SHORT COMMUNICATION

The Effect of Thin Film Deposition Angle and Substrate Surface Roughness on Film Dissolution in Molten 60% Sn–40% Pb Solder

L. J. RICKABAUGH

Bell Telephone Laboratories, Incorporated, 555 Union Boulevard, Allentown, Pennsylvania 18103, U.S.A.

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Thin film conductor dissolution rates in 60% Sn – 40% Pb solder have been shown to be related to substrate surface texture.¹ This paper summarizes work to show that “shadowing” phenomenon resulting from a combination of ceramic substrate surface texture and film deposition angle causes film “islands” which influence the dissolution process. These islands, more predominant in thin *evaporated* films than *sputtered* films, dissolve rapidly since their dissolution occurs from the sides as well as the top surface. The use of both glass and ceramic substrates (smooth and rough surface texture respectively), several film deposition angles, and composite film depositions indicate that thin film dissolution in 60% Sn – 40% Pb solder is indeed dependent on substrate surface texture.

Conductor film consisting of a 1200 Å thick D.C. sputtered tantalum nitride film followed by subsequent layers of evaporated Ti and Pd (1800 Å each) were deposited on ceramic and glass substrates. These films were deposited using three deposition angles;

24, 48 and 70 degrees.² Deposition angle or angle of incidence is the angle formed between the path of the impinging metal atoms and a normal to the substrate surface. The evaporation equipment used was characterized at each deposition angle to minimize run-to-run film thickness variations.

Since the “float method”¹ was used for dissolution rate determination, the metallized substrates were patterned and separated into 1in x 1in coupons as shown in Figure 1. All metallized coupons were subjected to a PdO reduction process to enhance solderability and reduce the error in determining dissolution rates. Auger Electron Spectroscopy was used to verify that the process actually reduces the PdO layer. Figure 2 shows a typical Auger spectra for coupons that were metallized at each of three deposition angles and subjected to the PdO reduction process. The presence of only a minimal oxygen peak in conjunction with the normal peaks for Pd indicate that the reduction process was indeed effective.

Each 1in x 1in coupon was placed on a molten solder reservoir, metallization side up, and a sufficient amount of mildly activated water white rosin base flux was applied to the patterned Pd film surface. A 60% Sn – 40% Pb solder preform in the shape of a solid hemisphere was placed on the Pd film and as it melted, flowed around the patterned ring. (See Figure 1a.) The dissolution time interval was initiated when the solder preform first showed signs of melting and wetting the Pd metallization, and was terminated when signs of dewetting occurred along the pattern edge. (See Figure 1b.) A short time later the Pd film was completely dissolved in the solder as shown in Figure 1c. Dissolution time was recorded for two coupons from each of the three deposition lots. Average dissolution time for coupons with identical deposition angles was used in conjunction with the

FIGURE 1 Film dissolution sequence of annular ring pattern.

FIGURE 2 Typical Auger spectra for film subjected to the PdO reduction process.

measured Pd thickness to calculate dissolution rate as follows:

$$\text{D.R.} = \frac{t_{sf}}{t_{dAvg}}$$

where:

D.R. = Dissolution Rate (Å/sec.)

t_{sf} = Soluble Film Thickness (Å)

t_{dAvg} = Dissolution Time Average (sec.)

The calculated dissolution rates are tabulated in Table I and are presented graphically in Figure 3.

TABLE I
Ceramic coupons

Deposition angle	Dissolution time (sec)			D.R.
	t_1	t_2	t_{Avg}	
24°	20.4	31.1	25.75	69.9
48°	10.5	10.2	10.35	113.91
70°	6.6	7.6	7.1	253.51

These results clearly indicate that a significant increase in dissolution rate occurs as the deposition angle increases. Samples were then analyzed by scanning electron microscopy (SEM) to verify that the increase in dissolution rate is a result of film "island" formation due to substrate surface texture and film deposition angle. Both contribute to film "island" formation. Photomicrographs of film deposited on ceramic coupons at 24° and 70° deposition angles are shown in Figure 4. The arrows in both photomicrographs indicate the path of evaporated metal atoms during film deposition. The light areas (areas of charging due to the SEM incident electron beam) indicate poor metal film coverage due to "shadowing". The samples deposited with a 70 degree deposition angle result in pronounced shadowing, hence "island" formation.

Since shadowing is most predominant on ceramic coupons due to the rough surface texture, the dissolution rate of identical evaporated films on a relatively smooth surface such as glass should not change significantly with deposition angle. The dissolution rate experiment was therefore repeated with identical films deposited on 7059 glass coupons. The dissolution rate results are presented in Table II. As expected, the

Pd DISSOLUTION RATE AT 200°C

FIGURE 3 Dissolution rate as a function of deposition angle for ceramic and glass coupons.

FIGURE 4 SEM micrographs showing film coverage variation as a function of deposition angle for ceramic coupons.

TABLE II
Glass coupons

Deposition angle	Dissolution time (sec)			D.R.
	t_1	t_2	t_{Avg}	
24°	29.9	32.4	31.15	57.78
48°	28.2	21.2	24.7	72.87

large difference in dissolution rate between 24 and 48 degree deposition angles as previously measured on ceramic (see Table I) was not observed for the same films deposited on glass. In fact, the slight difference in dissolution rate for film deposited at 24° and 48° can be attributed to experimental error.

Based on the dissolution rate data of evaporated Pd film on both ceramic and glass coupons, it is concluded that dissolution rate varies directly with the deposition angle on ceramic coupons. This result is explained by a "shadowing" phenomenon primarily due to the ceramic surface texture but enhanced by the film deposition angle. SEM photomicrographs verified that an increase in deposition angle leads to increased "island" formation in evaporated film. Since "islands" dissolve more quickly than continuous film, the dissolution rate for this film is quite high. To

verify that the change in dissolution rate is due primarily to "shadowing" as a result of substrate surface texture, the experiment was repeated using identical film deposited on relatively smooth 7059 glass. Dissolution rate data for these samples indicate that the dissolution rate dependence upon film deposition angle is insignificant when compared to that obtained for ceramic samples.

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