Resodyn™ ACOUSTIC MIXERS

Innovative Mixing Solutions

Innovations in Advanced Materials Processing Enabled By ResonantAcoustic® Mixing

Testimonials • Published Articles • Patents & Patent Applications

Graphene

Additive Manufacturing

Advanced Materials

Polymers

Elastomers

Technical Ceramics

September 2021

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 advanced material 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 advanced materials such as nanomaterials, graphenes, ceramics and polymers.

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Resodyn™ ACOUSTIC MIXERS

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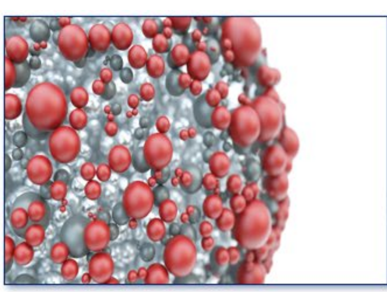
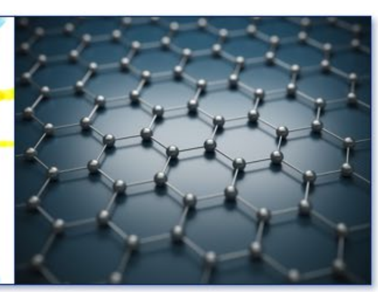
Advanced Materials Processing

The category of advanced materials generally includes **technical ceramics**, **polymers**, semiconductors, biomaterials and **nanomaterials**. Nanomaterials are generally defined as material having at least one dimension less than 100 nanometers, and offer uniquely beneficial qualities for optical, electronic, mechanical and thermo-physical types of applications. **Graphenes** are a class of nanomaterial that is rapidly being adopted due to its exceptional tensile strength, electrical conductivity, transparency, and being the thinnest two-dimensional material known to man. Technical ceramics enable innovations in aerospace, defense, energy production, and industrial processing industries by expanding on the unique thermal, wear and corrosion resistance of conventional ceramics. Synthetic polymers include elastomers, polymer fibers and thermoplastics.

Developers of leading-edge products enabled by advanced materials rely upon ResonantAcoustic® Mixing technology to conceive and deliver innovative new products across a wide spectrum of industries.

= Locations of customers of ResonantAcoustic® Mixers



What advanced material processors are saying about RAM

"ResonantAcoustic® mixers from Resodyn have proven to be extremely valuable in graphene development for our clients. It is critical for nanotechnologies such as graphene to be processed with the level of exacting consistency and particle distribution, especially at low loadings, that RAM has proven to consistently achieve."

- Dr. Arun Prakash Aranga Raju, Graphene Engineering Innovation Centre
The University of Manchester, Manchester, England

"RAM has given us the ability to increase solids loading in our ceramic slurries to levels not possible with bladed mixers. RAM can also mix thixotropic materials that bladed mixers can't."

- U.S.-based Advanced Ceramics Materials Company

"...ResonantAcoustic® mixing allows for large-scale synthesis of nanoparticle solutions and the formation of nanoparticles of desirable sizes...We believe this new technique will facilitate the development of lyotropic mesophase materials and new methodologies for the fabrication of nanoparticles. The technique will have a significant impact in shaping the future of nanoscience..."

- Australian Government Science Research Organization

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

Number of RAM systems sold for advanced materials mixing: **>50**
Number of RAM advanced materials customers worldwide: **>43**
Number of RAM systems sold worldwide (33 countries): **>1,000**

PUBLISHED ARTICLES

Resodyn™ ACOUSTIC MIXERS
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Icon Legend

