Studies on Combustion of Single Ni-Coated Al Particles in Normal and Reduced Gravity

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Combustion of metal particles coated by another metal (e.g. aluminum coated by nickel) has been proposed as a method for synthesis of intermetallic compounds and for use in propulsion applications. Such particles can be produced by a variety of methods, including electroplating, electroless plating, and others, which provide uniform coatings and are not expensive.

Metal coated Al particles can potentially be used to directly synthesize aluminide powders. Aluminides display several useful qualities, such as outstanding strength characteristics, high melting points, and excellent corrosion resistance. These materials can be produced by various methods including *combustion synthesis* (Varma and Mukasyan, 2002). The latter can be conducted as a batch process using either mixtures of Al and Ni powders or samples of Ni-clad Al particles. In addition, experiments performed by Mukasyan *et al.* (2001) in microgravity showed that the ignition of Ni-clad Al particle *clouds* in an inert atmosphere leads to propagating combustion fronts. This finding indicates that it is possible to synthesize aluminide powders through a *continuous* combustion process, which is desirable from the technological viewpoint.

Aluminum powder is currently used as a fuel in propellants for large solid rocket engines (e.g. Space Shuttle boosters), allowing rockets to achieve better performance characteristics. However, while the use of aluminum powder is beneficial, there are some drawbacks. Due to the existence of an alumina (Al_2O_3) film on the surface, the particles have a high (~2300K) ignition temperature, which results in longer ignition times. Aluminum particles also have a tendency to agglomerate, which causes incomplete combustion of Al and slag formation inside the rocket engine. Studies by Breiter *et al.* (1988) demonstrated that the use of Al particles coated by metals with high melting temperatures (e.g. nickel, iron, copper) reduces particle agglomeration. In addition, the ignition temperature of compacted Ni-clad Al particles in vacuum is between 1050 and 1240 K depending on sample heating rate (Shafirovich *et al.*, 2002).

Combustion of compacted samples of Ni-clad Al particles was examined by Mukasyan *et al.* (2001) and Thiers *et al.* (2002). To provide insight into combustion of a single burning particle, small (30-70 μm diameter) particles were suspended in an electrodynamic levitator and ignited by a laser (Shafirovich *et al.*, 2002, 2005). The ignition and combustion mechanisms, however, were not fully investigated.

The current research focuses on using large (~2.5 mm diameter) Ni-clad Al particles to study their ignition and combustion mechanisms. To eliminate natural convection, which distorts the flame shape, experiments will be performed in microgravity during parabolic flights aboard NASA's C-9B aircraft. During the initial experiments, the type of atmosphere and the Ni fraction will be varied. Figure 1 shows the experimental setup, which includes a main rack and a computer rack. The essential components of the setup are: a combustion chamber, Phantom 5.1 high speed digital camera (Vision Research), Firestar t-100 laser head (100W, Synrad), RF power supply (Synrad), DC power supply (Synrad), thermocouple data acquisition module (Data Translation), computer (Hewlett Packard), and LCD monitor (Samsung). Figure 2 shows the interior of the combustion chamber. A two-axis linear translation stage provides precise alignment of particles to the laser beam, which is directed through a ZnSe window into the chamber. A remote controlled motorized linear stage rotates a sample spool during the flight, allowing for several experiments to be performed without opening the chamber.

