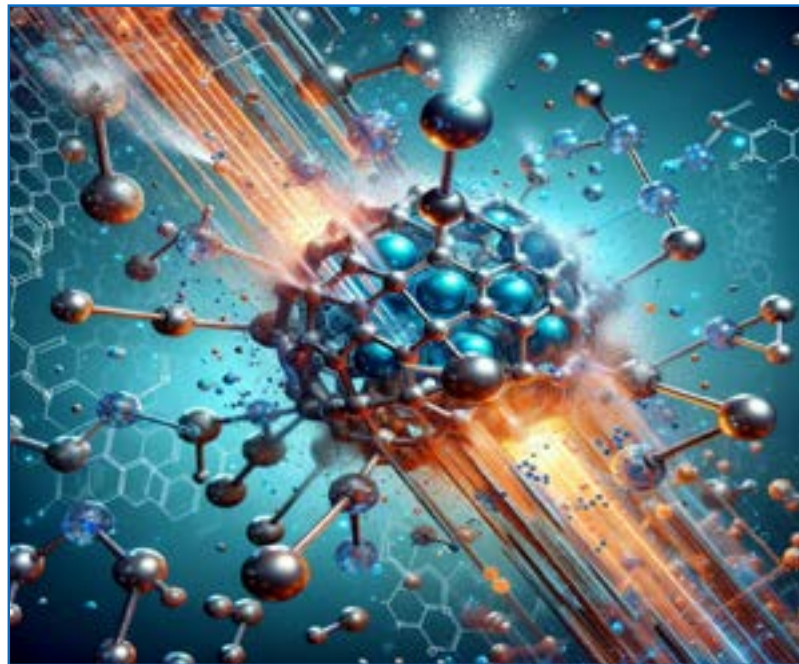


# Advances in Mechanochemistry Processing Enabled by ResonantAcoustic® Mixing

Testimonials • Published Articles • Patents & Patent Applications



May 2024

This document is a portfolio of articles, patents/patents pending and user testimonials that reference Resodyn's ResonantAcoustic® Mixing (RAM) technology in a variety of mechanochemistry materials 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 the development of "Green" Chemistry Processes.

# Mechanochemistry



Mechanochemistry is the initiation of chemical reactions by mechanical forces such as grinding, shearing, milling, or mixing. Traditional mechanochemistry processing methodologies vary from hand grinding (i.e., mortar and pestle) to shaker and planetary mills for laboratory scale production. Previously, eccentric and horizontal high-energy ball mill devices were preferred for scaling up to batch production, while twin-screw and single-screw extrusion equipment were used for continuous mechanochemical processing.

**ResonantAcoustic® Mixing (RAM)** demonstrates clear advantages over conventional mechanochemical processes, including reduced processing times, increased conversion efficiencies and eliminated contamination risks. **RAM** technology leverages low frequency acoustic waves to generate controlled mechanical force within a reaction vessel. **RAM** enables particle-to-particle collisions by promoting reaction kinetics, supplying the activation energy necessary to break and form chemical bonds. Acceleration and frequency are precisely controlled elements of **RAM** technology, allowing chemists to tailor the reaction. Temperature control and vacuum options are also available. The ability of **RAM** to fine-tune the reaction is invaluable toward managing specific product outcomes.

