Argonne NATIONAL LABORATORY



# Opening the door to faster rockets and high-capacity hydrogen storage

## Unique process produces first stable suspensions of aluminum nanoparticles

Argonne National Laboratory's Chemical Engineering Division has developed a unique process for making aluminum nanoparticles that remain dispersed in solution. This will allow scientists to study the behavior of these materials, which are of interest for use in propellents and hydrogen storage.

Chemist and project leader Robert Klingler examines a sample of aluminum nanoparticles in preparation for testing at Argonne's high-pressure NMR facility.

Finely divided aluminum has been a subject of intense interest over the years for use in energetic materials (those that can store large amounts of chemical energy and release it very quickly) such as propellants and pyrotechnics (fireworks). More recently, aluminum nanoparticles have attracted interest as building blocks for high-capacity hydrogen storage materials.

Currently, micron-sized aluminum is commonly used, but interest is focused on nano-sized aluminum particles whose smaller size provides more surface area for reaction, leading to faster overall energy storage and release. Making aluminum nanoparticles has remained a challenge because finely divided aluminum powders quickly agglomerate.

Argonne's Chemical Engineering Division has developed a unique process for making aluminum nanoparticles that will not agglomerate, but instead remain dispersed in solution as stable solid materials. This allows study of the oxidation of these energetic materials for use in propellants and their hydrogenation for hydrogen storage using a range of powerful solution-phase spectroscopic methods such as UV, IR, and NMR, as well as traditional solid-state techniques such as SAXS, EXAFS and TEM. Significantly, this solid form of aluminum nanoparticles can be isolated and redispersed into a range of organic solvents including aromatics, tetrahydrofuran, and acetonitrile.

Analysis of the solid aluminum nanoparticles by transmission electron microscopy (TEM) indicates that they are nanocrystalline and exhibit a predominately hexagonal morphology with well-defined faces. Electron diffraction spectra of isolated nanoparticles results in a large number of sharp diffraction spots consistent with a high degree of crystallinity. Significantly, the TEM images of the aluminum nanocrystallites demonstrate that they are well-separated, isolated particles with little tendency to form larger clustered aggregates, overcoming the rapid agglomeration that is characteristic of finely divided aluminum powders. The metallic nature of these aluminum nanoparticles was confirmed by the characteristic $^{27}Al$ NMR Knight shift for aluminum metal.

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