Resodyn™
ACOUSTIC MIXERS
Innovative Mixing Solutions

Additive Manufacturing Materials Processing Enabled By ResonantAcoustic® Mixing

Testimonials • Published Articles • Patents & Patent Applications

May 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 Additive Manufacturing Materials 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 additive manufacturing materials such as 3D print media.

Resodyn Acoustic Mixers, Inc. 130 N. Main Street, Suite 630, Butte, MT 59701
406-497-5333 | info@resodynmixers.com | www.resodynmixers.com

Resodyn™
ACOUSTIC MIXERS
Innovative Mixing Solutions

Additive Manufacturing Materials

A major aerospace research organization pioneers an additive material (AM) that functionalizes virtually fireproof fuselages. Another develops a new, high-performance metal alloy for repeatably precise consistency for high-volume AM printing. The core of these and other rapid innovations is made possible by ResonantAcoustic® Mixer (RAM) technology. This folio of testimonials, technical articles and patents provides links to detailed, compelling insights into the material discoveries and AM innovations enabled by RAM technology.

RAM's single-technology platform provides an essential processing methodology for additive manufacturing organizations to develop, process, and manufacture additive feed stock from virtually any AM format, including materials previously impossible or impractical to mix and process. These Folio contents recount pioneered, unheard of yet, practical processes and applications for new streams of revenue with greater productivity and faster time-to-market and profitability realized through the direct application of RAM technology for developing and manufacturing a broad range of AM materials.

Leading developers of 3-D print and other additive manufacturing materials rely upon ResonantAcoustic® Mixing technology to deliver exceptional material quality, unparalleled processing capability, higher productivity, and greater profitability.

Australia
Belgium
Canada
China
Czech Republic
Costa Rica
France
Germany
Greece
Hungary
India
Ireland
Israel
Italy
Japan
Latvia

Liechtenstein
Mexico
Netherlands
New Zealand
Norway
Puerto Rico
Saudi Arabia
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Turkey
Taiwan
United Kingdom
United States

= Locations of customers of ResonantAcoustic® Mixers

What the AM industry is saying about ResonantAcoustic® mixing

"... [ResonantAcoustic® mixing] is a fantastic technology. It has revolutionized the way we mix for development of materials for additive manufacturing..."

- Nik Ninos, Research and Development Manager
Calix Ceramic Solutions

"…The LabRAM II has yielded some surprising and exciting results for us. We actually made a new metal alloy for additive manufacturing..."

- Research Scientist
U.S Government Agency

"… We were using reciprocal shakers to dissolve product we sampled off one of our production lines, and it was taking four hours just to prep the material for testing. Once we started using the LabRAM, it cut that time from four hours down to 20 minutes..."

- Lab Supervisor
U.S. Polymer Products Company

RAM: 21st Century Mixing Technology for Additive Manufacturing 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

3D printing

Material/chemical properties

Materials processing

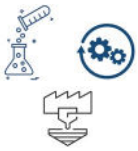
Additive manufacturing

Powder/powder

Materials/product quality

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	3D-printed nanoporous ceramics: Tunable feedstock for direct ink write and projection microstereolithography	"The 3YZ inks were made using solids loading in PEGDA ranging from55 to 70 wt% (18–30 vol%, Table 2). The ink was mixed with spherical zirconia grinding beads (4mm diameter) in an acoustic mixer (LabRAM II, Resodyn Acoustic Mixers, Butte, MT) for 3h at 70 g-force to break up agglomerates and disperse the particles. The LabRAM II mixing time was determined by SEM images of the inks at different time points to ensure homogeneous dispersion... "	2021
	Feasibility of Cryomilled 17-4 Stainless Steel Powder as Feedstock for Additive Manufacturing	"...The blending process was carried out with a Resodyn LabRAM II acoustic mixer operating for 1 h with 10 g's of acceleration."	2020
	Efficient production of a high-performance dispersion strengthened, multi-principal element alloy	"To produce AM 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 ResonantAcoustic™ mixer was employed to coat the NiCoCr powder with one weight percent of nanoscale Y2O3...[the LabRAM II] 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
	Additive manufacturing of ammonium perchlorate composite propellant with high solids loadings	"...20g batches of propellant were hand mixed in a 473 ml jar until the AP was wetted. The mixture was then placed into a [Resodyn Acoustic Mixers LabRAM] resonant mixer. The HTPB binder propellant was mixed for 3 min at 80g for three repetitions with further hand mixing between cycles while the UV binder propellant was mixed in the Resodyn Acoustic Mixer for 2 min at 80g for 30s followed by a rest period of 30s...the techniques demonstrated in this paper could be used to create a wide range of complex grain structures that were not previously possible to manufacture."	2019

