Acoustic Liquid Manipulation Used to Enhance Electrochemical Processes

Working in concert with the NASA Technology Transfer and Partnership Office, the Great Lakes Industrial Technology Center, and Alchemitron Corporation of Elgin, Illinois, the NASA Glenn Research Center has applied nonlinear acoustic principles to industrial applications.

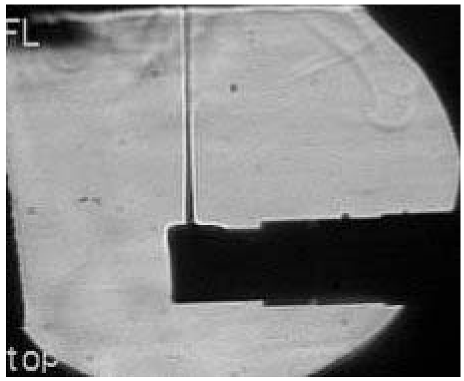
High-intensity ultrasonic beam techniques employ the effects of acoustic radiation pressure and acoustic streaming to manipulate the behavior of liquids. This includes propelling liquids, moving bubbles, and ejecting liquids as droplets and fountains. Since these effects can be accomplished without mechanical pumps or moving parts, we are exploring how these techniques could be used to manipulate liquids in space applications. Some of these acoustic techniques could be used both in normal Earth gravity and in the microgravity of space.

The electroplating process is one Earth-based industry that benefits from the manipulation of liquids. Collaborating with Alchemitron Corporation, we adapted an acoustic transducer to create acoustic streaming in a tank of gold electroplating electrolyte typically used in the manufacture of electronic circuit boards.

Normally, the selective plating process uses masking tapes or coatings to distinguish the surface areas selected to be plated and to protect nonselected areas. Masking is the most labor- and tooling-intensive aspect of the plating process, and the subsequent removal and disposal of masking materials often becomes a source of toxic waste. The substantial cost, health, and environmental issues motivate us to eliminate the masking process.

In a normal electroplating process, the depletion of the electrolyte in the immediate vicinity of the part impedes the process, so agitation is typically used to keep fresh electrolyte in contact with the part. In contrast, the acoustically enhanced process treats this depleted electrolyte envelope as a virtual mask and uses an acoustically driven liquid jet to penetrate the envelope with fresh electrolyte. The plating rate in the area defined by the acoustic beam is dramatically higher, and it appears that further refinement of the process may yield a mask-free process.

In our most recent work, we sought to improve the efficiency of acoustic streaming, which was believed to be the main mechanism for the enhanced plating. This was done by increasing the acoustic frequency from 2 to 45 MHz. In addition, we employed a Schlieren imaging system to observe the streaming process. As shown in the photograph, acoustic streaming can form a distinct and unusually long laminar flow. Surprisingly, the enhanced streaming did not improve the deposition. Further study revealed that the beam reflection observed at lower frequencies contributes to defining a distinct plating area. This finding also implies that acoustic phased arrays (common in medical ultrasound) could now be employed to dramatically improve the process by providing dynamic beam steering and focusing. Future development will involve flexible beam control to perform selective plating by scanning the acoustic beam and “painting” preprogrammed plating patterns without masks. This development is covered by U.S. Patent 6,368,982 and is available for licensing by commercial users.



Schlieren image of an acoustic transducer producing acoustic streaming.
Long description of figure. Acoustic transducer immersed in an electroplating tank. Note the unusually long laminar flow driven entirely by intense ultrasound.

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