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POLYMER COATING OF GLASS MICROBALLOONS LEVITATED IN A FOCUSED ACOUSTIC FIELD

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ABSTRACT

Inertial confinement fusion (ICF) glass microballoons (GMBs) levitated in a focusing radiator acoustic device can be coated with liquid materials by deploying the liquid into the levitation field with a stepped-horn atomizer. The GMB can be forced to the center of the coating liquid with a strong acoustically generated centering force. Water solutions of organic polymers, uv-curable liquid organic monomers, and paraffin waxes have been used to prepare solid coatings on the surface of GMBs using this technique.

INTRODUCTION

Acoustic levitations of samples in gaseous media have been demonstrated by T. Wang, et al. [1] and others [2-4] in the audio and near-ultrasonic frequency regions on materials with sizes of several millimeters or larger. These acoustic energies can be readily generated with piezoelectric transducers. A major drawback in the use of piezoelectric transducers is their poor coupling coefficients with gaseous media. In order to levitate objects with any significant mass in ambient environments, large surface areas of transducers must be used. In addition, focusing of the levitation forces will help in concentrating these forces. Hemispherical-focusing acoustic radiators provide both these features in levitation systems designed to counter the forces of gravity in a terrestrial environment. [5]

Recent work at the Jet Propulsion Laboratory has concentrated on the development of a focusing acoustic radiator device which can be employed in the fabrication of inertial confinement fusion (ICF) targets for laser fusion studies. This apparatus is designed to handle submillimeter samples such as 200 to 500-micron glass microballoons used as deuterium-tritium fuel containers in ICF studies.

FOCUSING RADIATOR

The levitation device consists of a section of a spherical shell with piezoelectric transducers, along with acoustic alignment equipment and data acquisition instrumentation, a sample deployment system, and ultraviolet and infrared sources for sample treatment.

The focusing dish is constructed from a section of an aluminum spherical shell, 12-in diam and 0.6-in thick, occupying 3.63 sr of solid angle which has been machined to a smooth surface finish (Fig. 1). The aluminum shell is driven

by 130 pieces of about 1-in diam cylindrical piezoelectric transducer discs 0.4-in thick which have been lapped to conform to the outside surface of the aluminum shell. The designed fundamental frequency of this system is 10 kHz. The experimental free-field frequency response at the focal point gave the resonance at 107 kHz and two other resonances at 75 kHz and 163 kHz. The total clamped capacitance of the device was measured at 55,000 pF.

A spherically concave reflector is placed approximately one-half wavelength above the focal point in order to improve stability of the levitated sample. Depending on the resonant frequency used, the lateral dimension of the reflector is approximately two-thirds of the wavelength.

In order to maintain field stability the system is maintained at room temperature by cooling with nitrogen gas from the boil off of liquid nitrogen.

SAMPLE DEPLOYMENT DEVICES

Solid samples can be deployed into the acoustic-force well using a vacuum chuck. The vacuum chuck is prepared by pulling a 2-mm-diam glass tube to a tip about 50- μ m diam.

Liquid samples are deployed into the focal region of the apparatus using an acoustic atomizer which uses a stepped-horn arrangement and operates at 20 kHz. This unit atomizes a liquid droplet into a fine mist of 10- μ m-diam particles directed toward the focal point of the acoustic field. The particles are attracted into the force-well where they rapidly coalesce to form a single droplet, the size of which can be controlled by the amount of liquid atomized. If a GMB already resides in the force well, the atomized droplets of liquid coalesce over the surface of the microballoon, coating it.

DATA ACQUISITION

In order to monitor the levitation and coating process of a levitated sample, a television camera with microscope optics is focused on the force-well area. The image is displayed on a television monitor and can be stored on a video tape recorder for future analysis. The levitated samples are backlit with a collimated source.

RESULTS AND DISCUSSION

The purpose of this investigation is to study the use of the focused radiation acoustic-levitation device in the coating of polymeric materials on glass microballoons for ICF targets. Because of the density difference between the GMB and coating liquids, the GMB is buoyant in the liquid and floats to the top of the liquid droplet.

Centering of a GMB in a liquid droplet can be accomplished by exciting the droplet's surface at its normal-mode oscillation frequencies. The resultant hydrodynamic forces developed in the liquid drive the GMB to the center. [6] Normal-mode frequencies are highly dependent on the surface tension, the viscosity, and the density of the liquid, as well as on the radius of the droplet and the ratio of the radius of the droplet to the radius of the core material; i.e., the GMB. The simplest way to generate the oscillations is to modulate the amplitude of the carrier voltage, exciting the transducers of the focusing radiator. For liquids with relatively low viscosities, such as water, the buoyancy forces can be readily overcome with amplitude modulation, and a GMB can be forced to the center of a liquid water droplet as shown in Fig. 2.

If the water droplet contains a small amount of polymeric material dispersed as a solution or emulsion, evaporating the water from the solution while the levitated GMB is centered in the levitated solution droplet should lead to a polymeric coating on the GMB. Figure 3 shows a GMB coated in just such a manner. The coating of acrylic polymer ASE-60 [7] was applied from a 5% solution in water in several consecutive layers by deploying the solution into the acoustic-force well containing a 200- μ m-diam GMB. The water in each layer was completely evaporated by heating before the next layer was applied.

Attempts to coat a levitated GMB with an ultraviolet-light (uv)-curable monomer mixture made up of a diene and a dithiol with viscosity of 100 centipoise met with less success. Because of the higher viscosity of the uv-curable system, core centering forces were less effective in obtaining a uniform coating on the GMB. Addition of evaporative diluents such as acetone or methanol gave the desired centered core, but evaporation of the diluent returned the system to an uncentered state.

More success has been obtained when a hot melt material is deployed along with a GMB into the acoustic-force well. A piece of paraffin wax about 200 μ m in diam containing a small amount of infrared absorbing dye was deployed along with a GMB into the acoustic-force well, and a heating lamp turned on. As the wax melted it coated a portion of the microballoon. Applying the core centering force centering the GMB in the liquid wax. Turning off the heat source resulted in an almost instantaneous freezing of the wax around the centered microballoon.

SUMMARY

It has been successfully demonstrated that a spherical glass microballoon can be levitated and centered in a liquid material in a terrestrial environment with a focusing radiation acoustic device. We have successfully used this technique to apply a uniform coating of a plastic or wax material around the GMB. Further studies are underway to prepare plastic-, metal-, and plastic-foam-coated GMBs for ICF targets.

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6. M. M. Saffren, D. D. Elleman, and W-K. Rhim, Proceedings of the Second International Colloquium on Drops and Bubbles, Monterey, CA, Nov., 1981, in press.
7. ASE 60 is an alkali-soluble acrylic polymer emulsion manufactured by Rohm and Haas Co., Philadelphia, PA, 19105.

1. Focusing radiator acoustic levitation device.

2. Glass microballoon centered in a liquid water droplet.

3. Glass microballoon coated with an acrylic polymer.