Resodyn™
ACOUSTIC MIXERS
Innovative Mixing Solutions

Advances in Material Processing for Battery and Energy Storage Enabled By ResonantAcoustic® Mixing

Testimonials • Published Articles • Patents & Patent Applications

This document is a portfolio of user testimonials, articles, and patents/patents pending that reference Resodyn's ResonantAcoustic® Mixing (RAM) technology in a variety of battery manufacturing industry applications. This collection of abstracts and links to published articles is intended to provide insight into the value of RAM technology as a means of solving challenges, improving quality, and raising productivity in development and processing of materials for battery applications.

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Battery and Energy Storage Material Processing

Scientists, researchers and technical experts agree that ResonantAcoustic® Mixing (RAM) is unprecedented in a wide variety of mixing and processing functions across the rapidly developing battery and energy storage industries. The information in this Folio reveals specific roadmaps to new discoveries, consistently higher quality, significant boosts in productivity, shorter time to market, and robust profitability for a broad range of battery and energy storage materials processing applications.

Critical environmental and economic forces are demanding significant improvement in battery and energy storage performance. Industrial, consumer, vehicle, medical, defense sectors all crave higher energy density and shorter cycle time. Significant increases in energy storage life cycles drives transformative adoption across the entire suite of battery and energy storage materials processing technology applications and industry requirements.

Reaching exceptionally high standards of battery and energy storage materials performance relies heavily on high-grade material processing. ResonantAcoustic® technology accomplishes this requirement by enabling rapid discovery, development, and production methods at unparalleled quality and consistency. Developers and producers world-wide, as represented in this Folio, are adopting RAM technology as their processing technology of choice.

Developers of 21st century electrical energy storage rely upon RAM technology to innovate and deliver new products and solutions.

= Locations of customers of ResonantAcoustic® Mixers

What are battery and energy storage professionals saying about RAM?

"…we have made our first steps with the new LabRam II from Resodyn Acoustic Mixers. With this second resonant acoustic mixer, we were able to add another batch size to our large portfolio of different mixing technologies…"

- European battery materials research organization

"We work with multiple battery material mixes, including powder-powder, slurries and pastes. [RAM] gives us a quick, easy and convenient method of mixing, milling and sieving those materials in a single unit."

- Global energy storage products company

"... the cathode exhibited a higher specific capacity and improved rate performance because of the minimal side reactions at the cathode–solid electrolyte interface. These results demonstrate the success of the Resonant Acoustic® coating of NiCo2S4 NPs on NCM 622."

- NiCo2S4 Bi-metal Sulfide Coating on LiNi0.6Co0.2Mn0.2O2 Cathode for High-Performance All-Solid-State Lithium Batteries
Young-Jin Kim, Rajesh Rajagopal, Sung Kang, and Kwang-Sun Ryu
ACS Omega 2021 6 (10), 6824-6835 DOI: 10.1021/acsomega.0c05942

RAM: The mixer of choice for battery and energy storage material processing

More than a thousand RAM systems are in use in 35 countries around the world. RAM is the world's preferred choice for innovation in materials processing.

PUBLISHED ARTICLES

Icon Legend

- RAM testing, evaluation
- Material/chemical properties
- Powder/powder
- Liquid/powder
- Materials processing
- Materials/product quality

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Novel dry deposition of LiNbO3 or Li2ZrO3 on LiNi0. 6Co0. 2Mn0. 2O2 for high performance all-solid-state lithium batteries	"ResonantAcoustic® Mixing (RAM) technology is preferred embodiment modification of NCM."	2020
	Physical Property Analysis of Composite Electrodes with Different Active Material Sizes and Densities using 3D Structural Modeling	"...cast anode supports via resonant acoustic mixing technology for solid oxide fuel cells..."	2020
	Evaluation of RAM [Resonant Acoustic Mixing] Performance	"Resonant acoustic mixing can significantly reduce blending time, making it a good candidate for improving the efficiency of powder mixing processes."	2020
	Use of carbon coating on LiNi0. 8Co0.1Mn0.1O2 cathode material for enhanced performances of lithium-ion batteries	"...powders were mixed with different amounts (SPB 0.1 wt%, SPB 0.3 wt%, SPB 0.5 wt% and SPB 0.7 wt%) of super-P carbon black via resonant acoustic mixer (PharmaRAM™ I, Resodyn Acoustic Mixers Inc.) at the acceleration of high mix for 20 min. and then calcined at 300 °C for 3 h."	2020
	In Situ Metal Matrix Nanocomposites: Towards Understanding Formation Mechanisms and Microstructural Control	"A study (thesis) using ball mill and RAM mixing to observe interactions between particles and melt during solidification; determined these are highly complex processes."	2020
	Ultra-fast fabrication of tape-cast anode supports for solid oxide fuel cells via resonant acoustic mixing technology	"[RAM] Slurry optimization in 30 minutes vs. 4,320 minutes using ball mill"	2019
	Molten electrolyte dual-phase membranes for intermediate temperature fuel cells	Multiple application uses with varying materials are discussed.	2019

