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

**Testimonials • Published Articles • Patents & Patent Applications**

**December 2023**

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 and energy storage manufacturing industry applications. Also provided is a collection of abstracts and links to published articles that provides 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 and energy storage 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 insights 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.

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.

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

## 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 battery and energy storage material processors are 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 $NiCo_2S_4$ NPs on NCM 622."***

-Young-Jin Kim, et al.
ACS Omega

## RAM: The Mixer of Choice for Battery and Energy Storage Professionals

More than a thousand RAM systems are in use in 38 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 |
|---|---|---|---|
| | A Comparative Analysis of Cathode Stripping Methods for Direct Recycling of Spent Li-Ion Batteries | "Our results show that solvent dissolution & resonant acoustic vibration-based cathode stripping achieves an efficiency of up to 92%, without introducing impurities such as small aluminum fragments and powders." | 2023 |
| | From waste graphite fines to revalorized anode material for Li-ion batteries | "... mixed by resonant acoustic mixer (RAM, ResoDyn LabRam) at ..." | 2023 |
| | Functional Surface Coating to Enhance the Stability of $LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$ | "The wet powder was then further mixed using Resodyn Acoustic Mixer for 2 min to ensure uniform coverage of the modification solution on the NMC622 surface." | 2023 |
| | New insight into degradation mechanisms of conductive and thermally resistant polyaniline films | "...to ensure a homogeneous dispersion, SDP, carbon black, PANI-DNNSA and toluene were acoustically mixed using a Resonant Acoustic Mixer (Resodyn)..." | 2023 |
| | Stabilization of NCM811 cathode for Li-ion batteries by N-doped carbon coating | "In order to obtain uniform carbon coating, Sim et al. [34] developed a resonant acoustic mixing method to prepare carbon-coated NCM811..." | 2023 |
| | Resonant acoustic-mixing technology as a novel method for production of negative-temperature coefficient thermistors | "To the best of our knowledge, RAM was applied to produce NTC thermistors for the first time in this study." | 2022 |
| | Material extrusion additive manufacturing of dense pastes consisting of macroscopic particles | "Two mixing methods have emerged as leaders, dual-axis centrifugal mixing and resonant acoustic mixing.." | 2022 |
| | Control of carbon dioxide concentration in headspace of multiple flasks using both non-electric bellows pump and shaking incubator | "... setting space for wiring or batteries to provide electric power. ... the flask gas phase, thus making the gas composition in the ... The recently developed resonant acoustic mixing (RAM) for ..." | 2022 |

# PUBLISHED ARTICLES

| Icons | Publication Title (Live Links)* | RAM Application Summary | Year |
|---|---|---|---|
|  | NiCo2S4 Bi-metal Sulfide Coating on LiNi0. 6Co0.2Mn0.2O2 Cathode for High-Performance All-Solid-State Lithium Batteries | "the mixture was transferred into a specially designed zirconia container (fill up to 80%) and vibrated with a Resonant Acoustic Mixer (LabRAM II, Resodyn Inc.) at the vibration energy until 60 G for 20 min." | 2021 |
|  | Use of Zirconium Dual-Modification on the LiNi0.8Co0.1Mn0.1O2 Cathode for Improved Electrochemical Performances of Lithium-Ion Batteries | "the NCM811 powders were mixed with different amounts of ZrO 2 (0, 0.25, 0.5, and 0.75 wt %) using a resonant acoustic mixer..." | 2021 |
|  | Diffusion of Zirconium (IV) Ions from Coated Thick Zirconium Oxide Shell to the Bulk Structure of Ni-Rich NMC811 Cathode Leading to High-Performance 18650 Cylindrical Li-Ion Batteries | "… one of the most important eneWrgy storage devices for a wide … on NMC811 by using a resonant acoustic mixing and sintering at 750 C … Figure 8a shows the images of all 18650 fabrication …" | 2021 |
|  | Novel dry deposition of LiNbO3 or Li2ZrO3 on LiNi0. 6Co0. 2Mn0. 2O2 for high performance all-solid-state lithium batteries | "ResonantWAcoustic® 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 |

# 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 Direct Current Cables | "...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" "energy storage"*

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**A Comparative Analysis of Cathode Stripping Methods for Direct Recycling of Spent Li-Ion Batteries**

**Yaohong Xiao, Jinrong Su, & Lei Chen**

Our results show that solvent dissolution & resonant acoustic vibration-based cathode stripping achieves an efficiency of up to 92%, without introducing impurities such as small aluminum fragments and powders. These findings demonstrate the potential of resonant acoustic vibration-based cathode stripping for scaling up the cathode powder recovery and direct recycling of spent Li-ion batteries.

