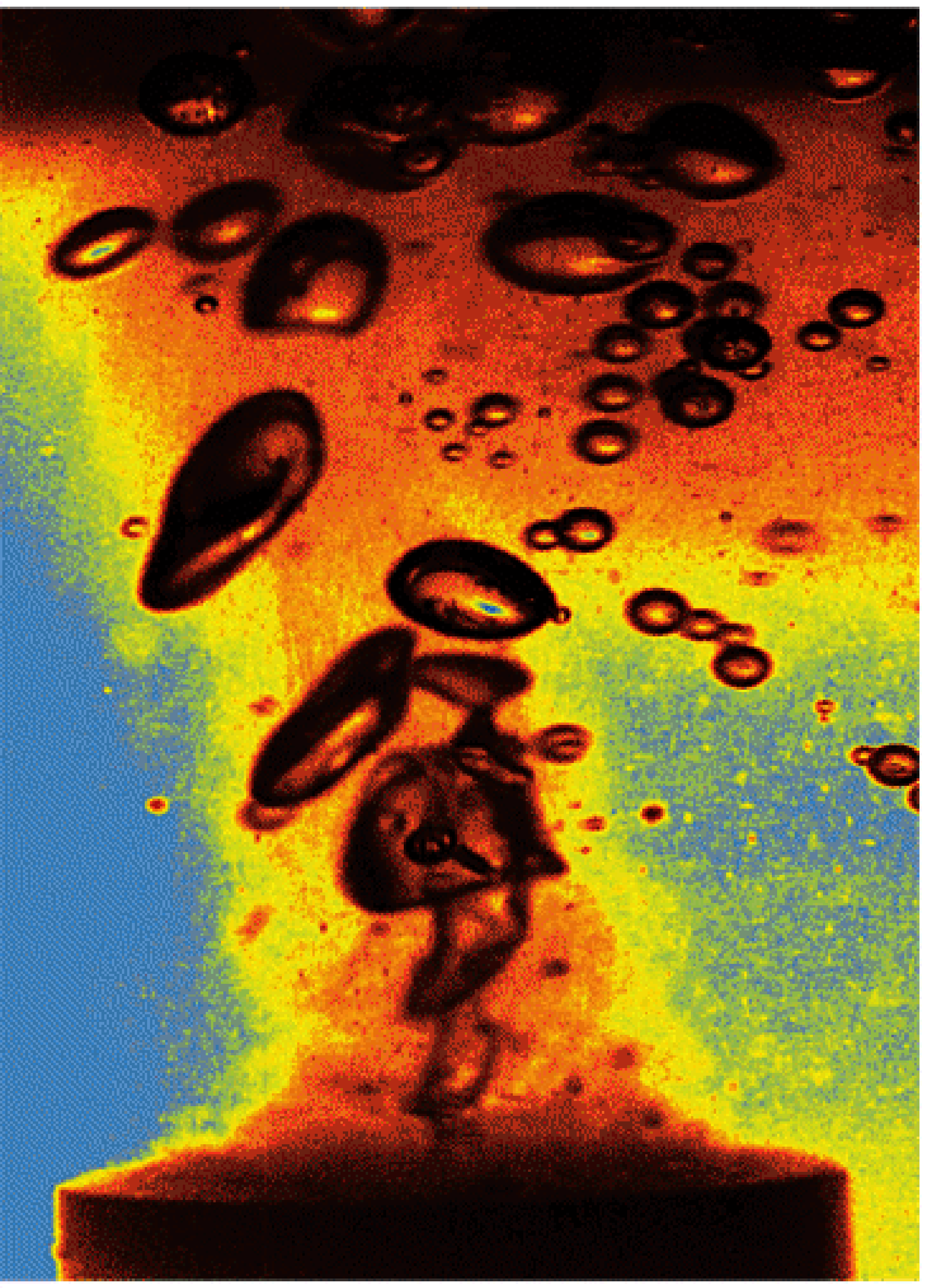
Soldering the Unsolderable

With ultrasonics, assemblers can solder aluminum, titanium and other difficult materials without flux.



In ultrasonic soldering, the vibrational energy induces cavitation in the molten solder. This enhanced image shows cavitation in water. Cavitation is the sequential formation and collapse of vapor bubbles and voids in a liquid subjected to acoustic energy of high frequency and intensity. *Photo courtesy NASA*

By **John Sprovieri**
Editor

Ultrasonic energy can be used to weld metal and plastic; clean and degrease parts; and spray thin coatings of flux, conductive ink and other liquids. Now, assemblers can add one more application to that list—soldering.