PUBLISHED ARTICLES

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Polyethylene/Graphene Nanoplatelet Nanocomposite-Based Insulating Materials for Effective Reduction of Space Charge Accumulation in High-Voltage …	"...LDPE pellets and GNP powders were mixed in a dry state using a resonant acoustic mixer (RAM). GNP particles were uniformly embedded (or coated) on the LDPE pellet surfaces [and] aggregated GNP particles . . . were effectively pulverized by strong collisions between particles in the RAM mixing step..."	2019
	Synergetic effect of carbon and AlF3 coatings on the lithium titanium oxide anode material for high power lithium-ion batteries	"[Lithium Titanium Oxide] with a simultaneous coating layer of carbon and AlF3 formed by acoustic mixing and post heat treatment shows a potential to further improve commercially-optimized carbon-coated LTO by alleviating its inherently low conductivity. "	2019
	The Future of Advanced Materials and Manufacturing for Defence	"Key technologies of relevance . . . are: nano-scale energetics; structurally reactive materials; the processing technology of resonant acoustic mixing, additive manufacturing . .. "	2018
	How silicon electrodes can be calendered without altering their mechanical strength and cycle life	" … remarkable improvement of the cycle life is observed."	2017
	Electrostatic discharge sensitivity and resistivity measurements of Al nanothermites and their fuel and oxidant precursors	"Nanothermite formation mixing was achieved using a lab-scale Resodyn Resonant Acoustic Mixer (LabRAM) with 500 g maximum capacity...lower fill volumes, with resultant reductions in particle-particle interactions, are attractive for the present application."	2017
	Metal Oxide-Carbon Nanocomposites for Energy Storage	To attain a well-dispersed network of carbon nanotubes and RuO2 nanoribbons in a composite paper, a resonant acoustic mixing technique was applied for 10 min prior to filtration. Acoustic mixing plays important role to break agglomerates and blend both	2017
	Synthesis of boron-doped Si particles by ball milling and application in Li-ion batteries	"...It was shown that the use of a resonant acoustic mixer for the mixing of the (Si + carbon black + carboxymethyl cellulose) components increases the cycle life of the composite electrode."	2012
	Vanadium oxide nanowire–carbon nanotube binder-free flexible electrodes for supercapacitors	"...a low frequency resonant acoustic mixing technique made for … improvements in battery applications and nanowires in the composite paper..."	2011
	ResonantAcoustic® Mixing for Lithium-ion Battery Manufacture	"Investigation of RAM for blending materials used in Li-ion battery electrodes. Mixing process took less than one minute compared to six hours by traditional mixers."	2010

PUBLISHED ARTICLES

Partial (edited) selection of searched technical articles using the following search terms (articles are live links): "Resonant Acoustic Mixing" AND/OR: "battery," "batteries," "RAM," "Resodyn."

NiCo2S4 Bi-metal Sulfide Coating on LiNi0.6Co0.2Mn0.2O2 Cathode for High-Performance Solid-State Li Batteries
YJ Kim, R Rajagopal, S Kang, KS Ryu- ACS omega, 2021- ACS Publications
NiCo2S4 nanoparticles (NPs) were dry coated on LiNi0. 6Co0. 2Mn0. 2O2 (NCM622)cathode using a resonant acoustic coating technique to produce all-solid-state lithiumbatteries.

Novel dry deposition of LiNbO3 or Li2ZrO3 on LiNi0. 6Co0. 2Mn0. 2O2 for high performance all-solid-state lithium batteries
[[TTE: Resonant-Acoustic technique was adapted for modification of NCM.]] YJ Kim, R Rajagopal, S Kang, KS Ryu- Chemical Engineering Journal, 2020- Elsevier
… recent years. In addition, Li-conducting polymer and solid electrolyte as well as electrodes have been investigated since the 1960s to develop and commercialize the Li-S batteries, Li-ion battery, and ASSLBs [9], [10]. In recent …
Related articles