PUBLISHED ARTICLES
Cont'd.

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Additive manufacturing of carbon fiber reinforced silicon carbide solid rocket nozzles	"Suitable green body formulations were developed and tested prior to being printed. The final formulation was viscous enough to hold its shape during the 3D printing process so there was minimal deformation before the part was thermoset. 40 g batches were made in a Resodyn ResonantAcoustic™ mixer for three cycles of 3 minutes at 80g. The properties of the mixture did not vary over the course of a few days, making it printable within that time frame."	2019
	Resonant Acoustic® Mixing: Processing and Safety	"New processing technologies are allowing researchers, industry and academia to probe new materials space not previously achievable. These technologies include additive manufacturing and Resonant Acoustic® Mixing (RAM), both of which have expanded in their use and application over the last 15–20 years."	2019
	Environmentally Friendly Boron-Based Pyrotechnic Delays: An Additive Manufacturing Approach	"Three dry powder reactive systems were formulated: B/BaCrO4, B/SrMoO4, and B/BaMoO4. The B/BaCrO4 system was formulated with 14.6 wt % boron and 85.4 wt % barium chromate (4:1 molar ratio). were integrated into an aqueous 2.5 wt % Methocel (K4M) solution to produce printable inks. The gel matrix generated by the Methocel solution provided stability while promoting homogeneity to the suspended particles during mixing and deposition of the inks. On the basis of comparable viscosity, 60 wt % solids was chosen for the B/BaCrO4 system and 70 wt % solids was chosen for the B/SrMoO4 and B/BaMoO4 systems...The three reactive systems were formulated with an equivalent amount of dry powder Methocel using a Resodyn LabRAM mixer and same method as the dry powder mixtures that did not contain Methocel."	2019
	Two-component additive manufacturing of nanothermite structures via reactive inkjet printing	"...a pre-mixed aluminum copper (II) oxide suspension was mixed at a 6% volumetric solid loading. 15 To prepare the material, nCuO was mixed with nAl and suspended in a solution of DMF and PVP and placed in a 10ml syringe (BD, slip tip). The syringe was loaded into a custom polytetrafluoroethylene (PTFE) holder and secured on a LabRAM ResonantAcoustic™ Mixer. The syringe was mixed at 80% intensity for 16 min and inverted after 8 min."	2017

PUBLISHED ARTICLES
Cont'd.

Partial (edited) selection of searched technical articles using the following search terms (articles are live links): "resonant acoustic," "acoustic mixing," "Resodyn," AND/OR: "additive manufacturing," "3-D printing," "3D printing"

3D-printed nanoporous ceramics: Tunable feedstock for direct ink write and projection microstereolithography
AL Troksa, HV Eshelman, S Chandrasekaran…- Materials & Design, 2021- Elsevier
… Typically, ceramic inks for DIW are made from a highly viscous paste composed of ceramic … Ceramic AM can allow for creation of macroporous ceramics based on the geometry being … order to create micro- or nanoporous ceramics, extra post-processing steps are necessary. …
Related articles

