DRY FILM PHOTORESIST PROCESSING TECHNOLOGY

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SAMPLE PAGES

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PRELAMINATION SURFACE PREPARATION

6.1 PRINCIPLE

The copper surface's chemical composition and topography are prepared for optimal dry film adhesion and subsequent clean release. The surface preparation can be by a mechanical, chemical or electrochemical process, or a combination thereof. Processes will vary depending on the type of copper surface to be prepared (e.g., vendor copper, electroless copper; or electroplated copper). Surface preparation processes typically roughen the surface to increase film contact area and they remove chemical impurities, antitarnish coatings, or oxides which could interfere with film adhesion.[134-137]

6.2 CRITICAL VARIABLES

Film contact area and chemical composition of the copper surface are critical variables.

Contact area is normally not measured. It is a function of the copper topography, film thickness and flow characteristics, and lamination conditions.

Copper topography has been optimised empirically in a variety of mechanical and chemical processes. For example, in brushing operations, brush construction, grit, pressure, brush foot print etc. have been recognised as important variables. Likewise, for pumice operations, pumice type, size, spray pressure etc. are known to affect copper topography. Attempts have been made to correlate surface profilometry values such as R_z or R_a with desirable topographies. Non-contact profilometry (optical interferometry) has been used to quantify the total surface area.

Chemical composition of the copper surface can be measured by sophisticated analytical techniques such as Auger, ESCA or FTIR. However, these analyses are not in use as process controls but rather serve as tools in the development and characterisation of surface preparation methods. Chemicals to be removed from the copper surface are usually organic contaminants, antitarnish coatings, or excessive copper oxide. A 'water break test' will give some indication of the presence or absence of hydrophobic contaminants. Other tests use the inhibition to a chemical reaction at the surface of the copper as indicator for the presence of a surface contamination ('inhibition tests'). Examples are tests to check for the presence of chromate

Also, spray pressure is a critical variable. Compressed pad brushes create finer debris than bristle brushes, which needs to be removed from the surface and the through-hole. The recommended spray pressure is 10 bar (about 150 psi). Lower spray pressure (2 bar; about 30 psi) is acceptable for nylon bristle brushes. Finally, it should be mentioned that all brushing processes share a common detriment that becomes critical with very thin innerlayers and fine line design: the brushing action stresses the copper and distorts thin laminate. The stressed copper panel then gets laminated, imaged and developed. When the board is then etched, the copper stress releases (snaps back) to yield a distorted circuitry image, which leads to registration problems. This phenomenon becomes significant at a total board thickness of approximately less that 0.2 mm (8mil).

6.11.2 Pumice, Aluminium Oxide, Quartz (Hand Applied, Jet Applied, Brushed)

Pumice

The cluster of processes covered in this section is often loosely referred to as 'pumicing'. This can lead to misunderstandings because, depending on the type of scrubbing material in use and the mode of application, different results are achieved and different variables need to be controlled. The commonality of these processes lies in the use of 'loose' grit, suspended in a slurry, compared with 'stationary' grit particles impregnated on to brushes.

The word pumice is sometimes used as a generic term for a variety of abrasive materials whether they are chemically pumice or not. Pumice is a complex silicate (Figure 6.37) of varying composition and structure depending on where it is mined. The most commonly used pumice is mined on the small island of Lipari off the shore of Italy.

Chemical Analysis

SiO_2	70.90
Al_2O_3	12.76
TiO_2	0.14
Fe_2O_3	1.75
FeO	0.64
MnO	0.09
CaO	1.36
MgO	0.60
Na_2O	3.23
K_2O	3.83
P_2O_5	0.015
CO_2	0.04
SO_3	0.21
H_2O^+	3.88