**From waste graphite fines to revalorized anode material for Li-ion batteries**

**Juan Carlos Abrego-Martinez, Youling Wang, Victor Vanpeene, & Lionel Roué**

Lithium-ion batteries (LIBs) have become a prominent energy storage … mixed by resonant acoustic mixer (RAM, Reso-Dyn LabRam) at …

**Functional Surface Coating to Enhance the Stability of $LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$**

**Yingying Xie, Matthew Li, Jiantao Li, Xiaozhou Huang, Jiyu Cai, Zhenzhen Yang, Hoai Nguyen, Baasit ali Shaik sulaiman, Niloofar Karami, & Natalya A. Chernova**

First, 10 g NMC622 was added to a plastic bottle, followed by 2 mL of surface modification solution with the appropriate amount of acid based on the designed ratios.... The wet powder was then further mixed using Resodyn Acoustic Mixer for 2 min to ensure uniform coverage of the modification solution on the NMC622 surface

**New insight into degradation mechanisms of conductive and thermally resistant polyaniline films**

**Dilek Yalcin, Sarah Bamford, Maria Espiritu, Nick Rigopoulos, Ivan Martinez-Botella, David Alexander, Yesim Gozukara, Mark Greaves, Eric A. Bruton, Patrick J. Kinlen, Shaun Howard, Paul J. Pigram, Benjamin W. Muir & Thomas M. Kohl**

First, to ensure a homogeneous dispersion, SDP, carbon black, PANI-DNNSA and toluene were acoustically mixed using a Resonant Acoustic Mixer (Resodyn) at 90 g (g refers to g force) for 15 min.

**Stabilization of NCM811 cathode for Li-ion batteries by N-doped carbon coating**

**Zhiheng Wang, Shuxin Zhuang, Gaoxing Sun, Xiaoxiao Pan, Jiayi He, Yuqing Sun, Shengyu Jiang & Yan Ren**

In order to obtain uniform carbon coating, Sim et al. [34] developed a resonant acoustic mixing method to prepare carbon-coated NCM811, finding that the uniform carbon coating layer could more effectively avoid direct contact between active materials and electrolyte and suppress the side reaction, thus boosting its cycling performance.

**Resonant acoustic-mixing technology as a novel method for production of negative-temperature coefficient thermistors**

**B. Yüksel Price, S.R. Kennedy**

The 0.1 mol% B2O3-added NiMn2O4, Ni0.5Co0.5Cu0.3Mn1.7O4 and 0.1 mol% B2O3-added Ni0.5Co0.5Cu0.3Mn1.7O4 negative-temperature coefficient thermistors (NTC) prepared by Resonant Acoustic-Mixing (RAM) technology were compared with samples produced by the traditional ball-milling technique... To the best of our knowledge, RAM was applied to produce NTC thermistors for the first time in this study.

# PUBLISHED ARTICLES

**Material extrusion additive manufacturing of dense pastes consisting of macroscopic particles.**
**Dobbs A. Marnot, A. Dobbs, & B. Brettmann**
Two mixing methods have emerged as leaders, dual-axis centrifugal mixing and resonant acoustic mixing, but neither is universally optimal and further work is needed to link the...

**Control of carbon dioxide concentration in headspace of multiple flasks using both non-electric bellows pump and shaking incubator**
**Masato Takahashi, Hideki Aoyagi**
… setting space for wiring or batteries to provide electric power. … the flask gas phase, thus making the gas composition in the … The recently developed resonant acoustic mixing (RAM) for …

**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, & Kwang-Sun Ryu**
...the mixture was transferred into a specially designed zirconia container (fill up to 80%) and vibrated with a Resonant Acoustic Mixer (LabRAM II, Resodyn Inc.) at the vibration energy until 60 G for 20 min.

