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Ultrasonically Enabled Low Temperature Electroless Plating for Sustainable Electronic Manufacture

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Abstract

Electroless copper plating is an important process for the metallization of non-conductive substrates and is therefore widely utilized throughout the electronics industry. Electroless processes are characterised by high temperature operation and although the effect of ultrasound on electroless plating has been studied for many years, its use as an enabling technology to reduce the electroless plating operating temperature has not been investigated. In this study a catalysed electroless copper process was utilized and it was found that the use of low frequency ultrasound under optimised conditions can lead to a reduction in electroless copper plating temperature.

Introduction

Printed circuit board and printed electronics manufacture both use electroless plating extensively and it is also an important process for surface mount assembly and waveguide production. Electroless processes are characterised by high temperature operation since this has been found to be the main factor in achieving acceptable plating rates (electroless nickel, 80-90 ºC and electroless copper, 30-70 ºC). However, to reduce energy usage, manufacturing costs and improve sustainability, methods to lower these process temperatures need to be investigated. One technology with great potential to achieve this is ultrasound. The use of ultrasound to enable low temperature electroless and immersion plating processes is a novel concept that has not previously been investigated. Acoustic cavitation will induce microjetting in an electrolyte and this can affect electrochemical processes through thinning of the Nernst diffusion layer[1] and improved mass transport[2]. Thus in electroplating processes ultrasound can influence responses such as the limiting current[3] and throwing power[4] as well as the morphology and mechanical properties[5] of the deposit. Electroless plating is also an electrochemical process but in contrast to electroplating no external current is applied. The object to be plated is often non-conductive and is ‘catalysed’ using a palladium or platinum colloid. When the catalysed object is placed in the electroless solution a reducing agent is oxidized which releases electrons that are used at the cathodic sites to reduce the metal ions in solution to deposit metal. Many electroless processes have to be operated at high temperatures are required to achieve acceptable plating rates. There have been several studies on the use of ultrasound on electroless processes which have shown that its employment can increase plating rates[6]. A full review of the use of ultrasound in electroless plating has been written by Cobley and Saez[7]. However, all previous studies on the use of ultrasound with electroless plating processes have studied them at their normal operating temperatures and have not investigated whether ultrasound can enable low temperature operation. Initial studies by this group[8] have shown some promising results when ultrasound was applied to an electroless nickel formulation. However in this study ultrasound was applied to a catalysed electroless copper process and its effect on the plating bath operating temperature was determined.

Experimental

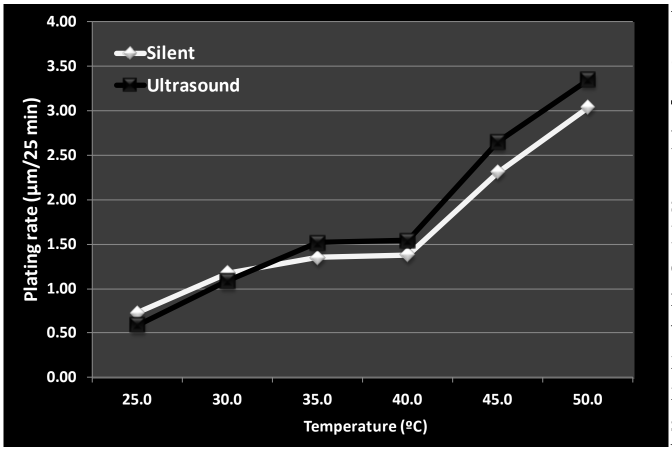
A commercially available electroless copper (Circuposit 3350-1) was utilized for these experiments. The plating rate was determined by the ‘weight gain’ method whereby test coupons of a bare PCB laminate material (Isola Duraver 104) with dimensions 2.5 cm X 2.5 cm were first dried in an oven at 120 ºC for 24 hours and weighed. They were then processed in the electroless copper pre-treatment line. This involved conditioning (or functionalising) the materials before immersing them in a palladium-tin colloidal solution. The electroless copper solution is described as ‘self-accelerating’ and is designed to remove the tin from the colloid, exposing the palladium which acts as a catalyst for the electroless copper deposition reaction. At this point the coupons were divided into two lots. One lot was processed in the 3350-1 electroless copper solution under ‘silent’ conditions i.e. with only a magnetic stirrer to provide agitation. The other set of coupons were plated in an electroless copper solution which was immersed in a 40 kHz ultrasonic bath. In both cases the test coupons were plated for 25 minutes. They were then dried again at 120 ºC for 24 hours and weighed allowing the plating rate to be calculated from the weight gain. In this way the plating rates of the electroless copper solutions were determined at a range of temperatures from 25-50 ºC with or without sonication.