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

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Resonant Acoustic Mixing Method to Produce Lipid-Based Liquid-Crystal Nanoparticles	“We have found that when compared to traditional sonication-based methods, the use of resonant acoustic mixing allows for large-scale synthesis of nanoparticle solutions and the formation of LLC nanoparticles of desirable sizes. We believe this new technique will facilitate the development of lyotropic mesophase materials and new methodologies for the fabrication of nanoparticles.”	2021
	3D-printed nanoporous ceramics: Tunable feedstock for direct ink write and projection microstereolithography	“The [ceramic additive manufacturing] ink was mixed with spherical zirconia grinding beads (4 mm diameter) in a LabRAM II acoustic mixer for 3 h 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
	Resonant Acoustic Mixing Method to Produce Lipid-Based Liquid-Crystal Nanoparticles	“Compared to traditional sonication-based methods, the use of resonant acoustic mixing (RAM) allows large-scale synthesis of nanoparticle solutions and formation of LLC nanoparticles of desirable sizes...[RAM] will have a significant impact in shaping the future of nanoscience, providing a rapid and efficient mixing/fabrication platform for materials for cosmetics to therapeutics to vaccines.”	2021
	Investigation of the impact of particle size on properties and applications of a ceramic slurry	“To make the ceramic slurry, 3YZrO2 nanoparticles were mixed with polyethylene glycol diacrylate (PEGDA Mn 575, Sigma Aldrich) and zirconia grinding media and mixed for 3 hours in a Resodyn™ LabRAM II acoustic mixer.”	2019

* Article links may be limited by copyright restrictions. Detailed links on following pages.
^ Results excerpted/paraphrased from articles.

PUBLISHED ARTICLES

Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Investigating High Energy Mixing in Cement-based Materials	"RAM mixing does not use a tool [e.g., impeller] that directly interacts with the mixing medium. This makes it an attractive mixing device as it reduces the cost of wear and tear of the mixing device...A 30% increase in 3-day and 20% increase in 28-day mechanical properties were observed in UHPC specimens mixed with RAM. The improved mechanical properties support there is more uniform mixing energy transmitted to the system during mixing which enhances cement hydration and reduces air voids."	2018
	Final Report on creation of the Energetic Materials Laboratory, Univ. of Texas at El Paso	"The objective of this project was to acquire equipment and instrumentation for research and education on energetic materials that would enhance the University's capabilities in materials preparation, materials characterization, and combustion experiments...The [Resodyn Acoustic Mixers LabRAM] will enhance the academic experience for students and help prepare them for productive work in advanced areas of engineering important for the U.S. Department of Defense."	2015
	A new and improved method for the preparation of drug nanosuspension formulations using acoustic mixing technology	"[We used] low shear acoustic mixing to rapidly identify optimized nanosuspension formulations for a wide range of compounds with dramatically improved material and time efficiencies."	2014
	Preparation of an energetic-energetic cocrystal using resonant acoustic mixing	"Resonant acoustic mixing (RAM) was applied to the preparation of an energetic-energetic cocrystal comprised of CL-20 and HMX in a 2:1 mol ratio. We have prepared the cocrystal using the RAM technology in a resource-efficient manner providing near quantitative yield. The cocrystalline product from the RAM preparation is consistent with the product from solution crystallization."	2014
	Preparation and characterization of aqueous nanothermite inks for direct deposition on SCB initiators	"...[RAM] uses an environmentally friendly mixing medium, can result in a higher density final material, and allows safe one-step mixing and deposition."	2014
	Nano-aluminum thermite formulations: characterizing the fate properties of a nanotechnology during use	"The thermite formulations were prepared using a one-step mixing process in a Resodyn LabRAM mixer as opposed to typical ultrasonication."	2013

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^ Results excerpted/paraphrased from articles.