**Use of Zirconium Dual-Modification on the LiNi0.8Co0.1Mn0.1O2 Cathode for Improved Electrochemical Performances of Lithium-Ion Batteries**
**Sung-Joo Jo, Do-Young Hwang, & Seung-Hwan Lee**
The NCM811 powders were mixed with different amounts of ZrO 2 (0, 0.25, 0.5, and 0.75 wt %) using a resonant acoustic mixer (PharmaRAM I, Resodyn Acoustic Mixer Inc.)

**Diffusion of Zirconium (IV) Ions from Coated Thick Zirconium Oxide Shell to the Bulk Structure of Ni-Rich NMC811 Cathode Leading to High-Performance 18650 Cylindrical Li-Ion Batteries**
**Suchakree Tubtimkuna, Nutthaphon Phattharasupakun, Panyawee Bunyanidhi, & Montree Sawangphruk**
… one of the most important energy storage devices for a wide … on NMC811 by using a resonant acoustic mixing and sintering at 750 C … Figure 8a shows the images of all 18650 fabrication …

**Novel dry deposition of LiNbO3 or Li2ZrO3 on LiNi0. 6Co0. 2Mn0. 2O2 for high performance all-solid-state lithium batteries**
**YJ Kim, R Rajagopal, S Kang & KS Ryu**
… 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 …

**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, M-H. Ryou, & Y. M. Lee**
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. …

# PUBLISHED ARTICLES

**Evaluation of resonant acoustic mixing performance**

**Juan G. Osorio, Fernando J. Muzzio**

Overall, the LabRAM reached the minimum blend homogeneity in as low as 30 s depending on process parameters. The temperature of the final blend increased with fill level, time and acceleration. Resonant acoustic mixing can significantly reduce blending time, making it a good candidate for improving the efficiency of powder mixing processes.

**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**

… 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 …

**In Situ Metal Matrix Nanocomposites: Towards Understanding Formation Mechanisms and Microstructural Control**

**C Reese**

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, …

**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**

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).

**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**

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 …

**Synergetic effect of carbon and AlF3 coatings on the lithium titanium oxide anode material for high power lithium-ion batteries**

**Youngmin Chung, Youngho Shin, Yuzi Liu, Joong Sun Park, Carine L. Margez, & Thomas A. Greszler**

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 …

# PUBLISHED ARTICLES

**The Future of Advanced Materials and Manufacturing for Defence**

**Mark Burnett, Paul Ashton, Andrew Hart, Dmitri Kamenetsky, Nigel McGinty, Dale Quinn, Shannon Ryan, Alex Shekhter, & Paul Solomon**

When compared with conventional energetic material processing technologies, the mixing ability of RAM enables the incorporation of a higher proportion of high energy-density solids, including hard to process materials such as nano-energetics, into the polymeric resins that constitute the remainder of the resultant energetic material.

**How silicon electrodes can be calendered without altering their mechanical strength and cycle life**

**Z. Karkar, T. Jaouhari, A. Tranchot, D. Mazouzi, D. Guyomard, B. Lestriez, & L. Roué**

… 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 …

**Electrostatic discharge sensitivity and resistivity measurements of Al nanothermites and their fuel and oxidant precursors**

**David G. Kelly, Pascal Beland, Patrick Brousseau, & Catalin-Florin Petre**

However, the powders used in the present work do not display significant agglomeration and the principal function of resonant acoustic mixing is simply to distribute fuel and oxidant through the mixture. Thus, lower fill volumes, with resultant reductions in particle-particle interactions, are attractive.