Physical Property Analysis of Composite Electrodes with Different Active Material Sizes and Densities using 3D Structural Modeling
S Yang, J Park, S Byun, N Kim…- Journal of the Korean …, 2020- koreascience.or.kr
Composite electrodes for rechargeable batteries generally consist of active material, electric conductor, and polymeric binder. And their composition and distribution within the composite electrode determine the electrochemical activity in the electrochemical systems. However, it is not easy to quantify the physical properties of composite electrodes themselves using conventional experimental analysis tools. …
Related articles

Use of carbon coating on LiNi 0.8 Co 0.1 Mn 0.1 O 2 cathode material for enhanced performances of LIBs
SJ Sim, SH Lee, BS Jin, HS Kim- Scientific RepoRtS, 2020- nature.com
… The demand of lithium-ion batteries (LIBs) has been intensively increasing with growing large-scale devices such as … 0.3 wt%, SPB 0.5 wt% and SPB 0.7 wt%) of super-P carbon black via resonant acoustic mixer (PharmaRAM™ I, Resodyn Acoustic Mixers Inc.) at …
Related articles

In Situ Metal Matrix Nanocomposites: Towards Understanding Formation Mechanisms and Microstructural Control
C Reese- 2020- deepblue.lib.umich.edu
Lightweight materials are critical to meet the ever-increasing demands for improved fuel economy in the automotive, aerospace and defense industries. Consequently, aluminum alloys have been employed extensively in these industries for structural applications owing to their high strength-to-weight ratio. However, Al alloys suffer from several shortcomings, such as poor thermal stability of mechanical properties, …
Related articles

Ultra-fast fabrication of tape-cast anode supports for solid oxide fuel cells via resonant acoustic mixing technology
JH Park, KT Bae, KJ Kim, DW Joh, D Kim…- Ceramics …, 2019- Elsevier
Herein, for the first time, we demonstrate ultra-fast fabrication of a tape casted NiO-yttria stabilized zirconia (YSZ) anode support for solid oxide fuel cells (SOFCs) using resonant acoustic mixing (RAM) technology. Due to its characteristics of non-contact and high-intensity acoustic field-assisted mixing, NiO-YSZ tape-cast slurry is prepared via a RAM process within 0.5 h,> 140 times faster than use of a conventional ball-milling (BM) process (72 h).
Related articles

PUBLISHED ARTICLES

Molten electrolyte dual-phase membranes for intermediate temperature fuel cells
P Campbell, MC Hernandez…- US Patent App. 16 …, 2019- Google Patents
In one aspect of an inventive concept, a fuel cell system includes a cathode and an anode, a porous ceramic support positioned between the cathode and anode, and a molten electrolyte mixture in pores of the ceramic support. In another aspect of an inventive concept, a method for producing energy includes directing a gas stream through a cathode, where an inner side of the cathode is adjacent to a dual phase membrane including a ceramic support infiltrated with a molten electrolyte mixture, sweeping an outer side of the anode with water …
Related articles

Polyethylene/Graphene Nanoplatelet Nanocomposite-Based Insulating Materials for Effective Reduction of Space Charge Accumulation in High-Voltage …
JS Park, YS Kim, HJ Jung, D Park, JY Yoo…- Journal of …, 2019- hindawi.com
… The maximum enhanced electric field showed a value of 67kV/mm inside the neat LDPE sample due to the movement of positive packet-like charges from anode to cathode; field enhancement factor (FEF), which is the ratio of the electric field before and after the accumulation …
Related articles

Synergetic effect of carbon and AlF3 coatings on the lithium titanium oxide anode material for high power lithium-ion batteries
Y Chung, Y Shin, Y Liu, JS Park, CL Margez…- Journal of …, 2019- Elsevier
A carbon coated commercial lithium titanium oxide (Li 4 Ti 5 O 12; LTO) was acoustically mixed with nano-sized AlF 3 and heat treated to form a simultaneous coating layer of carbon and AlF 3 on LTO particles. The surface modified LTO samples were characterized by a variety of means such as X-ray diffraction, Fourier transform infrared spectrometer, high-resolution transmission electron microscope, and inductively coupled plasma mass spectrometry. The results indicate that both carbon and AlF 3 layers exist on the surface of …
Related articles

The Future of Advanced Materials and Manufacturing for Defence
DST Edinburgh- 2018- dst.defence.gov.au
[[TTE: RAM Technology covered]]
… Gradually evolving Li-ion batteries will provide continued growth in battery energy density, through incremental innovations like higher-voltage cathodes and electrolytes, paired with higher-capacity active materials such as silicon-based composites …
Related articles

