# Microgravity Investigation of Dynamic Oxygen Adsorption in Molten Solder Jetting Technology

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Surface forces play a critical role in fluid dynamical phenomena which are important in materials processing. These forces are generally more important in liquid-metal systems than in their ceramic or polymer counterparts because of the high surface tensions of metal melts in comparison to other classes of materials. The surface tension of liquid metals has been found to be very susceptible to small amounts of adsorbed oxygen. Consequently, the kinetics of oxygen adsorption can influence the capillary breakup of liquid-metal jets targeted for use in electronics assembly applications where low-melting-point metals (such as tin-containing solders) are utilized as an attachment and/or structural material for mounting of electronic components to substrates. By interpreting values of surface tension measured at various surface ages, adsorption and diffusion rates of oxygen on the surface of the melt can be estimated.

This new research program will investigate the adsorption kinetics of oxygen on the surface of an atomizing molten-metal jet. Oxygen adsorption poses a severe impediment in processing technologies involving jetting of pure tin or tin-based alloys. While the problem of interest is one of fundamental fluid transport and surface science, it is also directly related to the novel technology of dispension (printing) of microscopic solder deposits for the surface mounting of microelectronic devices. This technology, known as solder jetting, features deposition of solder droplets in very fine, very accurate patterns using techniques analogous to those developed for the ink-jet printing industry. A major development challenge in the commercialization of solder jetting technology stems from the need to maintain adequate control of the local inert environment around the atomizing jet and the formed droplets for a wide variety of industrial applications. To this end, the limitations of solder jetting must be quantified as a function of oxygen content in the local inert environment. Alternatively, this requires the quantification of the influence of oxygen gaseous impurities in the ambient on the dynamic surface tension properties of the employed solder melts.

The study involves the design, fabrication and performance of drop tower experiments in the microgravity facilities of the NASA Lewis Research Center on the experimental front. On the theoretical front, the kinetics of oxygen adsorption on the surface of molten-solder alloys and pure tin will be quantified at surface ages from 0.1 ms to several ms. Jets will be formed by forcing the molten metal under pressure through a glass capillary. The jets will be excited by a time periodic

electric field, illuminated stroboscopically, observed and photographed through a microscope. The oxygen adsorption tests will be conducted first in an isothermal environment and subsequently in gradually lower ambient temperatures in order to decouple the effect of temperature from the chemical effects. The specific technique identified for the measurement of dynamic surface tension and its temporal variation has a time resolution of 0.1 ms, but requires detailed spatial resolution of the capillary jet breakup geometry. This can be achieved by using mm-diameter jets, which, however, are vulnerable to the masking effects of gravity. Hence, even though larger diameter jets yield significantly improved resolution of fluid breakup dynamics, deviations from axisymmetry in normal gravity hinder the implementation of the selected surface tension measurement technique in a terrestrial laboratory. Conducting experiments in a microgravity environment (thus eliminating the unwanted influence of gravity) allows the experimental investigation of large-diameter jets in conjunction with the planned surface tension measurement technique. Experiments in normal gravity will also define the equilibrium values of surface tension of the melts as a function of ambient oxygen concentration as well as temperature. Comparisons between equilibrium and dynamic surface tension values will provide fundamental information about the kinetics of surface adsorption on lead-tin alloys.

In addition to its merit from the scientific standpoint, the research will provide a science base for the dynamic oxygen adsorption phenomena occurring in the novel solder dispensing technology, thus having a significant effect on Solder Jet development efforts. The study will allow the generation of designs and operating parameters for environmental control systems that are more efficient (in terms of nitrogen usage, space allocation, and energy usage) towards the production of solder deposits of highest quality; this, in turn, will aid the successful commercialization of this innovative technique in electronic component manufacturing or other relevant technologies.