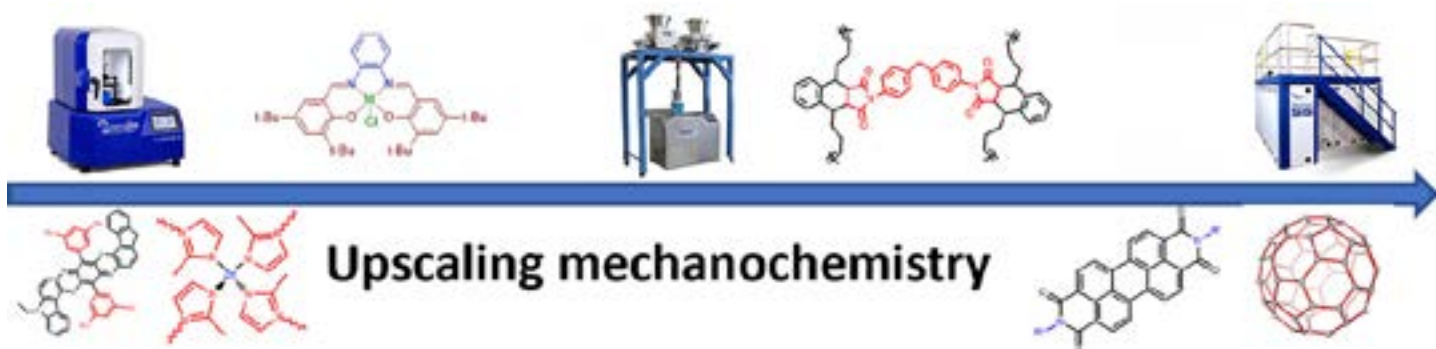
Mechanochemistry with **RAM** often eliminates, or substantially reduces, the use of solvents, heat, electricity and other external elements to complete chemical reactions. Furthermore, reactions requiring multiple intermediary products may also be simplified by employing **RAM** mechanochemistry.

System and process scale up is a pressing challenge for the further advancement of mechanochemistry production. **RAM** provides a consistent platform for scale-up of batch mechanochemical processing. **Continuous Acoustic Mixing (CAM)** for mechanochemistry improves mass and heat transfer and reaction rates, processes multiphase reactions, and scales readily.

## Companies all over the world rely upon RAM technology for mechanochemistry research and development



**RAM technology is making Mechanochemistry a Global Reality.**



# What “Green” Chemistry professionals are saying about RAM

*“... RAM mechanosynthesis is shown to be faster, operationally simpler than conventional ball-milling, while also providing the first example of a mechanochemical strategy for ruthenium-catalyzed ene-yne metathesis. Reactions by RAM are readily and directly scaled-up ...”*

-Dr. Tomislav Friščić, et al  
University of Birmingham, U.K.

*“The RAM exhibited remarkable performance in the Suzuki coupling reaction, achieving yields of approximately 90 % after 60 min and complete conversion after 90 min. The longevity of the milling vessel in the RAM was significantly extended compared to previous systems, thus offering increased durability for multiple reactions without deterioration ...”*

-Maximilian Wohlgemuth, et al  
Ruhr-Universität Bochum, Germany

*“ ... it was shown that resonant acoustic mixing provides the mixing intensity required of lab-scale mechanochemical methods, such as liquid-assisted grinding, but now on a platform more amenable to larger-scale manufacture. Resonant acoustic mixing in general has been demonstrated to be scalable to volumes greater than 200 L and thus affords a potential new platform for co-crystallization processes.”*

-David J. am Ende, et al  
Nalas Engineering Services, Essex, Conn., U.S.

