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Self-assembly of granular crystals

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Acoustic meta-materials are engineered materials with the ability to control, direct, and manipulate sound waves. Since the 1990s, several groups have developed acoustic meta-materials with novel capabilities including negative index materials for acoustic super-lenses, phononic crystals with acoustic band gaps for wave guides and mirrors, and acoustic cloaking device. Most previous work on acoustic meta-materials has focused on continuum solids and fluids. In contrast, we report on coordinated computational and experimental studies to use macro-self-assembly of granular materials to produce acoustic meta-materials. The advantages of *granular* acoustic materials are three-fold: 1) *Microscopic control:* The discrete nature of granular media allows us to optimize acoustic properties on both the grain and network scales. 2) *Tunability:* The speed of sound in granular media depends strongly on pressure due to non-linear contact interactions and contact breaking. 3) *Direct visualization:* The macro-scale size of the grains enables visualization of the structure and stress propagation within granular assemblies. We report simulations and experiments of vibrated particles that form a variety of self-assembled ordered structures in two- and three-dimensions. In the simplest case of mono-disperse spheres, using a combination of pressure and vibration we produce crystals with long-range order on the scale of 100's of particles. Using special particle shapes that form "lock and key" structures we are able to make binary crystals with prescribed stoichiometries. We discuss the mechanical properties of these structures and methods to create more complicated structures.