PUBLISHED ARTICLES

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Icons	Publication Title (Live Links)*	RAM Application Summary	Year
	Feasibility study and demonstration of an aluminum and ice solid propellant	“Although this current propellant formulation is far from optimized, improvements in the mixing procedure [using RAM] have produced a consistent and homogeneous propellant. While the performance of ALICE is too low for practical use, the knowledge gained through formulating and experimenting with nanoscale particles in a simple mixture is of great interest for ongoing research activities on advanced propellants.”	2012
	The Effect of Varied Amounts of LiF Sintering Aid on the Transparency of Alumina Rich Spinel Ceramic with the Composition MgO	“Starting powders are prepared from combinations of high purity $Mg(OH)_2$ and γ-Al_2O_3 thoroughly mixed in an aqueous slurry, and the solids are collected, dried, calcined, mixed with LiF sintering aid, and sieved...mixing was performed using a Resodyn Acoustic Mixer.”	2012
	Graphene–aluminum nanocomposites	“Aluminum–graphene composite powders were fabricated by initially blending the constituent precursory powders of Valimet Al and graphene. Blending was conducted using a Resodyn LabRAM acoustic mixer for approximately 5 minutes.”	2011
	Preparation morphology and properties of reduced graphene oxide/natural rubber nanocomposites	“Two routes for exfoliation of graphite oxide (GO) to graphene oxide yield different aspect ratio platelets... Resodyn Acoustic Mixer and Ultrasonication. Both methods exfoliate to single-layer graphene oxide but prolonged exfoliation times lead to smaller platelets, thus a smaller Af [aspect ratio].”	2011

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^ Results excerpted/paraphrased from articles.

PUBLISHED ARTICLES

Resodyn™ ACOUSTIC MIXERS
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Partial (edited) selection of searched technical articles using the following search terms (articles are live links): "resonant acoustic" "acoustic mixing" AND/OR: "Resodyn," "nanomaterials," "ce-

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Resonant Acoustic Mixing Method to Produce Lipid-Based Liquid-Crystal Nanoparticles
D Yalcin, S Rajesh, J White, SC Howard...- The Journal of ..., 2021- ACS Publications
... Chem. C 2021, XXXX, XXX, XXX-XXX. ADVERTISEMENT. RETURN TO ARTICLES ASAPPREVC: Physical Properti...C: Physical Properties of Materials and Interfaces NEXT. Journal Logo. Resonant Acoustic Mixing Method to Produce Lipid-Based Liquid-Crystal Nanoparticles ...

Related articles

3D-printed nanoporous ceramics: Tunable feedstock for direct ink write and projection microstereolithography
AL Troksa, HV Eshelman, S Chandrasekaran...- Materials & Design, 2021- Elsevier
... Common methods for making porous ceramics make use of sacrificial pore formers, direct foaming ...beads (4 mm diameter) in an acoustic mixer (LabRAM II, Resodyn Acoustic Mixers ... Once the initiator was added, the ceramic ink was ready for subsequent characterization and ...

Related articles

The Effects of Resonant Acoustic Mixing on the Microstructure of UHPC
A Vandenberg, K Wille- International Interactive Symposium ..., 2019- iastatedigitalpress.com
... High-intensive mixers that provide high energy input to the system and have power consumption instrumental capabilities have advanced the field of ... (b) Resodyn LabRAM ... "Monitoring of Concrete Homogenisation with the Power Consumption Curve." Materials and Structures ...

Related articles

Investigation of the impact of particle size on properties and applications of a ceramic slurry
HV Eshelman- 2019- osti.gov ... Aldrich) and zirconia grinding media and mixed for 3 hours in a Resodyn™ LabRAM II ... Thermal initiator and photoinitiator (if needed) were added and the slurry was mixed in a ... https://www.tosoh.com/our-products/advanced-materials/zirconia-powders (accessed Apr 15, 2019).

Related articles

Investigating High Energy Mixing in Cement-based Materials
A Vandenberg- 2018- opencommons.uconn.edu
... and carbon nanofibers (CNF), with and without polyvinyl phenol polymer-wrapping ... The heart of the project is to learn many material characterization skills and apply them to different questions relating to cementitious materials. Rheology, electron microscopy, dynamic light ...

