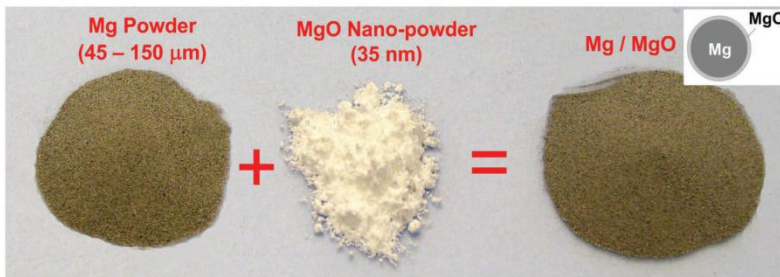


### Background

Resodyn Acoustic Mixers, Inc. has developed a novel mixer product line that uses low-frequency, high-intensity acoustic energy for mixing. The technology, trademarked as ResonantAcoustic® Mixing (RAM), is applicable to a broad range of mixing classes that include liquid-gas, liquid-liquid, liquid-solid and powder-powder systems. Highlighted in this bulletin is: **Coating of micron materials with nanopowder**, just one of many applications.

### Technical Approach

ResonantAcoustic® Mixing is capable of cost and time effective mixing of nano- and micron-sized powders (Figure 1). Nano-sized powder such as MgO can be, within minutes, uniformly dispersed and attached to micron-sized Mg powder in the form of an ultrathin film covering surface of all Mg powder particles. After ResonantAcoustic® Mixing, composite Mg/MgO powder can further be processed using conventional Powder Metallurgy, Casting, or Thermal Spray technologies resulting in an Mg microstructure reinforced coatings with uniformly distributed 3D network of MgO nanophase.



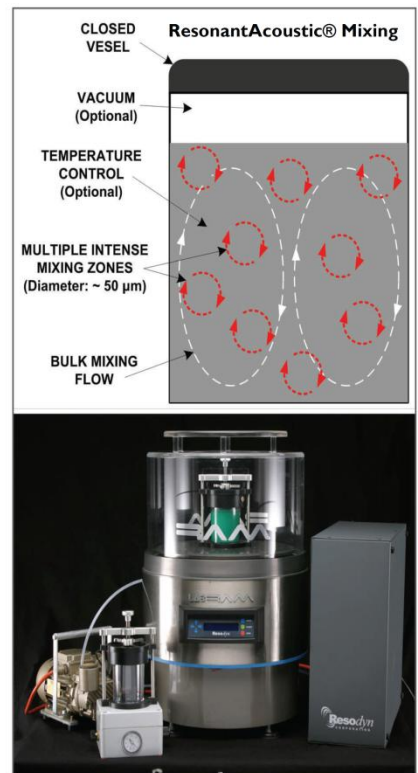
**Figure 1:** Appearance of micron-sized Mg powder mixed with 2 vol. % 35 nm MgO nanopowder using ResonantAcoustic® Mixing.

### Key Advantages of RAM Technology:

ResonantAcoustic® Mixing (Figure 2) provides a cost effective method of de-agglomerating MgO nano-powders and thoroughly mixing them with micron-sized Mg powders as a precursor for various conventional technologies used to create Mg parts with uniformly distributed MgO nanophase.

The following are key advantages for using ResonantAcoustic® Mixing for processing Mg/MgO material:

- Creating fully and uniformly mixed MgO/Mg precursor powder in minutes.
- Safe processing of highly reactive Mg powder because the resulting composite powder consists of Mg particles encapsulated with a protective nanofilm of MgO.
- Mixing can be conducted in air, vacuum, inert gas, or other controlled atmospheres.
- Laboratory and production mixers are commercially available.



**Figure 2:** ResonantAcoustic® Mixing principles (top); LabRAM benchtop mixer with accessories (bottom)

## Technology Description

ResonantAcoustics® Mixing (Figure 2) is a newly developed technology that is based on the use of low-frequency, high-intensity acoustic energy to create a uniform shear field throughout an entire mixing vessel. A closely controlled electromechanical oscillator is used to excite mix material using a proprietary method that is designed to operate at resonance. The entire system oscillates in resonance, allowing highly efficient energy transfer and rapid mixing. Multiple micro-mixing zones, with mixing lengths of nominally 50 microns, are created throughout entire mixing vessel forcing all powder particles to simultaneously move and interact during the entire mix time. This micro-mixing process rapidly creates a uniformly mixed combination of micron/nano-sized powders that cannot be reproduced with the same effectiveness using conventional impeller agitation, ball milling, or ultrasonic mixing.

## Results

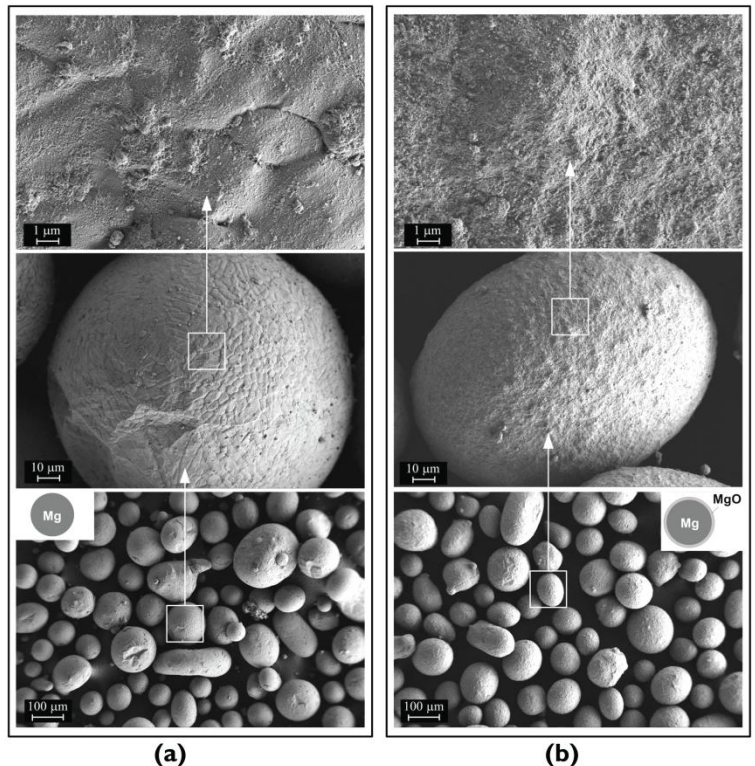
Preliminary, un-optimized testing has demonstrated the capability of ResonantAcoustics® to completely mix MgO nanopowder and micron-sized Mg powder. Mixing time was in the order of minutes. Operating conditions are proprietary.