Feasibility of Cryomilled 17-4 Stainless Steel Powder as Feedstock for Additive Manufacturing
F Kellogg, A Kudzal, C Mock, J Taggart-Scarff…- 2020- apps.dtic.mil
…Additive manufacturing (AM) is a catchall term for a suite of manufacturing processes that produces parts in a layer-by-layer method. Laser powder bed … The blending process was carried out with a Resodyn LabRAM II acoustic mixer operating for 1 h with 10 g's of acceleration…
Related articles

Efficient Production of a 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 … A Resodyn LabRAM II resonant mixer was employed to coat the NiCoCr powder with one weight percent of…
Related articles

Additive manufacturing of ammonium perchlorate composite propellant with high solids loadings
MS McClain, IE Gunduz, SF Son- Proceedings of the Combustion Institute, 2019- Elsevier
...The effective solid propellant burning rate in a rocket depends on surface area andpropellant composition. Currently, the surface area geometry in a rocket is limited to whatcan be practically cast using molds, etc. Additive manufacturing (AM) could allow the…
Related articles

Additive manufacturing of carbon fiber reinforced silicon carbide solid rocket nozzles
MS McClain, IE Gunduz, SF Son- AIAA Scitech 2019 Forum, 2019- arc.aiaa.org
…low manufacturing costs, and/or reduced weight. However, manufacturing costs could be further reduced by using additive manufacturing (AM… 40 g batches were made in a resonant mixer (Resodyn) for three cycles of 3 minutes at 80 g's. The properties of the mixture did not vary…
Related articles

PUBLISHED ARTICLES
Cont'd.

Additive manufacturing of carbon fiber reinforced silicon carbide solid rocket nozzles
MS McClain, IE Gunduz, SF Son- AIAA Scitech 2019 Forum, 2019- arc.aiaa.org
Additive manufacturing is a technology that has been proven to be advantageous,particularly in the aerospace industry. Naturally, there is an interest in 3D printing ablative materials for applications such as solid rocket nozzles. Currently, fiber reinforced materials that are printable (ie thermoplastics) are not high performing ablatives since they significantly deform at temperatures below 300 C, which is far below exhaust temperatures. There is also a limitation on how much fiber can be used to reinforce the thermoplastic if it is …
Related articles

Resonant Acoustic® Mixing: Processing and Safety
MR Andrews, C Collet, A Wolff…- Propellants, Explosives …, 2020- Wiley Online Library
...New processing technologies are allowing researchers, industry and academia to probe new materials space not previously achievable. These technologies include additive manufacturing and Resonant Acoustic® Mixing (RAM) which are being demonstrated to reduce processing times, environmental impact and of course cost. With the introduction of any new technology it is imperative that users, managers and national bodies provide the resources and time to determine, understand and provide guidance associated with the safe…
Related articles

Environmentally friendly boron-based pyrotechnic delays: an additive manufacturing approach
IT Walters, LJ Groven- ACS Sustainable Chemistry & Engineering, 2019- ACS Publications
…Additionally, manufacturing of delay systems can be problematic due to the dispersion of harmful powders into the air. Additive manufacturing of … Each dry powder formulation was mixed using a Resodyn LabRAM at 60 g intensity for 1 min for three total times with a 1 min pause…
Related articles

Two-component additive manufacturing of nanothermite structures via reactive inkjet printing
AK Murray, T Isik, V Ortalan, IE Gunduz…- Journal of applied …, 2017- aip.scitation.org
…The syringe was loaded into a custom polytetrafluoroethylene (PTFE) holder and secured on a LabRAM resonant mixer (Resodyn … for the dual nozzle manufacturing technique. The ignition progression of a 5 layer sample prepared by dual nozzle printing is shown in Fig. (a). …
Related articles

Printed Energetics: The Path Toward Additive Manufacturing of Munitions
LJ Groven, MJ Mezger- Energetic Materials, 2017- taylorfrancis.com
… In their work, it was shown that by using a Resodyn LabRam mixer, the nanothermite could be processed directly within the deposition … additive manufacturing for energetics—if certain barriers can be overcome. The first major barrier to the development of additive manufacturing …
Related articles