Related articles

[Final Report on creation of the Energetic Materials Laboratory, Univ. of Texas at El Paso]
E Shafirovich- 2015- apps.dtic.mil
… a glovebox isolator (Terra Universal Series 300) • an acoustic mixer (Resodyn LabRAM) • a …research on the enhancement of reactive materials, propellants, and advanced structural and …and Safe Chemical Gas Generators with Nanocomposite Reactive Materials.” The results …

[A new and improved method for preparation of drug nanosuspension formulation using acoustic mixing technology]
DH Leung, DJ Lamberto, L Liu, E Kwong…- International journal of …, 2014- Elsevier
… In addition, the acoustic mixer agitates the entire container and does not contact the components of … This drug slurry is then acoustically mixed in the presence of zirconia grinding media, resulting …Herein we report this new acoustic milling process in detail as well as advantages …

[Related articles]

[Preparation of an energetic-energetic cocrystal using resonant acoustic mixing]
SR Anderson, DJ am Ende, JS Salan…- Propellants …, 2014- Wiley Online Library
… supported by a commercial platform of RAM mixers available through the Resodyn Corporation … care must be taken to ensure complete dissolution of the starting materials before non … rate can greatly influence formation of cocrystal or precipitation of discrete material from solution …

[Related articles]

[Preparation and characterization of aqueous nanothermite inks for direct deposition on SCB initiators]
RR Nellums, SF Son, LJ Groven- Propellants, Explosives …, 2014- Wiley Online Library
… polytetrafluoroethylene (PTFE) fixture 18, clamped in a LabRAM resonant mixer (Resodyn Acoustic Mixers … 30 mg increments to mitigate dangers presented by inadvertent reaction of material …Additional materials and powders used for stability verification included iron(III) oxide …

[Related articles]

Relevant Patents

Resodyn™ ACOUSTIC MIXERS *Innovative Mixing Solutions*

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

*Including patents with RAM as the preferred embodiment

Integral 3D graphene-carbon hybrid foam

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-layer graphene sheets have 2-10 layers of stacked graphene planes having an inter-plane spacing d002 from 0.3354 nm to 0.40 nm and the graphene sheets contain a pristine graphene material having essentially zero % of non-carbon elements, or a non-pristine graphene material having 0.01% to 25% by weight of non-carbon elements wherein said non-pristine graphene is selected from graphene oxide, reduced graphene oxide, graphene fluoride, graphene chloride, graphene bromide, graphene iodide, hydrogenated graphene, nitrogenated graphene, doped graphene, chemically functionalized graphene, or a combination thereof. Also provided are a process for producing the hybrid form, products containing the hybrid foam, and its applications.

Supercapacitor with integrated 3D graphene-carbon hybrid foam-based electrode

A supercapacitor having an anode, a cathode, a porous separator / electrolyte, wherein at least one electrode comprises an integral 3D graphene-carbon hybrid foam composed of a plurality of pores and pore walls, Includes a single-layer or several-layer graphene sheet chemically bonded by a carbon material having a carbon material to graphene weight ratio of 1/100 to 1/2, and the several-layer graphene sheet has an interplanar spacing of 0.3354 nm to 0.40 nm a pure graphene material having 2 to 10 layers of graphene surfaces with d002, wherein the graphene sheet has substantially 0% non-carbon elements, or 0.01 wt% to 25 wt% non-carbon elements An impure graphene material, wherein the impure graphene includes graphene oxide, reduced graphene oxide, graphene fluoride, salt Graphene bromide graphene iodide graphene, hydrogenated graphene, nitrogen graphene, doped graphene, are selected from the chemical functionalization graphene, or a combination thereof, the super capacitor is provided.

Chemical-free production of graphene-wrapped electrode active material particles for battery applications

Provided is a simple, fast, scalable, and environmentally benign method of producing graphene-embraced or encapsulated particles of a battery electrode active material directly from a graphitic material, the method comprising: a) mixing graphitic material particles, multiple particles of an electrode active material, and non-polymeric particles of milling media to form a mixture in an impacting chamber, wherein the graphitic material has never been intercalated, oxidized, or exfoliated and the chamber contains therein no previously produced graphene sheets; b) operating the energy impacting apparatus with a frequency and an intensity for a length of time sufficient for peeling off graphene sheets from the graphitic material and transferring graphene sheets to surfaces of electrode active material particles to produce graphene-embraced active material particles; and c) recovering the graphene-embraced particles from the impacting chamber. Also provided is a mass of the graphene-embraced particles, electrode containing such particles, and battery containing this electrode.