## RAM: The Future of Mechanochemistry




## 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 href="#">Mechanochemical Synthesis of Boroxine-linked Covalent Organic Frameworks</a>	Real-time Raman spectroscopy permitted the first quantitative kinetic analysis of COF mechanosynthesis, while transferring the reaction design to <b>Resonant Acoustic Mixing (RAM)</b> enabled synthesis of multi-gram amounts of the target COFs.	2024
	<a href="#">Enhancement of CO<sub>2</sub> Adsorption Kinetics Onto Carbon by Low-Frequency High Amplitude Resonant Vibrations</a>	“In this work, a novel strategy is proposed to accelerate the CO <sub>2</sub> uptake rate on carbon adsorbents by utilizing Low-Frequency High Amplitude (LFHA) <b>resonant vibratory mixing</b> during the adsorption process to enhance adsorption kinetics.”	2024
	<a href="#">Solvent-free surface modification of milled carbon fiber using resonant acoustic mixing</a>	“ <b>Resonant Acoustic Mixing</b> used as a green alternative for surface modification.”	2023
	<a href="#">Halogen-bonded cocrystals via resonant acoustic mixing</a>	“We report here on the production of eleven halogen-bonded (XB) cocrystalline architectures via neat and liquid-assisted <b>resonant acoustic mixing (RAM)</b> .”	2024
	<a href="#">Resonant acoustic mixing (RAM) for efficient mechanoredox catalysis without grinding or impact media</a>	<b>RAM</b> proceeds without formal grinding or impact media, is faster than the analogous ball-milling strategy, and is readily scalable.	2023
	<a href="#">Milling Media-Free Suzuki Coupling by Direct Mechanocatalysis- From Mixer Mills to Resonant Acoustic Mixers</a>	“The <b>RAM</b> exhibits excellent performance in the Suzuki reaction, achieving yields of 90% after 60 minutes and complete conversion after 90 minutes. The longevity of the milling vessel is significantly improved in the <b>RAM</b> . . .”	2023
	<a href="#">Direct mechanocatalysis by resonant acoustic mixing (RAM)</a>	“... <b>RAM</b> -based direct mechanocatalysis methodology is simple, enables the effective one-pot, two-step synthesis of triazoles via a combination of benzyl azide formation and CuAAC reactions on a wide scope of reagents, provides control over reaction stoichiometry that is herein shown to be superior ...”	2023

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	<a href="#">The “<math>\eta</math>-sweet-spot” (<math>\eta_{max}</math>) in liquid-assisted mechanochemistry: polymorph control and the role of a liquid additive as either a catalyst or an inhibitor in resonant acoustic mixing (RAM)</a>	“ <b>Resonant acoustic mixing (RAM)</b> offers a simple, efficient route for mechanochemical synthesis in the absence of milling media or bulk solvents. Here, we show the use of <b>RAM</b> to conduct the copper-catalysed coupling of sulfonamides and carbodiimides.”	2023
	<a href="#">Application of resonant acoustic mixing in the synthesis of vitamin C–nicotinamide variable stoichiometry cocrystals</a>	“The use of <b>resonant acoustic mixing (RAM)</b> to synthesize variable stoichiometry cocrystals of nicotinamide and vitamin C was investigated...LA-RAM is demonstrated to be a scalable, environmentally friendly, ball-free method to make variable stoichiometry cocrystals.”	2023
	<a href="#">Tinkering with Mechanochemical Tools for Scale Up</a>	“... other mechanochemical syntheses.[37] Liquid-assisted <b>resonant acoustic mixing (LARAM)</b> ... rapid adoption at the R&D stage is evidenced by the increasing number of patents filed in the ...”	2023
	<a href="#">Metal-Catalyzed Organic Reactions by Resonant Acoustic Mixing</a>	“...catalytic organic synthesis by <b>Resonant Acoustic Mixing (RAM)</b> : a mechanochemical methodology that does not require bulk solvent or milling media... Reactions by <b>RAM</b> are readily and directly scaled-up without any significant changes in reaction conditions...”	2022
	<a href="#">Resonant acoustic-mixing technology as a novel method for production of negative-temperature coefficient thermistors</a>	“...This study will be the lead to guide future studies into the cost-effective fast fabrication of negative-temperature coefficient thermistors by <b>resonant acoustic mixing</b> technology due to reduction of manufacturing costs by reducing processing time.”	2022
	<a href="#">Time-resolved in situ monitoring of mechanochemical reactions</a>	“... <b>resonant acoustic mixing (RAM)</b> cocrystallization of carbamazepine and nicotinamide by TRIS-XRD, the degree of bulk powder ...”	2022
	<a href="#">Application of mechanochemical activation in synthetic organic chemistry</a>	" ... A recently emerged technique is <b>Resonant Acoustic Mixing (RAM)</b> , which uses low-...”	2021
	<a href="#">Simple, scalable mechanosynthesis of metal–organic frameworks using liquid-assisted resonant acoustic mixing (LA-RAM)</a>	“... mechanochemical syntheses. We demonstrate the use of liquid-assisted <b>resonant acoustic mixing</b> ... never been previously obtained in a mechanochemical environment ...”	2020
	<a href="#">Mechanochemistry for organic chemists: An update</a>	“... A recently emerged technique is <b>Resonant Acoustic Mixing (RAM)</b> , which uses low-frequency, high-amplitude acoustic resonance to agitate powder samples.”	2018

