

Powder Metal Innovations Enabled By ResonantAcoustic[®] Mixing

Testimonials • Published Articles • Patents & Patent Applications



January 2022

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 powder metal 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 and processing of powder metals.

Processing of Powder Metals

Powder metal products are used across a spectrum of industries such as aerospace, automotive, marine, and biomedical. Common products created with powder metals include engine components, auto brake shoes/pads, medical devices, and bearings impregnated with lubricants. Powder metals are also used in heat shields for spacecraft, high-voltage electrical contacts, and filters for gases. Powder metal parts are often used as additive manufactured prototypes as well as fully functional components.

Developers of leading-edge powder metal products rely upon ResonantAcoustic® Mixing technology to help their customers conceive and deliver innovative new products across a wide spectrum of industries.



What powder metal processors are saying about RAM

"... Acoustic mixing opens up the possibility of adding oxides or ceramics to any metal, which creates a huge design space that wasn't previously available..."

- Materials Engineer
U.S. Government Research Organization

"...[we] mix different rheologies with powder metals, highly viscous, and the LabRAM II has proven it can do that effectively. We're very impressed with the build quality of the mixer--it's a nice, solid, well-thought-out piece of equipment. It's done very well for us..."








- Research Scientist
U.S. Government Agency







RAM: 21st Century Mixing Technology for 21st Century Materials

More than a thousand RAM systems are in use in 33 countries around the world. RAM is the world's preferred choice for innovation in materials processing.





PUBLISHED ARTICLES

Icon Legend

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

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
 	Efficient production of a high-performance dispersion strengthened, multi-principal element alloy	“...additive manufacturing can be leveraged to produce dispersion strengthened (DS), multi-principal element alloys (MPEA) without the use of traditional mechanical alloying or chemical reactions. This new processing technique employed ResonantAcoustic® mixing to coat an equiatomic NiCoCr powder with nano-scale yttrium oxides. ...the acoustic mixing step successfully coated the NiCoCr powder. In addition, the powder maintains its spherical morphology as compared to the highly deformed platelet-like powder produced through MA making it more suitable for AM...”	2020
 	NiZnCu-ferrite coated iron powder for soft magnetic composite applications	“...We use a Resodyn™ acoustic mixer to reduce milling time and allow for more uniform mixing, as compared to ball milling or blending. This technique is capable of coating micron-sized powder with nanopowder completely in less than 15 min as shown by Resodyn™ for Mg powder coated with MgO nanopowder. An acoustic mixer is adopted to adequately coat iron powder with ferrite particles in this work. We coat large iron powder with small NiZnCu-ferrite particles of (0.4 to 0.6 μm) using a small amount (0.5%) of lubricant addition to assist in coating and compaction. This coating method allows for adequate coating layers to be deposited in minimal amounts of time, in order to create faster manufacturing procedures and reduce costs related to processing...”	2018
 	Low-Power Laser Ignition of Aluminum/Metal Oxide Nanothermites	“...A second method was subsequently used and does not involve the use of any solvent. A LabRAM mixer (Resodyn Acoustic Mixers, Inc.) was used, which can mix powders of different nature using low-frequency, high-intensity acoustic energy, creating a uniform shear field throughout the entire mixing container...The mixing procedure was done remotely. All resulting nanothermites were homogeneous...”	2014