Thermoelectric polymer composite, method of making and use of same

A thermoelectric composite includes a plurality of particles comprising a crosslinked polymer having a heat deflection temperature greater than or equal to 200° F. and a segregated network comprising a first filler material which is disposed between the particles to produce a thermoelectric response in response to application of a voltage difference or temperature difference across the thermoelectric composite. The first filler material includes a carbon material, a metal, a metal disposed on a carbon material, or a combination thereof. A process for preparing a thermoelectric article includes combining a first filler material and a plurality of particles comprising a polymer to form a composition and molding the composition to form a thermoelectric article, wherein the thermoelectric article is configured to produce a thermoelectric response in response to application of a voltage difference or temperature difference across the article.

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Patents, cont'd.

Graphene reinforced polyethylene terephthalate

A composition and a method are provided for graphene reinforced polyethylene terephthalate (PET). Graphene nanoplatelets (GNPs) comprising multi-layer graphene are used to reinforce PET, thereby improving the properties of PET for various new applications. Master-batches comprising polyethylene terephthalate with dispersed graphene nanoplatelets are obtained by way of compounding. The master-batches are used to form PET-GNP nanocomposites at weight fractions ranging between 0.5% and 15%. In some embodiments, PET and GNPs are melt compounded by way of twin-screw extrusion. In some embodiments, ultrasound is coupled with a twin-screw extruder so as to assist with melt compounding. In some embodiments, the PET-GNP nanocomposites are prepared by way of high-speed injection molding. The PET-GNP nanocomposites are compared by way of their mechanical, thermal, and rheological properties so as to contrast different compounding processes.

Method for producing a cemented carbide or ceramic metal powder using a resonant acoustic mixer

A method for producing a piece of cemented carbide or ceramic metal, comprising the steps of: forming a powder mixture comprising powders that form hard constituents and metallic binder;- subjecting said powder mixture to a mixing operation using a resonant non-contact acoustic mixer where acoustic waves are used that have a frequency that achieves resonance conditions to form a combination of mixed powders, where the frequency used is between-80 Hz,- subjecting said combination of mixed powders to a forming and sintering operation.

The electrode active material particles that graphene for battery applications is encapsulated are produced without chemicals formula

Provide a kind of battery electrode active material particle directly being surrounded from graphite material production graphene or encapsulating it is simple, quick, can scale and environmental-friendly method; the described method includes: graphite material particle and multiple solid electrode active material particles a) are mixed to form mixture in the impact room of energy impact device; wherein the graphite material never carries out intercalation, oxidation or extruding, and the room is wherein without containing the graphene film generated in advance and without containing ball-milling medium□B) the energy impact device is run with certain frequency and intensity and generates the electrode active material particles of graphene encirclement so that graphene film is transferred to the surface of electrode active material particles from the graphite material□And the particle c) is recycled from the impact room.Additionally provide block, the electrode containing such particle and the battery containing this electrode of a kind of particle that the graphene surrounds.

ResonantAcoustic mixing (RAM) of an explosive composition

The invention relates to a cast explosive composition, particularly to a pre-cure castable explosive composition comprising an explosive material, a polymerisable binder, a microencapsulated cross linking reagent, said microencapsulated cross linking reagent, comprising a cross linking agent encapsulated in a microcapsule. Providing a process for formulating a homogenous crosslinked polymer bonded explosive composition comprising the steps of: i) forming an admixture of pre-cure castable explosive composition, said composition comprising an explosive material, a polymerisable binder, a microencapsulated cross linking reagent, said microencapsulated cross linking reagent, comprising a cross linking reagent encapsulated in a microcapsule; wherein the microcapsule, comprises at least one shell wall polymer, wherein the microcapsule's shell wall polymer comprises at least one resonant acoustic stimulus labile linkage, ii) applying resonant acoustic stimulus to the admixture, causing the microcapsule to rupture and release said cross linking reagent, to cause the cure process to start.