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
   	<a href="#">Ball-free mechanochemistry: in situ real-time monitoring of pharmaceutical co-crystal formation by resonant acoustic mixing</a>	<p>“We present here the first in situ study of <b>RAM</b>-induced co-crystallisation monitored using synchrotron X-ray powder diffraction.”</p>	2018
   	<a href="#">High-throughput screening and scale-up of cocrystals using resonant acoustic mixing</a>	<p>“This paper explores the effectiveness of resonant acoustic mixing <b>RAM</b> for screening and scale up of cocrystals. . . . Theophylline Oxalic acid cocrystals at an 80 gram scale with a net yield of 94%. <b>RAM</b> is thus established as an environmentally friendly mechanochemical technique for both high throughput screening and scaled up production of cocrystals.”</p>	2017

\* Article links maybe limited by copyright restrictions. Detailed links on following pages

^ Results excerpted/paraphrased from articles.

# Articles

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## [Mechanochemical Synthesis of Boroxine-linked Covalent Organic Frameworks](#)

*Ehsan Hamzehpoo, Farshid Effaty, Tristan Borchers, Alexander Wahrhaftig-Lewis, Xavier Ottenwaelder, Tomislav Friščić & Dmytro F. Perepichka*

Mechanochemistry enabled a >20-fold reduction in solvent use and ~100-fold reduction in reaction time compared with solvothermal methods, providing target COFs quantitatively with no additional work-up besides vacuum drying. Real-time Raman spectroscopy permitted the first quantitative kinetic analysis of COF mechanochemistry, while transferring the reaction design to **Resonant Acoustic Mixing (RAM)** enabled synthesis of multi-gram amounts of the target COFs.

## [Enhancement of CO<sub>2</sub> Adsorption Kinetics Onto Carbon by Low-Frequency High Amplitude Resonant Vibrations](#)

*Amirhosein Riahi, Ethan Heggem, Mario Caccia & Richard LaDouceur*

In this work, a novel strategy is proposed to accelerate the CO<sub>2</sub> uptake rate on carbon adsorbents by utilizing Low-Frequency High Amplitude (LFHA) **resonant vibratory mixing** during the adsorption process to enhance adsorption kinetics. With this approach, the rates of adsorption (characterized by the adsorption rate constant) exhibit increases of 115% and 50%, as calculated by two different kinetic models, Weber and Morris and the Pseudo-first-order model.

## [Solvent-free surface modification of milled carbon fiber using resonant acoustic mixing](#)

*Daniel J. Eyckens, David J. Hayne, Luke C. Henderson, Shaun C. Howard, Thomas J. Raeber, Ranya Simons, Andrea L. Wilde, Dilek Yalcin & Benjamin W. Muir*

**Resonant Acoustic Mixing (RAM)** is used to rapidly modify the surface of milled carbon fiber using diazonium salts in solvent free conditions. This novel method allows tuning of the surface properties of this material and reduces the environmental footprint usually associated with surface modification of carbon fiber (discontinuous or otherwise)... Using **RAM** proved more efficient than positive controls produced under thermal conditions in solvent.

## [Halogen-bonded cocrystals via resonant acoustic mixing](#)

*Alireza Nari, Jeffrey S. Ovens & David L. Bryce*

However, an eleventh stoichiometric cocrystal of p-DITFB and TMP is obtained exclusively via **RAM**, suggesting that the combination of RAM and milling approaches may afford a broader exploration of the polymorphic and stoichiometric landscape than the use of a single technique in isolation.