In ultrasonic soldering, high-frequency vibrational energy is applied to a molten filler metal to solder parts without flux. The technology is different from ultrasonic plastic welding, in which the vibrations generate heat to melt the plastic. In ultrasonic soldering, heat from a separate energy source melts the filler metal before vibrational energy is applied. Ultrasonic soldering is similar to ultrasonic metal welding, in that both processes rely on high-frequency vibrations to break up and remove oxides on the surface of each part. In ultrasonic metal welding, however, the metal does not melt.

Actually, ultrasonic soldering is more akin to ultrasonic cleaning than either welding process. In ultrasonic cleaning, the vibrational energy induces cavitation in the water bath. Cavitation is the sequential formation and collapse of vapor bubbles and voids in a liquid subjected to acoustic energy of high frequency and intensity. The parts are scrubbed clean by the erosive effect of the bubbles. Similarly, in ultrasonic soldering, the vibrational energy induces cavitation in the molten solder. The cavitation breaks up and disperses surface oxides, allowing the liquid solder to wet and bond pure metal. It also ensures that the solder joint is free of voids.

"With ultrasonic plastic welding, the ultrasonic energy is applied up and down. You're creating friction to melt the plastic," explains Tom Dunn, president of Phase 4 Inc. (Gilbert, AZ). "With ultrasonic metal welding, the ultrasonic energy is applied side to side. You're using friction to disrupt oxides at the interface. With ultrasonic soldering, the ultrasonic energy doesn't melt the solder. It helps the solder to wet the parts. The solder is the ultrasonic bath."

"Ultrasonic soldering lets you solder materials that ordinarily couldn't be soldered." —Tom Dunn, Phase 4 Inc.

Besides direct metal-to-metal bonding, ultrasonic soldering creates strong attachments through two other mechanisms. The first is mechanical. The vibrational energy forces the liquid solder into tiny crevices and pores in the substrates. This helps to seal the parts and greatly increases the surface area to which the solder can bond.

The other mechanism is chemical. The filler metal is specially formulated to work with the ultrasonic process. Like conventional solder alloys, the filler metal is primarily composed of tin and lead. However, depending on the application, it can also contain trace amounts of aluminum, beryllium, indium, silicon, silver, titanium, zinc and rare earth elements. These elements have a strong chemical affinity with oxygen. During bonding, they combine with ambient oxygen to form oxides that chemically bind to glass, ceramics and metals. Indeed, unlike reflow soldering for circuit boards, ultrasonic soldering cannot be done in a nitrogen atmosphere. Without an atmospheric concentration of oxygen of at least 2 percent, the adhesiveness of the solder will be compromised.