**Metal Oxide–Carbon Nanocomposites for Energy Storage and Conversion**

**Wijayantha Asanga Perera**

… 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 …

**Synthesis of boron-doped Si particles by ball milling and application in Li-ion batteries**

**S. Rousselot, M. Gauthier, D. Mazouzi, B. Lestriez, D. Guyomard, & L. Roué,**

… 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 …

**Vanadium oxide nanowire–carbon nanotube binder-free flexible electrodes for supercapacitors**

**Perera, S.D., Patel, B., Nijem, N., Roodenko, K., Seitz, O., Ferraris, J.P., Chabal, Y.J., & Balkus, K.J., Jr.**

… 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 …

**ResonantAcoustic® Mixing for Lithium-ion Battery Manufacture**

**Resodyn**

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 ...

# Relevant Patents

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

*Including patents with RAM as the preferred embodiment

**Solvent-free process for preparing lithium-ion batteries**
WO FR FR31333709A1 French, Ohla, et al, Cabot Corp
Filed 2023-03-20 • Published 09-22-2023
A solvent-free process employs a multifunctional carbon black to prepare compositions and electrodes for lithium-ion batteries. The multifunctional carbon black provides two or more desirable characteristics, acting, for example, as a conductive carbon additive, as a fibrillation agent and/or as a mechanical reinforcement. In one example, an electroactive material, for example, graphite or a lithium transition metal compound, a binder and a multifunctional carbon black are combined in one or more steps. High shear mixing is used to process the binder in the presence of the multifunctional carbon black. The resulting composition can be formed into a film which can be applied to a suitable substrate to produce an electrode.

**Compositions and methods for parallel processing of electrode film mixtures**
US WO US20230216057A Ziying Wang, et al, Maxwell Technologies
Priority 2023-03-19 • Filed 2023-03-19 • Published 2023-07-06
Materials and methods for preparing electrode film mixtures and electrode films including reduced damage bulk active materials are provided. In a first aspect, a method for preparing an electrode film mixture for an energy storage device is provided, comprising providing an initial binder mixture comprising a first binder and a first active material, processing the initial binder mixture under high shear to form a secondary binder mixture, and nondestructively mixing the secondary binder mixture with a second portion of active materials to form an electrode film mixture.

**Cathode active material for secondary battery**
WO WO2023080629A1 Daijin Lee, LG Energy Solutions, Inc.
Priority 2022-11-01 • Filed 2022-11-02 • Published 2023-05-11
The present invention relates to a cathode active material for a secondary battery, wherein the cathode active material has a structure in which a shell composed of niobium oxide partially containing an alkaline earth metal is adsorbed onto the surface of a core containing lithium metal oxide, whereby the contact void phenomenon that may be generated between the cathode active material and the solid electrolyte and side reactions therebetween are reduced and the electrode resistance increase according to charging/discharging is suppressed. Thus, the secondary battery including same has the advantage of increasing life span.

**High molecular weight functionalized polymers for electrochemical cells**
WO WO20230494A1 Alexander Ali Ibrahim Mohamed, Andrew Paul Leitner, Ionic Materials, Inc.
Filed 2022-09-27 • Published 2023-03-30
High molecular weight functionalized polymers (“high dielectric polymers”) are disclosed herein, along with related methods of use and manufacture. The high dielectric polymers have a relatively high dielectric permittivity (e.g., greater than 10) as well as a relatively low glass transition temperature (e.g., less than-30˚C). The polymers may be produced utilizing addition polymerization or anionic ring opening to yield a linear or branched polymer backbone containing nu-

# Patents, cont'd.

merous residual nucleophiles. Then, nucleophilic substitution may be carried out to functionalize the residual nucleophiles. The functionalized polymer may then be purified and used as polymer electrolyte in an electrochemical cell (e.g., as nonaqueous polymeric electrolyte in a secondary Li-ion battery), if desired.

**Chlorinated polyvinyl chloride composition**
WO WO202225744A1 Corrigan, Thomas, et al, The Lubrizol Corporation
Filed 2022-04-12 • Published 2022-10-27
The disclosed technology relates to a conductive composition containing chlorinated poly(vinyl) chloride ("CPVC") and a conductive filler, such as, for example, a graphitic material. More particularly, the technology includes bipolar plates prepared from the conductive composition for use in electrochemical devices, such as fuel cells, flow batteries, electrolyzers, and the like.