## [Resonant acoustic mixing \(RAM\) for efficient mechanoredox catalysis without grinding or impact media](#)

*Farshid Effaty, Lori Gonnet, Stefan G. Koenig, Karthik Nagapudi, Xavier Ottenwaelder & Tomislav Friščić*

Resonant acoustic mixing (RAM) enables mechanoredox catalysis with BaTiO<sub>3</sub> as the piezoelectric catalyst on model diazonium coupling reactions. RAM proceeds without formal grinding or impact media, is faster than the analogous ball-milling strategy, and is readily scalable. X-ray diffraction and spectroscopy indicate that reusability of BaTiO<sub>3</sub> as a mechanoredox catalyst under ball-milling or RAM might be limited by boration.

## [Milling Media-Free Suzuki Coupling by Direct Mechano catalysis- From Mixer Mills to Resonant Acoustic Mixers](#)

*Maximilian Wohlgemuth, Sarah Schmidt, Maike Mayer, Dr. Wilm Pickhardt, Dr. Sven Grätz & Prof. Dr. Lars Borchardt*

RAMs exhibit excellent performance in the Suzuki reaction, achieving yields of 90% after 60 min and complete conversion after 90 min. The longevity of the milling vessel is significantly improved in a RAM, allowing for at least 20 reactions without deterioration.

## [Direct Mechano catalysis without Milling Media – From Mixer Mills to Resonant Acoustic Mixers](#)

*Maximilian Wohlgemuth, Sarah Schmidt, Maike Mayer, Wilm Pickhardt, Sven Graetz & Lars Borchardt*

Here we describe the development of a sustainable and cost-effective approach for catalytic cross-coupling reactions in mechanochemistry. ... The **RAM** exhibits excellent performance in the Suzuki reaction, achieving yields of 90% after 60 minutes and complete conversion after 90 minutes. The longevity of the milling vessel is significantly improved in the **RAM**, allowing for at least 20 reactions without deterioration.

## [The “ \$\eta\$ -sweet-spot” \( \$\eta\_{max}\$ \) in liquid-assisted mechanochemistry: polymorph control and the role of a liquid additive as either a catalyst or an inhibitor in resonant acoustic mixing \(RAM\)](#)

*Lori Gonnet, Tristan H. Borchers, Cameron B. Lennox, Jogirdas Vainauskas, Yong Teoh, Hatem M. Titi, Christopher J. Barrett, Stefan G. Koenig, Karthik Nagapudi & Tomislav Friščić*

**Resonant acoustic mixing (RAM)** offers a simple, efficient route for mechanochemical synthesis in the absence of milling media or bulk solvents. Here, we show the use of **RAM** to conduct the copper-catalysed coupling of sulfonamides and carbodiimides. This coupling was previously reported to take place only by mechanochemical ball milling, while in conventional solution environments it is not efficient, or does not take place at all. The results demonstrate **RAM** as a suitable methodology to conduct reactions previously accessed only by ball milling and provide a detailed, systematic overview of how the amount of liquid additive, measured by the ratio of liquid volume to weight of reactants ( $\eta$ , in  $\mu\text{L mg}^{-1}$ ), can affect the course of a mechanochemical reaction and the polymorphic composition of its product.

## [Application of resonant acoustic mixing in the synthesis of vitamin C–nicotinamide variable stoichiometry cocrystals](#)

*Minhthi Bui, Paroma Chakravartya & Karthik Nagapudi*

The use of **resonant acoustic mixing (RAM)** to synthesize variable stoichiometry cocrystals of nicotinamide and vitamin C was investigated. Liquid assisted **RAM** (LA-RAM) was used to generate two polymorphs, Form I and II, of the 1 : 1 cocrystal of nicotinamide and vitamin C at a 700 mg scale using ethanol and methanol respectively as the liquid additives. LA-RAM was used to scale up polymorphs I and II of the 1 : 1 cocrystal to 20 grams.