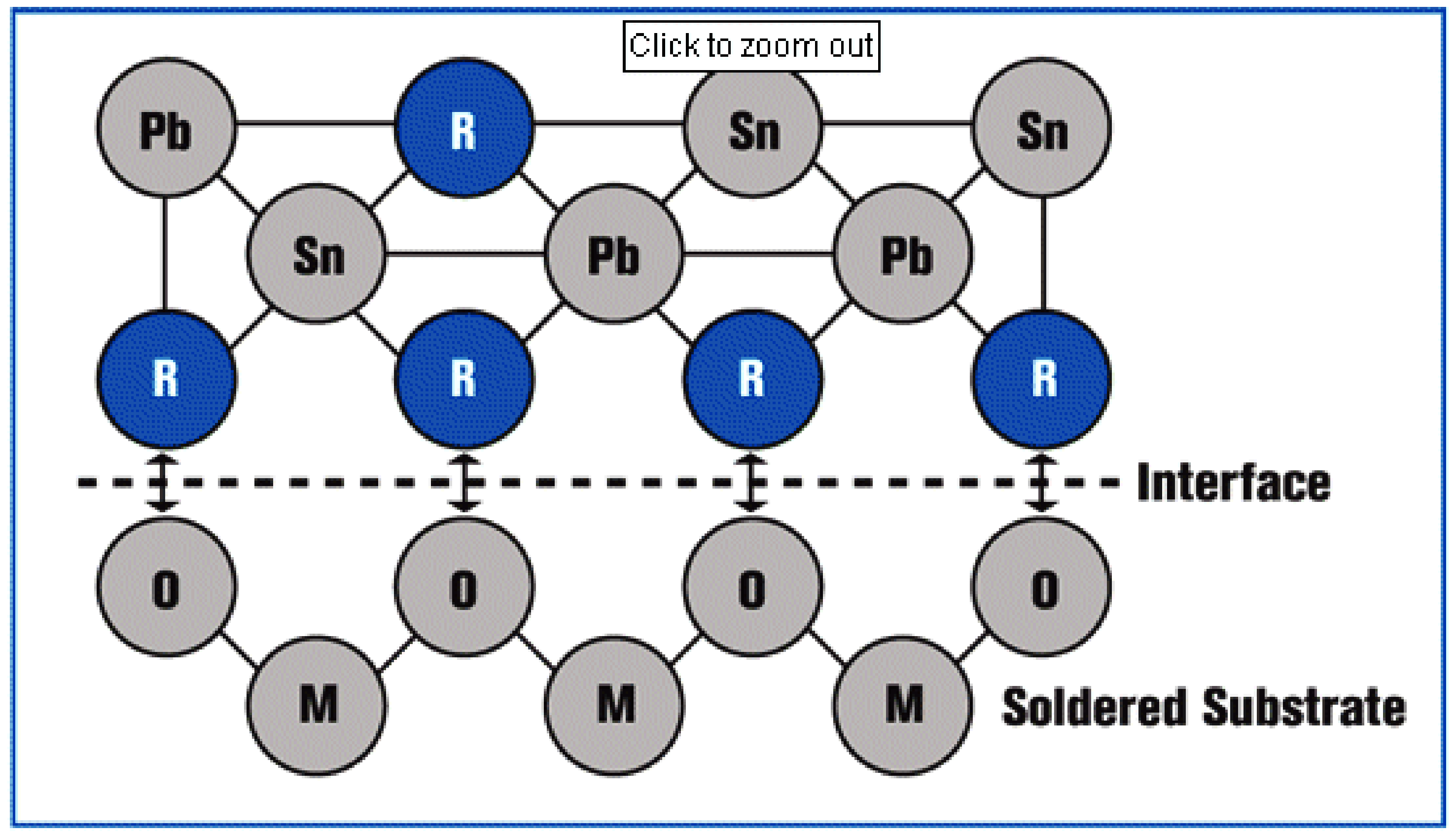
"In fact, if flux is applied with ultrasonic soldering, it will destroy the oxygen bonds," warns Ken Takahashi, president of Sanwa Components USA (San Diego).

Tin-lead solders are commonly used for easy-to-wet metals, such as silver, copper and nickel. Tin-silver solders are used on stainless steel, while tin-zinc and zinc-aluminum alloys are used on aluminum. Indium alloys are often used on glass and ceramics.