Spectrogram

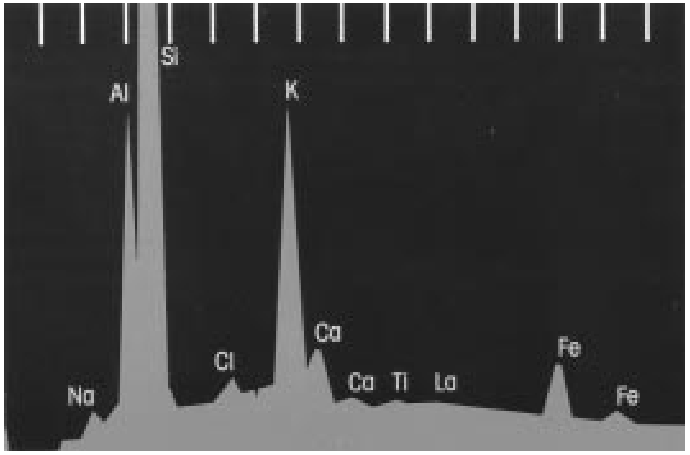


Fig. 6.37 Pumice chemical composition.

The pumice is ground (Figure 6.38) and used as is ('unfused') or heated ('fused') to yield harder particles (Slide SP62). Pumice mined in the US is normally Navajo pumice and is typically fused. Pumice comes in many grades. The most common are 3F and 4F, and the average particle size is about 60 micron (Figure 6.39). Occasionally, pumice powder is supplied premixed with an antitarnish, e.g., citric acid. Pumice powder containing citric acid will create a shiny, untarnished copper surface when sprinkled on a board. Pumice was first used in the surface preparation of circuit boards in the form of 'hand pumice', i.e., a pumice slurry is applied to the board through a hand-held rotating brush. This technique is very effective in cleaning as well as structuring the surface, but it is time consuming, not automated, and lacks the uniformity across larger surfaces that is desirable and that automated processes yield. The automated version of hand pumice is the brush pumice machine. Here pumice slurry is sprayed on the board as it moves through the spray module in a conveyorised mode.

Fig. 6.38 Pumice powder and brush. (Courtesy of U. Aiassa (I.S.))

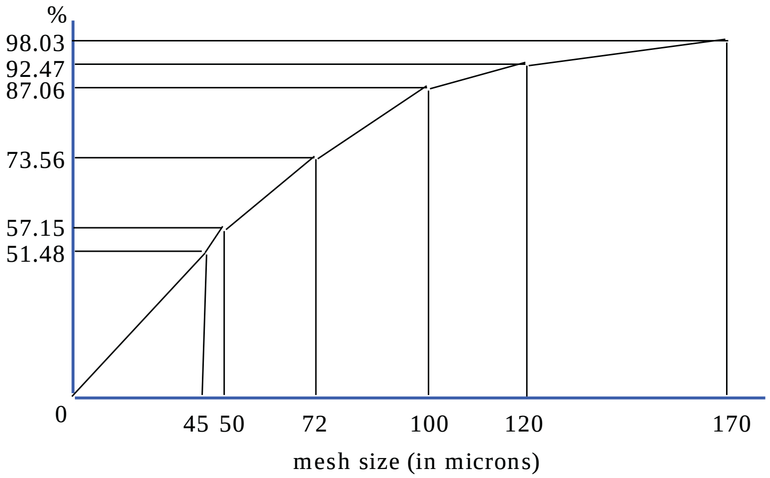


Fig. 6.39 Pumice – particle size distribution.

Soft rotating nylon brushes provide the abrasive action. Brush height can be adjusted for optimal pressure to give a 1/4-1/2 inch footprint (nominal 3/8 inch). The process is not very sensitive to too much brush pressure since the brushes are very soft. However, not enough brush pressure will yield a poorly structured surface. Early machine designs were flawed with leaking pumice slurry and insufficient rinsing. They would 'self-destruct' by abrading seals, nozzles and other structural elements. Improved designs are now available. They feature ceramic nozzles, and have better designed shielded, back flushing seals. Still, high pressure rinsing (10 -20 bar; about 150-300 psi) and rinsing assisted by brushing are very critical to remove pumice particles embedded in the surface of the board. The slurry concentration should be maintained at approximately 15% solids; the average particle size should be about 60 microns. During use, pumice particles wear and create fines. Since this reduces the abrasive action, the slurry has to be replenished with fresh pumice. The slurry is sampled into a graduated cylinder and is allowed to settle for half an hour before the percent solids by volume is determined. If percent solids are low, manual additions of fresh pumice powder will bring the percent solids in the desired range. Particle size and percent solids are usually indirectly controlled by empirically establishing a 'dump schedule': pumice slurry is batched up, there are no adjustments during use, and after a certain time interval (e.g., one shift) or a certain panel throughput (e.g., 1500 panels), the slurry is dumped and rebatched.