## [Tinkering with Mechanochemical Tools for Scale Up](#)

*Dr. Javier F. Reynes, Dr. Valerio Isoni & Dr. Felipe García*

Besides the previous systems, **resonant acoustic mixing (RAM)**, which is based on rapid mechanical agitation... The absence of milling media that eventually leads to product contamination and the fact that these reactors are simpler to control presents RAM as a prospective upscaling mechanochemical technology.



## [Metal-Catalyzed Organic Reactions by Resonant Acoustic Mixing](#)

*Dr. Lori Gonnet, Cameron B. Lennox, Jean-Louis Do, Ivani Malvestiti, Dr. Stefan G. Koenig, Dr. Karthik Nagapudi & Prof. Tomislav Friščić*

We demonstrate catalytic organic synthesis by **Resonant Acoustic Mixing (RAM)**: a mechanochemical methodology that does not require bulk solvent or milling media. Using as model reactions ruthenium-catalyzed ring-closing metathesis and copper-catalyzed sulfonamide-isocyanate coupling, **RAM** mechanosynthesis is shown to be faster, operationally simpler than conventional ball-milling, while also providing the first example of a mechanochemical strategy for ruthenium-catalyzed ene-yne metathesis. Reactions by **RAM** are readily and directly scaled-up without any significant changes in reaction conditions, as shown by the straightforward 200-fold scaling-up of the synthesis of the antidiabetic drug Tolbutamide, from hundreds of milligrams directly to 30 grams.

## [Resonant acoustic-mixing technology as a novel method for production of negative-temperature coefficient thermistors](#)

*Berat Yüksel Price & Stuart R. Kennedy*

The 0.1 mol% B<sub>2</sub>O<sub>3</sub>-added NiMn<sub>2</sub>O<sub>4</sub>, Ni<sub>0.5</sub>Co<sub>0.5</sub>Cu<sub>0.3</sub>Mn<sub>1.7</sub>O<sub>4</sub> and 0.1 mol% B<sub>2</sub>O<sub>3</sub>-added Ni<sub>0.5</sub>Co<sub>0.5</sub>Cu<sub>0.3</sub>Mn<sub>1.7</sub>O<sub>4</sub> negative-temperature coefficient thermistors (NTC) prepared by **Resonant Acoustic-Mixing (RAM)** technology were compared with samples produced by the traditional ball-milling technique. The metal oxide powders were weighed and mixed by a resonant acoustic mixer (**LabRAM 1, Resodyn Acoustic Mixers**) at 15 and 40 g acceleration for 20 min and 2 h... To the best of our knowledge, **RAM** was applied to produce NTC thermistors for the first time in this study.

## [Time-Resolved In Situ Monitoring of Mechanochemical Reactions](#)

*Dr. Adam A. L. Michalchuk & Franziska Emmerling*

Mechanochemical transformations offer environmentally benign synthesis routes, whilst enhancing both the speed and selectivity of reactions. In this regard, mechanochemistry promises to transform the way in which chemistry is done in both academia and industry but is greatly hindered by a current lack of mechanistic understanding. The continued development and use of time-resolved in situ (TRIS) approaches to monitor mechanochemical reactions provides a new dimension to elucidate these fascinating transformations. We here discuss recent trends in method development that have pushed the boundaries of mechanochemical research.

## [Application of mechanochemical activation in synthetic organic chemistry](#)

*Gábor Varga, Pál Sipos & István Pálinkó*

In recent years the use of mechanochemical activation in promoting synthetic reactions in organic chemistry became remarkably widespread. Indeed, mechanochemical treatment can be a very efficient form of energy transfer, and, often, it may provide with mild reaction conditions for otherwise difficult syntheses.