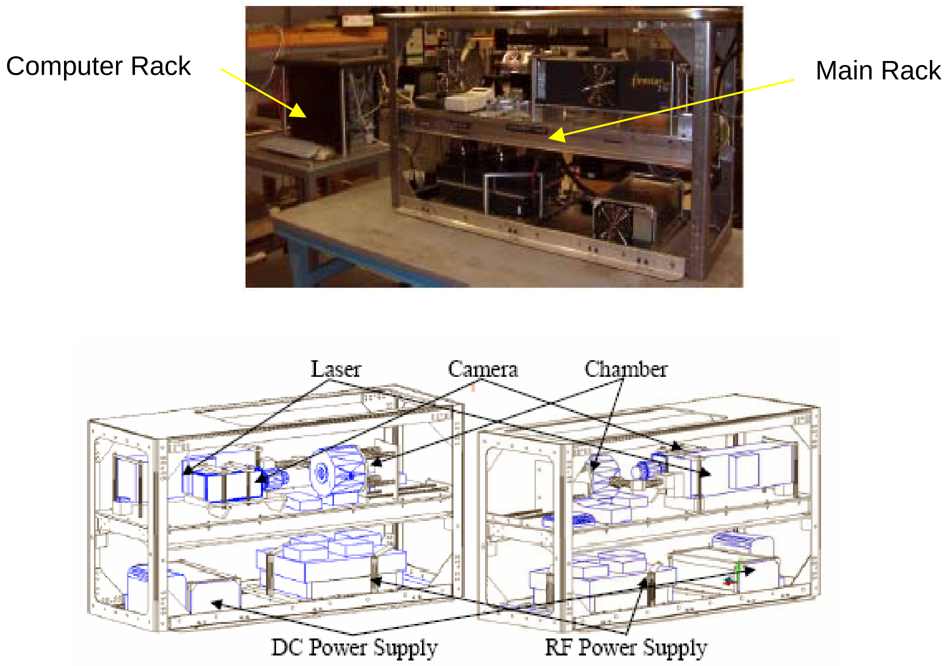

Figure 1: Experimental setup

Figure 2: Combustion chamber

Preliminary experiments have been performed in the laboratory (i.e. 1g environment). Figures 3 and 4 show 50 and 6 wt% Ni particles, respectively, burning in air. It may be seen that there exists a difference in ignition/combustion mechanisms based on Ni content. The 50 wt% Ni particle explodes upon ignition, while a liquid mass escapes the 6 wt% Ni particle prior to ignition. Detailed studies at 1g are currently in progress, and the first microgravity experiments are scheduled for the week of October 24, 2005.

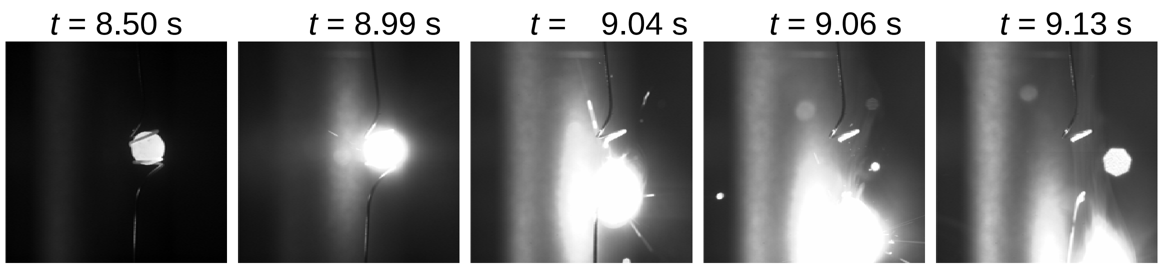

Figure 3: Combustion of Ni-coated Al particle (50 wt% Ni) in air

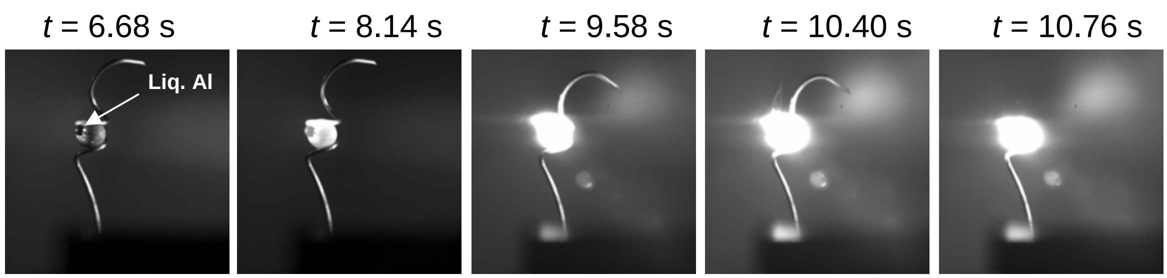

Figure 4: Combustion of Ni-coated Al particle (6 wt% Ni) in air

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