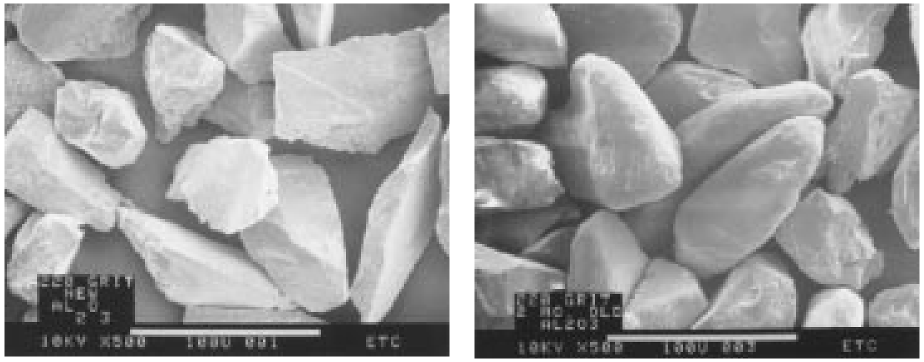
Pumice can undergo a slow hydrolysis in an aqueous slurry, that is, it reacts with water generating traces of sodium hydroxide and potassium hydroxide so that the pH slowly increases. Depending on the grade of pumice and the slurry life, this effect may or may not be noticeable. If this pH drift is noticed, it is recommended to make pH adjustments with citric or sulphuric acid to maintain the slurry pH between 5 and 7. This is a precaution to avoid alkali slowly building up in the rinses and traces of alkali staying on the board, acting as a stripper.

Jet pumice machines are distinctly different from brush pumice machines in design and in their effect on the copper surface. The conveyorised boards move through a spray module where a pumice slurry (about 15% solids) is sprayed on the bottom side of the board through spray nozzle manifolds, one board side at a time. As there are no brushes involved in this process, there is hardly any abrasion of the copper, except for very loosely held oxide layers. The pumice particles structure the copper surface in a 'hammering' action. Therefore, surface impurities should be chemically removed before jet pumice processing so that these impurities are not just beaten around and into the soft copper by the pumice action. Most jet pumice machine manufacturers recommend the use of non-fused (softer) pumice to avoid excessive wear on the machine. A good portion of these non-fused pumice particles disintegrates upon hitting the copper surface. Some manufacturers claim an inherent advantage of using non-fused pumice. As with brushed pumice, high pressure rinses are necessary after jet pumice. Control of percent solids, particle size distribution and pH is similar to that described under brush pumice.

Aluminium Oxide

A variation of a jet 'pumice' machine is offered by Hyoki (Japan). It is also referred to as 'jet brushing'. A slurry of aluminium oxide (Al_20_3) – 'pumice' is a misnomer here – is sprayed on the board in a conveyorised machine that looks very much like a jet pumice machine. IS (Italy) also offers a modification of its pumice brush machine to accommodate aluminium oxide (see Reference 170). According to this reference, brushing of aluminium oxide gives a rougher, more preferred surface than jetting. There are also data indicating that jetting distorts (elongates) thin copper foil more than brushing. If jet pressure is lowered to counteract this phenomenon, there may be a problem with insufficient surface roughening due to reduced particle impact.