## [Simple, scalable mechanosynthesis of metal–organic frameworks using liquid-assisted resonant acoustic mixing \(LA-RAM\)](#)

*Hatem M. Titi, Jean-Louis Do, Ashlee J. Howarth, Karthik Nagapudi & Tomislav Friščić*

We present a rapid and readily scalable methodology for the mechanosynthesis of diverse metal–organic frameworks (MOFs) in the absence of milling media typically required for other types of mechanochemical syntheses. We demonstrate the use of liquid-assisted **resonant acoustic mixing (LA-RAM)** methodology for the synthesis of three- and two-dimensional MOFs based on Zn(II), Co(II) and Cu(II), including a mixed ligand system. Impor-

tantly, the LA-RAM approach also allowed the synthesis of the ZIF-L framework that has never been previously obtained in a mechanochemical environment, as well as its Co(II) analogue.

## [Mechanochemistry for Organic Chemists: An Update](#)

*Davin Tan & Tomislav Friščić*

We provide a brief overview of recent advances in the use of mechanochemical techniques for the synthesis of organic molecules and materials, highlighting selected examples of mechanochemical organic transformations and mechanistic studies, and especially those that illustrate chemical reactions or syntheses of molecular targets that have remained elusive to conventional solution techniques.

## [Ball-free mechanochemistry: in situ real-time monitoring of pharmaceutical co-crystal formation by resonant acoustic mixing](#)

*Adam A. L. Michalchuk, Karl S. Hope, Stuart R. Kennedy, Maria V. Blanco, Elena V. Boldyreva & Colin R. Pulham*

**Resonant acoustic mixing (RAM)** is a new technology designed for intensive mixing of powders that offers the capability to process powders with minimal damage to particles. This feature is particularly important for mixing impact-sensitive materials such as explosives and propellants. While the **RAM** technique has been extensively employed for the mixing of powders and viscous polymers, comparatively little is known about its use for mechanochemistry. We present here the first in situ study of **RAM**-induced co-crystallisation monitored using synchrotron X-ray powder diffraction.

## [High-throughput screening and scale-up of cocrystals using resonant acoustic mixing](#)

*Karthik Nagapudi, Evelyn Yanez Umanzor & Colin Masui*

This paper explores the effectiveness of **resonant acoustic mixing RAM** for screening and scale up of cocrystals. 16 cocrystal systems were selected as test cases based on previous literature precedent. A 96 well plate set up in conjunction with zirconia beads was used for cocrystal screening using **RAM**. A success rate of 80% was obtained in the screen for plates containing solvent or solvent plus Zirconia beads. A proof of concept production of hydrated and anhydrous cocrystals of 1:1 Theophylline Citric acid system at a 400 mg scale was demonstrated using solvent and bead assisted **RAM**.

# Relevant Patents

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

\*With RAM as the preferred embodiment

## [Powder Blend Processability Improvements Through Minimal Amounts Of Synergistically Selected Surface Coating Agents](#)



*US US20240024241A1 Rajesh N. Dave, Sangah Kim & Zhixing Lin New Jersey Institute Of Technology*

*Priority 2022-07-12 • Filed 2023-07-12 • Published 2024-01-25*

High(greater than 30%) and/or low(less than 10%) loaded multiple API powdered/nanoparticle were tabulated with increased flowability and physical properties. Properties include blend flowability and uniformity, bulk packing density, compactability, tensile strength, and dissolution. Blending is done through solventless dry mechanical coating of at least one minority API component defined as the API component with the least weight per volume surface coated with nano-sized powders in lesser amounts by wt % of the blend, and preferably less than 10% dry coated of the minority API. An excipient may be dry coated in the lesser amount wherein the excipient is a minority component. Both minority excipient and minority API may be dry coated. Using dry coating instead of dry granulation and/or wet granulation techniques in producing tablets saves manufacturing steps, costs, and produces higher quality tablets with surprisingly higher properties than expected for low flowability solid powdered ingredients.