How silicon electrodes can be calendered without altering their mechanical strength and cycle life
Z Karkar, T Jaouhari, A Tranchot, D Mazouzi…- Journal of Power …, 2017- Elsevier
… silicon-based negative electrodes is one of the most promising ways to increase the energy density of the lithium-ion batteries, due to … a Fritsch Pulverisette 7 mixer at 500 rpm for 1 h with 3 silicon nitride balls (9.5 mm diameter) and (ii) the resonant acoustic mixing (RAM) method …
Related articles

PUBLISHED ARTICLES

Electrostatic discharge sensitivity and resistivity measurements of Al nanothermites and their fuel and oxidant precursors
D Kelly, P Beland, P Brousseau…- … European Journal of …, 2017- yadda.icm.edu.pl
… [21] Kelly, DG; Beland, P.; Brousseau, P.; Petre, CF The Performance Modification of Aluminum Nanothermites Prepared Using Resonant Acoustic Mixing … of Particle Size on the Electrochemical Properties of Aluminum Powders as Anode Materials for Lithium Ion Batteries …
Related articles

Metal Oxide–Carbon Nanocomposites for Energy Storage and Conversion
WA Perera- 2017- utd-ir.tdl.org
… 160.8 Wh kg-1 energy density and 276.66 F g-1 specific capacitance. There are many energy storage devices available ranging from fuel cells to batteries.4 Batteries are … paper, a high frequency resonant acoustic mixing technique was applied for 10 min prior to filtration …
Related articles

Synthesis of boron-doped Si particles by ball milling and application in Li-ion batteries
S Rousselot, M Gauthier, D Mazouzi, B Lestriez…- Journal of Power …, 2012- Elsevier
… grid energy storage applications, which are more challenging in terms of battery storage capacity …doping on the Si-based composite electrode performance for Li-ion batteries is presented … Resonant acoustic mixing is a new approach to mixing and dispersion of materials …
Related articles

Vanadium oxide nanowire–carbon nanotube binder-free flexible electrodes for supercapacitors
SD Perera, B Patel, N Nijem…- Advanced Energy …, 2011- Wiley Online Library
… its electrochemical performance as electrode materials for Li + ion batteries and electrochemical … to be investigated but improvements need to be made for battery applications.29 … and nanowires in the composite paper, a low frequency resonant acoustic mixing technique was …
Related articles

ResonantAcoustic® Mixing for Lithium-ion Battery Manufacture
resodyn.co.kr › file › ram-battery-material-mixing
In Li-ion battery production the mixing process plays a critical role in determining the quality of the electrode materials, and hence, the battery electrochemical ...
Related articles

Relevant Patents

Approved and pending applications for work involving the use of ResonantAcoustic® mixing technology.*

*Including patents with RAM as the preferred embodiment

Method of manufacturing electrode, electrode manufactured by the same, membrane …
WO EP US CN JP JP2020145210A
Priority 2016-12-28 • Filed 2020-06-08 • Published 2020-09-10
To provide an electrode with improved various performances by increasing a utilization rate of a catalyst and an ionomer and a carbon structure having improved dispersion stability of the carbon structure and the ionomer.SOLUTION: Provided are an electrode, including a catalyst 2 and an ionomer 3, …

Method for manufacturing ionomer coated carbon structure and ionomer coated …
KR KR102175008B1
Priority 2017-01-02 • Filed 2017-01-02 • Granted 2020-11-05 • Published 2020-11-05
The present invention relates to a method of manufacturing a carbon structure coated with an ionomer, a carbon structure coated with an ionomer, a carbon structure coated with the ionomer, a carbon structure assembly coated with an ionomer, and the film-ionomer A fuel cell comprising a coated …

Hydrophobic coatings comprising hybrid microspheres with nano/micro roughness
WO EP CN KR TW TW202003718A
Priority 2018-05-31 • Filed 2019-05-31 • Published 2020-01-16
Described herein are coatings based on a hydrophobic polymer matrix and hydrophobic nanoparticles that provide a damage tolerant hydrophobic, superhydrophobic, and/or snowphobic capability, wherein the nanoparticles can comprise modified and phyllosilicate nanoclays. The micro and nano roughness …

Graphene-carbon hybrid foam-protected anode active material coating for lithium …
WO WO2020154258A1 Bor Z. Jang Global Graphene Group, Inc.
Priority 2019-01-21 • Filed 2020-01-21 • Published 2020-07-30
Provided is a porous anode material structure for a lithium-ion battery (and method of manufacturing same), the structure comprising (A) an integral 3D graphene-carbon hybrid foam comprising multiple pores, having a pore volume Vp, and pore walls; and (B) coating of an anode active material, …