Figure 3 shows SEM images of 45 – 150 μm Mg powder particles before and after mixing with 2 vol.% of 35 nm MgO nanopowder in less than 15 minutes.

A characteristic change in surface texture was observed on all powder particles after acoustic mixing, which was confirmed to correspond to MgO thin film using EDS spectroscopy. See Figures 3 and 4.

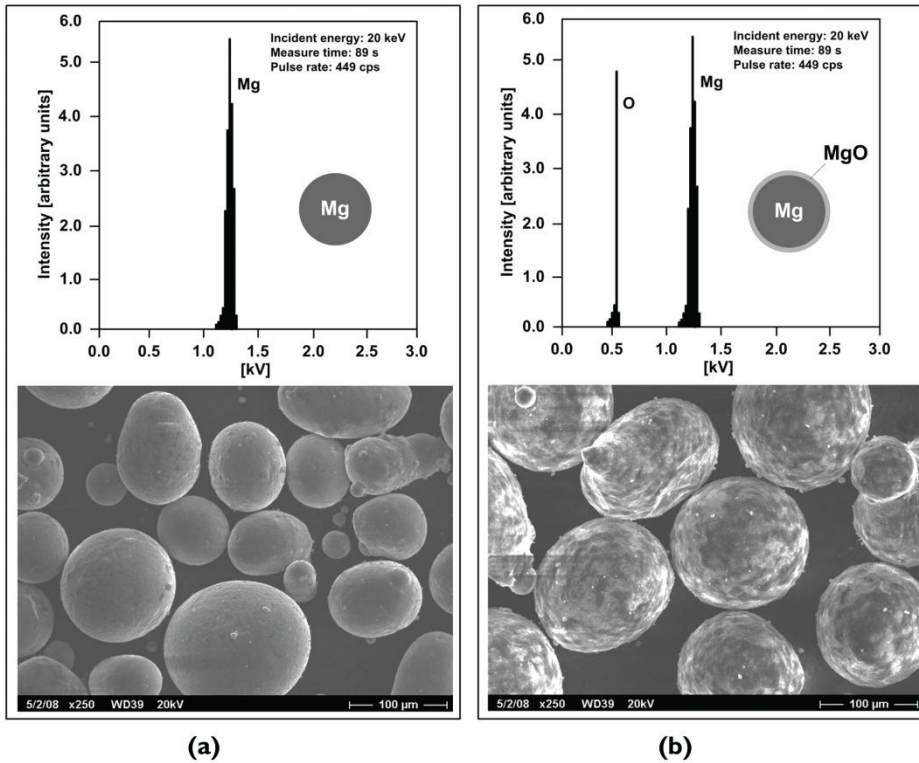
Moreover, no loose MgO nanopowder was identified anywhere throughout entire mix volume indicating that complete nanopowder content is attached to the surface of Mg particles during the mixing process. Even though EDS dot map could not be used at this scale to clearly distinguish between Mg and O elements, the high energy secondary electron image shown in Figure 4 confirmed the presence of “charging” phenomena only on mixed Mg/MgO particles due to nonconductive MgO film present on the surface of all Mg particles (Figure 4b).

As mentioned earlier, composite Mg/MgO powder rapidly formed using ResonantAcoustic® mixing can further be used as an effective precursor for various conventional technologies used to create Mg parts with uniformly distributed 3D network of MgO nanophase.



**Figure 3:** SEM images of (a) pure Mg powder and (b) Mg powder mixed with 2 vol.% of MgO nanopowder. Note that the surface texture in Figures (a), middle and top, appears to be “muted” and smoothed in corresponding Figures (b). This change in surface texture is attributed to the development of a MgO nanopowder coating that resulted during the mixing.

## Resonant Acoustic<sup>®</sup> Mixing Coating of Micron Materials With Nanopowder



**Figure 4:** (a) High energy secondary electron SEM images of pure Mg powder and (b) Mg powder mixed with 2 vol. % of MgO nanopowder that exhibited “charging” phenomena (light zones on particle surface) due to nonconductive MgO film present on the surface of all Mg particles.

In addition to the RAM technology approach used in this work, a proprietary method that can be incorporated to enhance its “milling” capabilities for strongly agglomerated particles. This approach is well suited for deagglomerating and mixing a wide range of materials, including homogeneously distributing other inert and ceramic materials into an Mg matrix.

### ResonantAcoustic<sup>®</sup> Mixer Benefits

- Easy cleaning
- Blends dissimilar powders
- Fast mixing times
- Can mix in the shipping container
- Blends cohesive powders
- Can mix hazardous materials
- Can combine processing steps such as coating and mixing



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**RAM 5  
Production Mixer**