LFP distribution on LNMO particle surfaces, confirmed through morphological analysis
- Specific capacity exceeding 125 mAh g^{-1} at C/10 in half-cell configuration, demonstrating that blending did not compromise the intrinsic capacity of the cathode
- Capacity retention exceeding 80% after 1,000 cycles at 1C in half-cell testing versus lithium
- Full-cell capacity retention of ~74% after 100 cycles, nearly 30% better than a pure LNMO cathode tested under identical conditions
- The 2 wt% LFP loading identified as the optimal formulation, delivering meaningful cycle-life improvement while preserving high energy density
- LFP confirmed as an active lithium donor, with electrochemical data supporting the mechanism by which LFP compensates for lithium loss during LNMO cycling

> "Capacity retention exceeding 80% after 1,000 cycles—enabled by uniform LFP distribution achieved through ResonantAcoustic® Mixing."
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> -Versaci et al., Journal of Power Sources, 2024

CONCLUSION:

Published in the Journal of Power Sources (2024), the work of Versaci et al. demonstrates that cathode blending becomes a viable and high-performing strategy when ResonantAcoustic® Mixing is applied. The ability to uniformly distribute LFP across LNMO particles was the prerequisite for achieving the cycle-life results the study documents.

For an industry under intense pressure to produce batteries that last longer, charge faster, and perform more reliably, the implications extend well beyond the laboratory. ResonantAcoustic® Mixing proved that the path to better battery chemistry runs directly through better mixing science.

Contact Resodyn Acoustic Mixers, Inc. to discuss revolutionizing your mixing process for advanced battery performance.

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CITATIONS

1. Versaci, D., Colombo, R., Montinaro, G., Buga, M., Cortes Felix, N., Evans, G., Bella, F., Amici, J., Francia, C., & Bodoardo, S. (2024). Tailoring cathode materials: A comprehensive study on LNMO/LFP blending for next generation lithium-ion batteries. Journal of Power Sources, 613, 234955. https://doi.org/10.1016/j.jpowsour.2024.234955
2. Kim, Taemin, Hyunsoo Oh, Seongmin Yang, and Hyeon Jeong Lee. "Unlocking 5 V-Class Lithium-Ion Batteries: Challenges and Perspectives on High-Voltage LNMO Cathodes." ACS Applied Energy Materials 8, no. 18 (2025): 13155–78. https://doi.org/10.1021/acsaem.5c02272