**Positive elecrode active material, producing method thereof, positive electrode and lithium secondary battery comprising the same**
WO KR KR20220125704A Kim, Wontae, LG Chemicals
Filed 2022-03-04 • Published 2022-09-14
The present invention relates to a positive electrode active material and a manufacturing method thereof, wherein the positive electrode active material includes: a lithium composite transition metal oxide including 70 atm% or more of nickel among all metal elements except lithium; and a coating layer formed on the surface of the lithium composite transition metal oxide and including Ti and B, and Ti of 300 to 800 ppm and B of 500 to 1000 ppm are included based on the total weight of the positive electrode active material.

**Method for manufacturing electrode, electrode manufactured thereby, membrane-electrode assembly comprising same electrode, and fuel cell including same membrane-electrode assembly**
US CN JP EP WO US20220158208A1 Jung Ho Kim, Hyeong Su Kim, Kolon Industries, Inc.
Priority 2016-12-28 • Filed 2022-02-04 • Published 2023-01-17
Disclosed are a method for manufacturing an electrode, an electrode manufactured thereby, a membrane-electrode assembly including the electrode, and a fuel cell containing the membrane-electrode assembly. The method includes the steps of: preparing an electrode forming composition by mixing a catalyst with an ionomer; applying a low-frequency acoustic energy to the electrode forming composition to perform resonant vibratory mixing so as to coat the ionomer on the surface of the catalyst; and coating the electrode forming composition to manufacture an electrode.

**Catalyst layer for fuel cell, method for manufacturing the same, membrane-electrode assembly comprising the same, and fuel cell**
WO EP CN KR TW TWI805118B Kim, Jung Ho, Kolon Industries
Filed 2021-12-08 • Publications 2022-08-11
The invention relates to a catalyst layer for a fuel cell, its manufacturing method, Including the membrane electrode combination and the fuel cell thereof, in more detail, it relates to a catalyst layer comprising a catalyst, a heat dissipation material and an ionomer, and has the effect of heat generated by heat dissipation reaction in the catalyst layer

# Patents, cont'd.

Catalyst layer for a fuel cell capable of being discharged to the outside and suppressing deterioration of the membrane-electrode assembly due to temperature rise of the catalyst layer, its manufacturing method, membrane-electrode assembly including the same, and a fuel cell.

**Catalyst, method for producing same, electrode containing same, membrane-electrode assembly and fuel cell**
KR EP JP US CN TW JP221349B2 Kim, Jung Ho
Filed 2021-09-14 • Published 2022-01-11
The present invention relates to a catalyst, a method for preparing the same, an electrode, a membrane-electrode assembly and a fuel cell containing the same, and in particular, to form a coating layer on the surface of a commercial catalyst or an existing catalyst in a relatively gentle manner without separate treatment. The durability is further improved by post-treating the catalyst containing the coating layer to form a carbon coating layer, and the carbon nanofibers or carbon nanotubes generated during the post-treatment process further improve the durability. The present invention relates to a catalyst having improved mass transfer ability and performance, a method for producing the same, an electrode, a membrane-electrode assembly and a fuel cell including the same.

**Positive Electrode Active Material, Positive Electrode Including the Positive Electrode Active Material, and Secondary Battery Including the Positive Electrode**
US US20230343936A1 Tae Gon Kim, et al, LG Energy Solution Ltd.
Filed 2021-08-31 • Published 2023-10-26
Provided is a positive electrode active material including a core and a coating layer disposed on the core, wherein the core includes $Li_{1+x}MyO_{2+z}$, wherein M is at least one element selected from the group consisting of nickel (Ni), cobalt (Co), manganese (Mn), iron (Fe), phosphorus (P), aluminum (Al), magnesium (Mg), calcium (Ca), zirconium (Zr), zinc (Zn), titanium (Ti), ruthenium (Ru), niobium (Nb), tungsten (W), boron (B), silicon (Si), sodium (Na), potassium (K), molybdenum (Mo), and vanadium (V), wherein $-0.2 \leq x \leq 0.2$, $0 < y \leq 2$, and $0 \leq z \leq 2$, wherein the coating layer includes carbon-based particles, wherein the carbon-based particles includes a structure in which a plurality of graphene sheets are connected to each other, and wherein a D/G peak ratio of the positive electrode active material is in a range of 0.9 to 1.3 during Raman spectrum measurement.