**Highlighted Use: A LabRAM coated an API with Aerosil A200.**

## [Composition, magnetic particle-containing film, and electronic component](#)



*WO EP US JP TW US20230238164A1 Tatsuo Ishikawa Fujifilm Corporation*

*Priority 2020-09-18 • Filed 2023-03-15 • Published 2023-07-27*

An object of the present invention is to provide a composition that can form a magnetic particle-containing film having excellent magnetic permeability and excellent acid resistance, and has excellent sedimentation stability. Another object of the present invention is to provide a magnetic particle-containing film that relates to the composition, and an electronic component that includes the magnetic particle-containing film. The composition according to an embodiment of the present invention contains magnetic particles that contain 70% to 90% by mass of Fe atoms and have a crystal structure of Fe, an average particle diameter of 2 to 30  $\mu\text{m}$ , and an aspect ratio less than 8, and a rheology control agent.

**Highlighted Use: RAM technology created a stable material with excellent magnetic anisotropy.**

## [Method for production of composite magnetic powders by autonomous grinding](#)



*SK SK132021A3, Bureš Radovan, Fáberová Mária*

*Priority 2021-2-25 • Filed 2021-2-25 • Published 2022-9-14*

Ferromagnetism in the form of powdered magnetically soft metal or alloy is placed together with electro-insulating ceramic powder in a cylindrical container. The ratio of the height to the diameter of the container is 2:1. The container is filled with powder to a maximum of 1/3 of the volume. The powder mixture is autonomously ground by the action of **resonant acoustic energy** for 15 minutes to 360 hours. The particles of the powder mixture are given a gravitational acceleration of at least 20 g. Ferromagnetic particles are at least

# Patents (cont.)

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one order of magnitude larger than ceramic particles. Particles of the powder mixture are precipitated, ceramic particles are fragmented into smaller particles. Ferromagnetic particles act as a grinding medium. Fragmented ceramic particles are attached to the surface of ferromagnetic particles, the size of which does not change significantly during autonomous grinding. The powder composite material is further processed by pressing and sintering into magnetically soft components.

**Highlighted Use: RAM combined ferromagnetic and ceramic particles.**

## [Complexes Comprising Carbohydrate Polymers and Active Ingredients and Methods for Their Preparation](#)



*WO, EP, AU, JP, CA, US, JP2023510089A Felix Polyak, Dmitry Budovich*

*Priority 2019-12-13 • Filed 2020-12-11 • Published 2023-3-13*

Disclosed herein are molecular complexes and compositions containing them. More specifically, carbohydrate polymers such as hyaluronic acid and its salts are bioactive selected from natural products and nutrients (amino acids, amino esters, hydroxy acids, hydroxy esters, vitamins, cannabinoids, etc.) and active pharmaceutical ingredients. Complexes with compounds to form stable molecular complexes. Complexation can be conveniently achieved using **resonant acoustic mixing** methods.

**Highlighted Use: RAM technology combined carbohydrate polymers and biologically active compounds.**

## [A method to produce and scale-up cocrystals and salts via resonant acoustic mixing](#)



*US, EP EP2845852A1 Jerry Salan, Stephen R. Anderson, and David J. Am Ende, Nalas Engineering Services Inc.*

*Priority 2013-9-4 • Filed 2014-9-4 • Published 2015-3-11*

A method to produce and manufacture cocrystals and salts is disclosed wherein crystalline solids and other components were combined in the desired proportions into a mixing chamber and mixed at high intensity to afford a cocrystalline product. No grinding media were required. The mixing system consists of a **resonant acoustic vibratory system** capable of supplying a large amount of energy to the mixture and is tunable to a desired resonance frequency and amplitude. The use of **resonant acoustic mixing** to assist cocrystallization is novel. This discovery enables the manufacture of cocrystals and salt forms, simplifying their manufacture and scale-up, and avoiding the use of grinding methods or grinding media. The present invention affords the manufacture of cocrystals and salts on kilogram to multi-ton scale and is adaptable to continuous manufacturing through the use of resonant mixing methods.

**Highlighted Use: RAM technology can eliminate solvents and grinding material.**



**Resodyn Mixers.com**