Relevant Patents

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

*Including patents with RAM as the preferred embodiment

Chemical-free fabrication of graphene reinforced polymer matrix composites

Abstract

A simple, rapid, scalable, environmentally friendly method of directly producing graphene reinforced polymer matrix composites from graphitic materials: (a) a plurality of graphitic materials in a collision chamber of an energy collision device. Mixing a plurality of particles of the solid polymer support material to form a mixture; (b) exfoliating the graphene sheet from the graphite material and transferring the graphene sheet to the surface of the solid polymer support material particles Operating the energy collision device with a frequency and intensity for a time sufficient to form graphene coated polymer particles or graphene embedded polymer particles inside the collision chamber; (c) graphene coated polymer particles or graphene-reinforced polymer matrix composite from embedded polymer particles Method comprising the steps of forming is provided. Also provided are materials of graphene coated polymer particles or graphene embedded polymer particles produced by this method.

Three-dimensional printing

Abstract

An example of a build material composition for three-dimensional (3D) printing includes a polyamide material and an antioxidant. The antioxidant consists of an aromatic multihydrazide; or an aromatic sulfonomonohydrazide; or a hydrazide having formula (I) disclosed herein, wherein: R is null, a C1 to C12 unbranched alkyl, a C3 to C8 branched alkyl, a C2 to C8 unbranched alkylene, a C4 to C8 branched alkylene, an alicyclic compound, a polyethylene glycol, or a combination thereof; A is C=O, O=S=O, P=O, or C=S; and n is an integer ranging from 1 to 4; or formula (II) disclosed herein wherein A is C=O, O=S=O, P=O, or C=S.

Method for resonant-vibratory mixing

Abstract

A method for mixing fluids and/or solids in a manner that can be varied from maintaining the integrity of fragile molecular and biological materials in the mixing vessel to homogenizing heavy aggregate material by supplying large amounts of energy. Variation in the manner of mixing is accomplished using an electronic controller to generate signals to control the frequency and amplitude of the motor(s), which drive an unbalanced shaft assembly to produce a linear vibratory motion. The motor may be a stepper motor, a linear motor or a DC continuous motor. By placing a sensor on the mixing vessel platform to provide feedback control of the mixing motor, the characteristics of agitation in the fluid or solid can be adjusted to optimize the degree of mixing and produce a high quality mixant.

Relevant Patents
Cont'd.

Apparatus and method for resonant-vibratory mixing

Abstract

An apparatus and method for mixing fluids and/or solids in a manner that can be varied from maintaining the integrity of fragile molecular and biological materials in the mixing vessel to homogenizing heavy aggregate material by supplying large amounts of energy. Variation in the manner of mixing is accomplished using an electronic controller to generate signals to control the frequency and amplitude of the motor(s), which drive an unbalanced shaft assembly to produce a linear vibratory motion. The motor may be a stepper motors a linear motor or a DC continuous motor. By placing a sensor on the mixing vessel platform to provide feedback control of the mixing motor, the characteristics of agitation in the fluid or solid can be adjusted to optimize the degree of mixing and produce a high quality mixant.

Continuous acoustic mixer

Abstract

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 acoustic agitator is configured to oscillate the continuous process vessel along the oscillation axis. An outlet passage is in fluid communication with the outlet. At least a portion of the outlet passage or at least a portion of the continuous process vessel is disposed within a portion of the acoustic agitator.

RAM 5 *Continuous*

RAM 55

*Omni***RAM** *Continuous*

RAM 5H

RAM 5

*Lab***RAM II** *Lab***RAM I**

*Lab***RAM II H**

*Omni***RAM**

Resodyn™
ACOUSTIC MIXERS
Innovative Mixing Solutions

Resodyn Acoustic Mixers, Inc. 130 N. Main Street, Suite 630, Butte, MT 59701
406-497-5333 I info@resodynmixers.com I www.resodynmixers.com