**Positive electrode active material, positive electrode comprising positive electrode active material, and secondary battery comprising positive electrode**
JP WO EP CN KR WO202050664A1 Tae Gon Kim, et al, LG Energy Solution, Ltd.
Priority 2021-08-31 • Filed 2021-08-31 • Published 2022-03-10
The present invention relates to a positive electrode active material, a positive electrode comprising the positive electrode active material, and a secondary battery comprising the positive electrode, the positive electrode active material comprising: a core; and a coating layer disposed on the core. The core comprises $Li_{1+x}MyO_{2+z}$, M being at least any one element selected from the group consisting of Ni, Co, Mn, Fe, P, Al, Mg, Ca, Zr, Zn, Ti, Ru, Nb, W, B, Si, Na, K, Mo and V, and $-0.2 \leq x \leq 0.2$, $0 < y \leq 2$, $0 \leq z \leq 2$. The coating layer comprises carbon-based particles, wherein the carbon-based particles comprise a structure having a plurality of graphene sheets connected to each other, and have a D/G peak ratio of 0.9 to 1.3 when measuring the Raman spectrum thereof.

# Patents, cont'd.

**Compositions and methods for electro-chemical cell component fabrication**
EP US WO US20230076834A1 Binson Li, et al, Navitas Systems LLC
Priority 2021-03-01 • Filed 2021-03-01 Published • 2023-03-09
Provided are methods of producing materials suitable for use as a component of an electrochemical cell such as electrode active layers or solid state electrolyte and/or separator materials. Processes include combining an active with a fibrillizable binder and intermixing in a screw fibrillator to produce a fibrillized material with greatly increased physical and optionally electrochemically characteristics relative to those materials produced by other processes such as simple slurry casting or intermixing in a jet mill.

**Method of manufacturing electrode, electrode manufactured by the same, membrane …**
WO EP US CN JP JP2020145210A Kim, Jung Ho, et al, Kolon Industries
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 Ryoichi Namba, Toyota Jidosha Kabushiki Kaisha
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 Guang Pan, et al, Nitto Denko Corporation
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

# Patents, cont'd.

walls; and (B) impregnating or infiltrating the pores with a …

**Molten electrolyte dual-phase membranes for intermediate temperature fuel cells**
WO US US20190379063A1 Patrick Campbell, et al, Lawrence Livermore National Security LLC
Priority 2019-06-07 • Filed 2019-06-07 • Published 2019-12-12
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 …

**Alkali metal battery with electrodes based on integrated 3D graphene-carbon-metal hybrid foam-based electrode**
WO US CN JP KR JP2019521476A Aruna Zhamu & Bor Z. Jang, Nanotek Instruments, Inc.
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 …

**Supercapacitor having an integral 3D graphene-carbon hybrid foam-based electrode**
WO US CN JP KR US9905373B2 Aruna Zhamu, Bor Z. Jang, Nanotek Instruments, In.
Priority 2016-01-04 • Filed 2016-01-04 • 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, Bor Z. Jang, Global Graphene Group, Inc.
Priority 2015-12-28 • Filed 2018-06-01 • 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 Derek Dane Jay, et al, 3M Innovative Properties Co.
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 …

# Patents, cont'd.

**Catalyst, preparation method therefor, electrode comprising same, membrane-electrode assembly, and fuel cell**
EP US CN JP KR TW KR20190078489A Jung Ho Kim
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 Jung Ho Kim, Hyung-soo Kim
Priority 2016-12-28 • Filed 2016-12-28 • 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 …

**Chemical-free production of 3D graphene-carbon hybrid foam**
US US9597657B1 Aruna Zhamu, Nanotek Instruments, Inc.
Priority 2015-12-28 • Filed 2015-12-28 • 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 • 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 …

RAM 5

RAM 5 Continuous

RAM 55

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OmniRAM H

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