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National Energy Technology Laboratory

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CONTACTS

Phuoc X. Tran
Principal Investigator
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-6024
phuoc.tran@netl.doe.gov

Yee Soong
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-4925
yee.soong@netl.doe.gov

David K. Lyons
Extreme Drilling Team Leader
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4379
k.david.lyons@netl.doe.gov

Nanofluids Preparation Using Multi-pulse Laser Ablation Technique

Project Goal

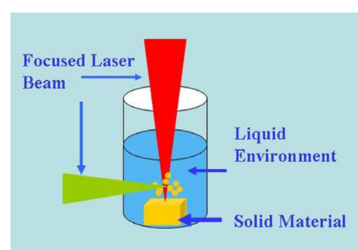
This research will develop and refine methods of creating nanofluids via the laser ablation technique. This specific research goal is a subset of a more encompassing project titled "Nanofluids for Use as Ultra-Deep Drilling Fluids, which the reader is encouraged to read in order to more fully appreciate the potential importance of nanofluid development with respect to high pressure high temperature drilling.

Background

Previous efforts to manufacture nanofluids have often employed either a single step that simultaneously makes and disperses the nanoparticles into base fluids, or a two-step approach that involves generating nanoparticles and subsequently dispersing them into a base fluid. Using either of these two approaches, nanoparticles are inherently produced from processes that involve reduction reactions or ion exchange. Furthermore, the base fluids contain other ions and reaction products that are difficult or impossible to separate from the fluids.

Another difficulty encountered in nanofluid manufacture is nanoparticles' tendency to agglomerate into larger particles, which limits the benefits of the high surface area nanoparticles. To counter this tendency, particle dispersion additives are often added to the base fluid with the nanoparticles. Unfortunately, this practice can change the surface properties of the particles, and nanofluids prepared in this way may contain unacceptable levels of impurities.

Most studies to date have been limited to sample sizes less than a few hundred milliliters of nanofluids. This is problematic since larger samples are needed to test many properties of nanofluids and, in particular, to assess their potential for use in new applications.



Technical Approach

Unlike the two-step methods discussed in this fact sheet's background, this project explores a single-step that will simultaneously make and disperse nanoparticles directly in the base fluids. This single-step method is founded on the laser ablation of solid metals or polymers which are submerged in the base fluid (water, lubrication oils, etc.). By creating a nanofluid in this way, stable nanofluids may result without the use of any property-changing dispersants.

ADDRESS

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

Laser ablation in liquid medium occurs when a high-power laser is focused at the submerged surface for an appropriate time. Laser ablation in liquid is simple and is not limited by the adverse consequences of processing described in other generation methods. Specifically, the surface of the nanoparticles created by laser ablation is free of extraneous ions or other chemicals because it can generate nanoparticles without counter-ions or surface active substances.

With the multi-pulse approach, the first pulse is focused on the solid to generate a vapor plume expanding into the liquid. The following pulses are then focused onto the expanding plume to further break the generated particles into smaller particles; thus, the particles become more uniform in size. Figure 1 shows ultraviolet-visual spectrum (UV-VIS) absorption spectra of the silver (Ag)- and aluminum (Al)-deionized (De) water nanofluids.

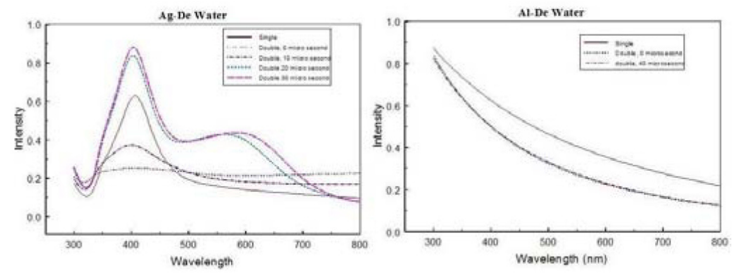


Figure 1. UV-VIS absorption spectra of Ag- and Al-De water nanofluids generated by laser ablation technique: effects of single pulse versus double pulses in cross-beam configuration.

The spectra demonstrate that using laser ablation in liquid can generate stable colloids containing nanosized metal particles without the use of any dispersants or surface reactive reagents. The effect of using double pulse versus single pulse was not observed clearly using the UV-VIS spectra of Al; however, the UV-VIS spectra of Ag-De water nanofluids suggest that the double pulse method has a profound and positive effect on particle size distribution.

With the single beam approach, Ag-De water nanofluid had a single surface Plasmon absorption peak around 400 nm, while for the double pulse approach, two peaks were observed when the time delays between the pulses were at 20 and 30 s. Since such observation has not been reported in literature, we are planning to conduct more tests on Ag-De water, and the results will be reported in due course.

Results on transmission electron microscopy analysis on Ag- and Al-de water nanofluids are shown in figure 2. The Ag nanoparticles are almost all spherical. For single pulse approach, the majority of the particle diameters are in the 14 – 32 nm range. There are some as large as 50 - 60nm in size. For double pulse approach, the particle sizes are more uniform and the majority of the particles are in the 9 - 21nm range. There are also some 23 - 26nm in size.

When performing laser ablation of Al in water, the ablated Al species reacts with the water to yield an amorphous gel that transforms to the crystallized aluminum hydroxide in nanometer range. Various particles shapes, shown in figure 2, are due to an aging process of the generated nanofluids. The shapes observed were triangular (bayerite), rectangular (gibbsite), and fibrous (boehmite).

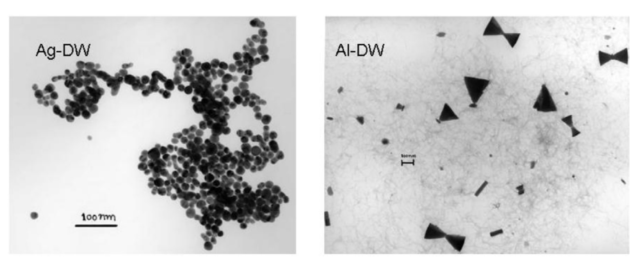


Figure 2. Nanoparticles generated using a single laser beam (1064 nm; 40 mJ; 5.5 ns pulse).