PUBLISHED ARTICLES

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Impact Ignition and Combustion Behavior of Amorphous Metal-Based Reactive Composites	“...Recently published molecular dynamic simulations have shown that metal-based reactive powder composites consisting of at least one amorphous component could lead to improved reaction performance...thermochemical equilibrium calculations were performed on various amorphous metal/metalloid based reactive systems with an emphasis on commercially available or easily manufactured amorphous metals, such as Zr and Ti based amorphous alloys in combination with carbon, boron, and aluminum. Based on the calculations and material availability material combinations were chosen. Initial materials were mixed via a Resodyn mixer...”	2013
	Synthesis of highly loaded gelled propellants	“... Based upon the results of this work, ResonantAcoustic® technology has been demonstrated as a feasible method for producing metallized and gelled propellants. The use of this technology has several unique advantages over conventional mixing technologies...”	2009
	Efficient production of a high-performance dispersion strengthened, multi-principal element alloy	“...To produce additive manufacturing material, equiatomic NiCoCr medium entropy alloy (MEA) powder which exhibited a diameter size range between 10–45µm and Y2O3 particles rated between 100–200 nm were acquired. A Resodyn LabRAM II resonant mixer was employed to coat the NiCoCr powder with one weight percent of nanoscale Y2O3...acoustic mixing employs a longitudinal pressure wave composed of a short amplitude and high frequency by attaining a resonance between a vibrating spring system and the stored mass of the powder and container. This process quickly homogenized the powder, eventually coating the larger NiCoCr powder with a thin film of Y2O3 after an hour of mixing in a polyurethane container...”	2020
	Sintering of tungsten powder with and without tungsten carbide additive by field assisted sintering technology	“...The tungsten (W) powder was used in as-received form for the experiment without WC additive. For the experiment with tungsten carbide (WC) additive, WC powder was mixed with W powder by Resodyn acoustic mixer to make W–5 vol.%WC and W–10 vol.%WC powder mixtures...By mixing 5 and 10 vol.% WC with W powder, densification was enhanced and finer grain size was obtained. Relative density above 99% with grain size around 3 µm was achieved in W–10 vol.% WC sintered at 1700 °C, 85 MPa, for 5 min...”	2012

PUBLISHED ARTICLES

Partial (edited) selection of searched technical articles using the following search terms (articles are live links): “powder metals,” AND/OR: “resonant acoustic” “acoustic mixing” “Resodyn.”

[Efficient production of high-performance dispersion strengthened, multi-principal element alloy](#)

TM Smith, AC Thompson, TP Gabb, CL Bowman... - Scientific reports, 2020 - nature.com

Additive manufacturing currently facilitates new avenues for materials discovery that have not been fully explored. In this study we reveal how additive manufacturing can be leveraged to produce dispersion strengthened (DS), multi-principal element alloys (MPEA) without the use of traditional mechanical alloying or chemical reactions. This new processing technique employed resonant acoustic mixing to coat an equiatomic NiCoCr powder with nano-scale yttrium oxides. Then, through laser powder bed fusion (L-PBF), the ...

[Related articles](#)

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

HM Titi, JL Do, AJ Howarth, K Nagapudi, T Friščić - Chemical science, 2020 - pubs.rsc.org

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. Importantly, the LA-RAM approach also allowed the synthesis of the ZIF-L framework that ...

[Related articles](#)

[NiZnCu-ferrite coated iron powder for soft magnetic composite applications](#)

KJ Sunday, ML Taheri - Journal of Magnetism and Magnetic Materials, 2018 - Elsevier

... We use a ResodynTM acoustic mixer to reduce milling time and allow for more uniform mixing, as compared to ball milling or blending. ... of coating micron-sized powder with nanopowder completely in less than 15 min as shown by ResodynTM for Mg powder coated with MgO ...

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[Low-power laser ignition of aluminum/metal oxide nanothermites](#)

CF Petre, D Chamberland, T Ringuette... - ... Journal of Energetic ..., 2014 - dl.begellhouse.com

... In addition to the above method, the three nanothermites were also produced using a Resodyn LabRAM mixer. A paraffin-coated spher... of aluminum and metal oxide nanopowders, unlike conventional thermites, which are composed of micrometer-sized powders. The rate of ...

[Related articles](#)

[Impact Ignition and Combustion Behavior of Amorphous Metal-Based Reactive Composites](#)

L Groven, B Mason, S Son - Bulletin of the American Physical Society, 2013 - APS

... that metal-based reactive powder ... metals, such as Zr and Ti based amorphous alloys in combination with carbon, boron, and aluminum. Based on the calculations and material availability material combinations were chosen. Initial materials were either mixed via a Resodyn ...pellants. Typically, metal powder used in making metallized propellants, is in the form of micron-sized particles. The liquid propellant is gelled with an additive...