Results and Discussion

As would be predicted, the main effect on plating rates was found to be the temperature of the electroles copper solution (Figure 1). Ultrasound only had a slightly positive effect on plating rate at 35 ºC and above but at lower temperatures the plating rates were either similar or lower.

As described above, the pre-treatment for the epoxy coupons used in these experiments incorporated a palladium/tin colloidal catalyst.

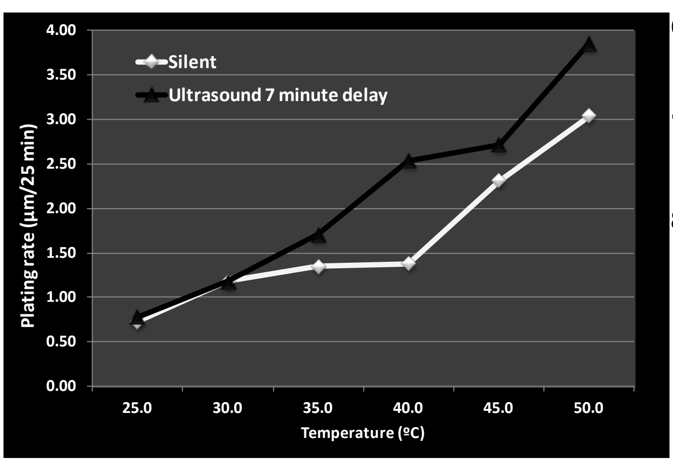
Figure 1. Effect of temperature and sonication on electroless copper plating rate.



It was thought that ultrasonically induced microjetting might be scrubbing the catalyst from the surface of the test coupon resulting in a poor plating rate. As the plating rate was slow at low temperatures the palladium catalyst would be exposed for longer and more prone to be 'knocked' off due to the effects of the ultrasonic field. At higher temperatures the catalyst would be rapidly covered by the electroless copper deposit which would prevent it from being removed by the sonication and the beneficial effects of ultrasound would be realised.

To test this theory a 'delay' time was introduced before the ultrasound was turned on. It was hoped that this would allow time for the Pd colloid to become coated with copper and thus prevent it being knocked off, of the substrate by ultrasonic microjetting. It was found that a 7 minute delay before turning on the ultrasound was optimal and Figure 2 shows that enhanced plating rates were now observed at most temperatures.

Figure 2. Effect of temperature and sonication (7 minute delay) on electroless copper plating rate.



This was particularly true at 40 ºC where the plating rate using ultrasound (with the 7 minute delay) is higher than under silent conditions at 45 ºC and is beginning to approach the plating rate under silent conditions at 50 ºC. It seems likely that the delay time allows the catalyst to become coated with copper which protects it from being scrubbed off, of the surface by ultrasonically induced microjetting.

Conclusions

This study has indicated that when ultrasound is applied at 40 kHz the plating rates are generally reduced compared to 'silent' (stirred) conditions at low temperature and only slightly enhanced at higher temperatures (35 ºC and above). Introducing a 7 minute delay before the ultrasound is switched on improves the results particularly at 40 ºC where plating rates are higher than under silent conditions at 45 ºC and begin to approach those recorded for the stirred bath at 50 ºC. There is strong evidence that this effect is due to ultrasonically induced microjetting scrubbing the palladium catalyst from the surface of the substrate. The delay time allows the catalyst to be covered by copper thus protecting it from the microjetting when ultrasound is turned on.

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