

Title: Nanosynthesis of Terfenol-D Enabled by High-Energy Ball Milling

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Abstract:

Magnetostrictive materials deform in response to a magnetic field or exhibit magnetization variation when mechanically stressed. This unique energy coupling between magnetic and mechanical domains is instantaneous and has resulted in a variety of acoustic sensors that can generate or detect surface acoustic waves, shear waves, or longitudinal waves. Such sensors could be utilized in nuclear reactors for in-pile measurements, structural monitoring, sonar exploration and communication, and medical devices. Despite their great potential, magnetostrictive acoustic sensors are currently limited in real-life application due to the difficulties in manufacturing and sensor integration. The U.S. Department of Energy (DOE) is pursuing research and development on additive manufacturing (AM) of advanced sensors to simplify sensor integration, slash waste production, and reduce fabrication costs. This study used a commercial high energy ball mill to synthesize magnetostrictive Terfenol-D nanoparticles that are crucial feedstock for fused filament fabrication, direct ink writing, or other AM techniques. The effect of ball milling settings, such as milling duration and surfactant, on particle size, purity, and morphology was systematically studied. Preliminary X-ray Diffraction (XRD) results showed that a high milling duration results in amorphous particles, while dynamic light scattering and scanning micron electroscop confirmed particles on the nanoscale after milling. Dry milling in argon effectively prevented particle oxidation and maintained the original material composition determined by XRD and energy dispersive spectroscopy. This research will not only broaden the material library for AM, but also provide innovative acoustic sensors enabling accurate structural health monitoring of nuclear reactors and infrastructures.