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Partial (edited) selection of searched technical articles using the following search terms (articles are live links): “powder metals,” AND/OR: “resonant acoustic” “acoustic mixing” “Resodyn.”

[Sintering of tungsten powder with and without tungsten carbide additive by field assisted sintering technology](#)

S Chanthapan, A Kulkarni, J Singh, C Haines... - International Journal of ..., 2012 - Elsevier

Abstract Tungsten powder (0.6–0.9 μm) was sintered by field assisted sintering technology (FAST) at various processing conditions. The sample sintered with in-situ hydrogen reduction pretreatment and pulsed electric current during heating showed the lowest amount of oxygen. The maximum relative density achieved was 98.5%, which is from the sample sintered at 2000° C, 85 MPa for 30 min. However, the corresponding sintered grain size was

22.2 μm . To minimize grain growth, nano tungsten carbide powder (0.1–0.2 μm) was used ...

[Related articles](#)

[Synthesis of highly loaded gelled propellants](#)

SL Coguill - Resodyn Corp., Butte, MT, 2009 - researchgate.net

... Aluminum, Boron, Carbon and Magnesium are the most commonly used metals used to synthesize gelled propellants. Typically, metal powder used in making metallized propellants, is in the form of micron-sized particles. The liquid propellant is gelled with an additive that is a ...

[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

[Glass-metal composites and method of manufacture](#)

WO EP US CN WO2014197094A2 Carsten Weinhold Schott Corporation
Priority 2013-03-15 • Filed 2014-03-14 • Published 2014-12-11

The shaped composites of the present disclosure have metal powder bonded with glass powder. This feature provides the advantages of metal, metal powder, or glass composite materials, without suffering from the disadvantages. The composite is prepared with simple sintering methods, and can easily ...

[Method of making a cemented carbide or cermet powder by using a resonant ...](#)

EP ES EP2584057B1 Carl-Johan Maderud Sandvik Intellectual Property AB
Priority 2011-10-17 • Filed 2011-10-17 • Granted 2016-08-03 • Published 2016-08-03

A method of making a cemented carbide or cermet agglomerated powder without milling, where the powder constituents are subjected to a non-milling mixing operation, comprising the steps of: forming a slurry of one or more powders forming hard constituents, metal binder powders and a mixing liquid, ...

[Cemented carbide containing tungsten carbide and finegrained iron alloy binder](#)

US US20180142331A1 John J. Pittari, III U.S. Army Research Laboratory Attn: Rdrl-Loc-I
Priority 2016-11-10 • Filed 2017-11-09 • Published 2018-05-24

A sintered cemented carbide body including tungsten carbide, and a substantially cobalt-free binder including an iron-based alloy sintered with the tungsten carbide. The iron-based alloy is approximately 2-25 % of the overall weight percentage of the sintered tungsten carbide and iron-based alloy.

[Continuous acoustic mixer](#)

WO EP US US20210069662A1 Peter Andrew Lucon Resodyn Corporation
Priority 2017-09-05 • Filed 2020-11-16 • Published 2021-03-11

A system for continuously processing a combination of materials includes a continuous process vessel having an outlet and one or more inlets. The continuous process vessel is configured to oscillate along an oscillation axis. An acoustic agitator is coupled to the continuous process vessel. The ...

[Glass-metal composites and method of manufacture](#)

WO EP US CN WO2014197094A2 Carsten Weinhold Schott Corporation
Priority 2013-03-15 • Filed 2014-03-14 • Published 2014-12-11

The shaped composites of the present disclosure have metal powder bonded with glass powder. This feature provides the advantages of metal, metal powder, or glass composite materials, without suffering from the disadvantages. The composite is prepared with simple sintering methods, and can easily ...



RAM 5 Continuous



RAM 55



OmniRAM Continuous



RAM 5



RAM 5H



OmniRAM



LabRAM II LabRAM I



LabRAM II H