Acoustic mixing for flocculant addition to mineral suspensions

The present invention relates to a process for mixing a flocculant composition with mineral suspensions, especially waste mineral slurries, using an acoustic mixer. Preferably the flocculant composition is a polymeric flocculant composition preferably comprising a poly(ethylene oxide) homopolymer or copolymer. The process of the present invention is particularly suitable for the treatment of tailings and other waste material resulting from mineral processing, in particular, processing of oil sands tailings.

Patents, cont'd.

Solvent-free emulsion process using acoustic mixing

A process for making toner particles is provided. In embodiments, a suitable process includes melt mixing a resin in the absence of an organic solvent, optionally adding a surfactant to the resin, adding to the resin at least one colorant and other optional toner additives, adding to the resin a basic agent and water to form a mixture, and subjecting the mixture to acoustic mixing at a suitable frequency to form to form an emulsion. A phase inversion may then be performed to create a phase inversed emulsion including a disperse phase comprising molten resin and the optional ingredients of the toner composition, at which time toner-sized droplets may be solidified from the disperse phase into toner particles, which can be recovered for use.

Thermoelectric polymer composite, method of making and use of same

A thermoelectric composite includes a plurality of particles comprising a crosslinked polymer having a heat deflection temperature greater than or equal to 200° F. and a segregated network comprising a first filler material which is disposed between the particles to produce a thermoelectric response in response to application of a voltage difference or temperature difference across the thermoelectric composite. The first filler material includes a carbon material, a metal, a metal disposed on a carbon material, or a combination thereof. A process for preparing a thermoelectric article includes combining a first filler material and a plurality of particles comprising a polymer to form a composition and molding the composition to form a thermoelectric article, wherein the thermoelectric article is configured to produce a thermoelectric response in response to application of a voltage difference or temperature difference across the article.

Method for producing a cemented carbide or ceramic metal powder using a resonant acoustic mixer

A method for producing a piece of cemented carbide or ceramic metal, comprising the steps of: forming a powder mixture comprising powders that form hard constituents and metallic binder;- subjecting said powder mixture to a mixing operation using a resonant non-contact acoustic mixer where acoustic waves are used that have a frequency that achieves resonance conditions to form a combination of mixed powders, where the frequency used is between-80 Hz,- subjecting said combination of mixed powders to a forming and sintering operation.

Supercapacitor having an integral 3D graphene-carbon hybrid foam-based electrode

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 chemically bonded by a carbon material having a carbon material-to-graphene weight ratio from 1/100 to 1/2, wherein the few-layer graphene sheets have 2-10 layers of stacked graphene planes having an inter-plane spacing d002 from 0.3354 nm to 0.40 nm and the graphene sheets contain a pristine graphene material having essentially zero % of non-carbon elements, or a non-pristine graphene material having 0.01% to 25% by weight of non-carbon elements wherein said non-pristine graphene is selected from graphene oxide, reduced graphene oxide, graphene fluoride, graphene chloride, graphene bromide, graphene iodide, hydrogenated graphene, nitrogenated graphene, doped graphene, chemically functionalized graphene, or a combination thereof.

Continuous acoustic chemical microreactor

A continuous acoustic chemical microreactor system is disclosed. The system includes a continuous process vessel (CPV) and an acoustic agitator coupled to the CPV and configured to agitate the CPV along an oscillation axis. The CPV includes a reactant inlet configured to receive one or more reactants into the CPV, an elongated tube coupled at a first end to the reactant inlet and configured to receive the reactants from the reactant inlet, and a product outlet coupled to a second end of the elongated tube and configured to discharge a product of a chemical reaction among the reactants from the CPV. The acoustic agitator is configured to agitate the CPV along the oscillation axis such that the inner surface of the elongated tube accelerates the one or more reactants in alternating upward and downward directions along the oscillation axis.

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