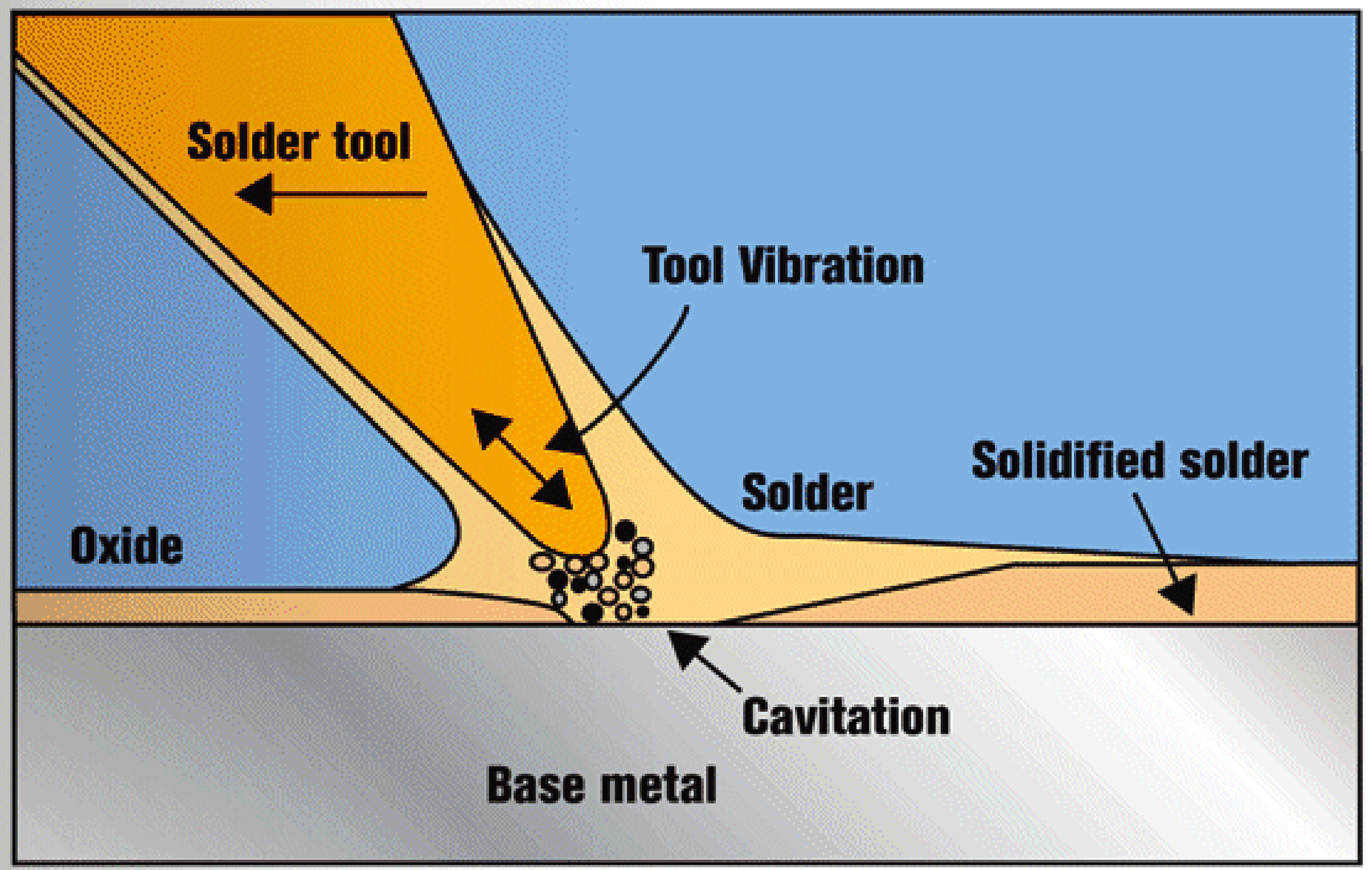
There are two methods of ultrasonic soldering: dip soldering and soldering with a handheld iron. In dip soldering, the part or parts to be soldered are partially immersed in a bath of molten metal. The ultrasonic transducer can be attached to the bottom of the crucible, or it can contact the molten metal directly.

In the manual method, the soldering iron looks and operates just like a conventional soldering iron, except that it also includes an ultrasonic transducer activated by a foot switch. The tip of the iron heats the parts and melts the solder wire. When enough solder has melted, the foot switch is activated and the tip vibrates at ultrasonic frequencies—55 to 60 kilohertz for a small iron or 37 to 43 kilohertz for a large one. For optimal results, operators should apply slight pressure on the tip. Large, heat-absorbing parts should be preheated prior to soldering.

Melting temperature of the solder ranges from 123 to 297 C, and lead-free formulations are available. For soldering with an iron, the filler metal is provided as wire either 1.2 or 1.6 millimeters in diameter. For dip soldering, the filler metal comes in bars of various sizes.



In ultrasonic soldering, the filler metal creates both a mechanical and a chemical bond to the surface of the part. The filler metal is primarily composed of tin (Sn) and lead (Pb). However, depending on the application, it can also contain trace amounts of aluminum, beryllium and other elements that have a strong chemical affinity with oxygen. During bonding, these elements combine with ambient oxygen to form oxides (R, O) that chemically bind to the substrate (M). *Source: MBR Electronics GmbH*



An ultrasonic soldering iron looks and operates like a conventional soldering iron, except that it also includes an ultrasonic transducer activated by a foot switch. The tip of the iron heats the parts and melts the solder wire. When enough solder has melted, the foot switch is activated and the tip vibrates at ultrasonic frequencies. The vibration induces cavitation in the solder, which breaks up and removes oxides and promotes wetting. *Source: Edison Welding Institute*

Benefits and Applications

With ultrasonics, assemblers can solder materials that are difficult or impossible to solder with conventional methods. The technology can be used on glass, including silica glass, crystal and soda-lime glass; ceramics, including silicon carbide and zirconium dioxide; hard-to-solder metals, including aluminum, stainless steel and titanium; and metal oxides, including aluminum oxide and magnesium oxide.

"Ultrasonic soldering lets you solder materials that ordinarily couldn't be soldered," says Dunn.