Method of producing graphene-carbon hybrid foam-protected anode active material …
US US20200235393A1 Bor Z. Jang Nanotek Instruments, Inc.
Priority 2019-01-21 • Filed 2019-01-21 • Published 2020-07-23
Provided is method of producing a porous anode material structure for a lithium-ion battery, the method comprising (A) providing an integral 3D graphene-carbon hybrid foam comprising multiple pores, having a pore volume Vp, and pore walls; and (B) impregnating or infiltrating the pores with a …

Alkali metal battery with electrodes based on integrated 3D graphene-carbon- …
WO US CN JP KR JP2019521476A
Nanotek Instruments Priority 2016-06-07 • Filed 2017-06-01 • Published 2019-07-25
The anode includes an integrated 3D graphene-carbon hybrid foam composed of a plurality of pores, pore walls, and a lithium adsorbing metal present in the pores, the metals being Au, Ag, Mg, Zn, Ti, Na , K, Al, Fe, Mn, Co, Ni, Sn, V, Cr, or alloys thereof, in an amount of 0.1% to 50% of the total …

Patents, cont'd.

Supercapacitor having an integral 3D graphene-carbon hybrid foam-based …
WO US CN JP KR US9905373B2 Aruna Zhamu Nanotek Instruments, Inc.
Priority 2016-01-04 • Filed 2016-01-04 • Granted 2018-02-27 • Published 2018-02-27
Provided is a supercapacitor having an anode, a cathode, a porous separator/electrolyte, wherein at least one of electrodes contains an integral 3D graphene-carbon hybrid foam composed of multiple pores and pore walls, wherein the pore walls contain single-layer or few-layer graphene sheets …

Integral 3D graphene-carbon hybrid foam separation device
US US10058842B1 Aruna Zhamu Nanotek Instruments, Inc.
Priority 2015-12-28 • Filed 2018-06-01 • Granted 2018-08-28 • Published 2018-08-28
Provided is an integral 3D graphene-carbon hybrid foam composed of multiple pores and pore walls, wherein the pore walls contain single-layer or few-layer graphene sheets chemically bonded by a carbon material having a carbon material-to-graphene weight ratio from 1/100 to 1/2, wherein the few- …"

Method for producing polymer matrix composite
WO EP US CN JP KR TW JP2021503525A
Priority 2017-11-16 • Filed 2018-11-15 • Published 2021-02-12
A method for producing a polymer matrix composite containing a porous polymer network structure and a plurality of particles dispersed in the polymer network structure, wherein the thermoplastic polymer, a solvent in which the thermoplastic polymer is soluble, and a plurality of particles are used …

Catalyst, preparation method therefor, electrode comprising same, membrane-electrode assembly, and fuel cell
EP US CN JP KR TW KR20190078489A
Priority 2017-12-26 • Filed 2018-11-28 • Published 2019-07-04
The present invention relates to a catalyst, a producing method thereof, and an electrode, a membrane-electrode assembly, and a fuel cell including the same. The catalyst comprises: a carrier; metal particles supported on the carrier; and a coating layer positioned on the metal particles and …

Method for manufacturing electrode, electrode manufactured by using the same, …
KR KR102189064B1
Priority 2016-12-28 • Filed 2016-12-28 • Granted 2020-12-09 • Published 2020-12-09
The present invention relates to a method of manufacturing an electrode, an electrode manufactured thereby, a membrane-electrode assembly including the electrode, and a fuel cell including the membrane-electrode assembly, wherein the method of manufacturing the electrode comprises mixing a …

Patents, cont'd.

Chemical-free production of 3D graphene-carbon hybrid foam

US US9597657B1 Aruna Zhamu Nanotek Instruments, Inc.

Priority 2015-12-28 • Filed 2015-12-28 • Granted 2017-03-21 • Published 2017-03-21

Provided is a method of producing an integral 3D graphene-carbon hybrid foam, comprising: (a) mixing multiple particles of a graphitic material and multiple particles of a solid polymer carrier material to form a mixture in an impacting chamber of an energy impacting apparatus; (b) operating the …

Synthesis of soluble conducting polymers by acoustic mixing

US US9441075B1 Marie C. Kane Sandia Corporation

Priority 2014-04-09 • Filed 2014-04-09 • Granted 2016-09-13 • Published 2016-09-13

A method including combining an aniline monomer, an oxidant, water and an organic solvent; subjecting the combination to acoustic mixing to form an emulsion; and recovering a polyaniliine from the combination. A method including combining a aniline monomer, an oxidant, water and an organic solvent …

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