Aluminium oxide does not disintegrate to fines as rapidly as pumice. The working Al_20_3 slurry settles readily and % solids determination is quickly accomplished by sedimentation in a graduated cylinder. As judged by the particle size distribution, aluminium oxide lasts much longer than pumice. There is less maintenance, downtime, and sludge disposal. On the other hand, aluminium oxide particles become 'rounded' with time (Figure 6.40). The particles become smoother, 'peening' the copper, and creating a smoother surface that is detrimental for dry film adhesion. Thus, aluminium oxide needs to be replaced before fine particle build-up suggests that replacement is due. A study was made of the correlation between aluminium oxide particle shape, use time (throughput), copper surface roughness (R_a), and resist lifting as an indicator of poor adhesion because of insufficient surface roughness.



Fresh Aluminium Oxide

Two Month Old Aluminium Oxide

Fig. 6.40 Effect of age on Al_2O_3 media.

The first board sample represented processing with a fresh charge of aluminium oxide medium after jet nozzles had been replaced. Additional sample panels were cleaned at different times during the life of the medium. The next three panels represented one week's use of the aluminium oxide particles, one month, and two months respectively. The monthly throughput of the jet spray machine was roughly equivalent to 60,000 panels, corresponding to about 2,700 square metres of surface area.

Resist lifting on panels processed through the one week and one month old alumina slurry was similar to those processed through fresh slurry. But after two months' use of the aluminium oxide slurry, an increase in lifting was

The process of choice that accomplishes these tasks appears to be brush scrubbing with 500-grit compressed pad brushes or brush pumice (Figure 6.49). There are, however, limits to the brushing of electroplated surfaces. If the electroplated surface belongs to a very thin innerlayer (with buried vias), then brushing may distort the thin material. *Chemical cleaning* is not a good alternative to brushing because the *very smooth plated* surface is *not sufficiently roughened by the micro-etch*. Electroplating a *matte copper surface* may offer a solution. Preceding the brushing of the panel plated surface, it is customary to 'de-nodule' the plated surface. These nodules are small protrusions of plated copper or foreign material overplated with copper. If left on the surface, the copper nodules will cause defects in fine line tent & etch applications. The removal of the nodules is often accomplished with a mechanical polishing operation such as a belt sander.

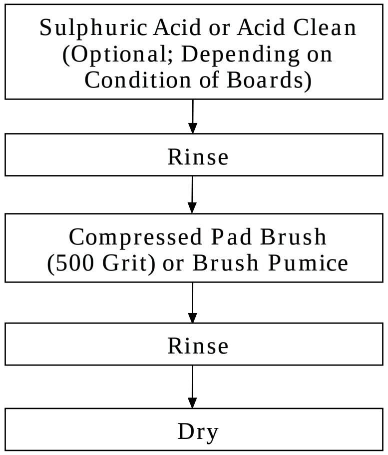


Fig. 6.49 Surface preparation process for electroplated copper.

6.13 CRITICAL SURFACE PREPARATION VARIABLES AND PROCESS FEATURES

See tables on following pages.

VARIABLE OR FEATURE	RANGE/ SPEC.	PRECISION	PROCESS EFFECT	TEST METHOD (FREQUENCY)	CONTROL METHOD
Surface Prep. Example #1: Acid Cleaning					
Acid (or Acid cleaner), Conveyorised, Spray: Concentration	5-20% Spec: Supplier's recommend.	+/- 2%	• Removal of oxides • (Partial) removal of antitarnishes, conversion coatings • (Partial) removal of organics	• Titration,e.g., 0.1N NaOH (daily)	• Acid (acid cleaner) addition or DI water addition or • Throughput based: panel counter and dump schedule or • Based on time elapsed (e.g., weekly dump, regardless of throughput)
Cleaner temperature	RT-60°C Spec: Supplier's recommend.	+/- 2°C	Higher temperatures cause more aggressive cleaning	Hand thermometer (weekly)	Thermocouple: heater on/off; high/ low temp. alarms
Cleaner Spray Time	1-3 minutes		Degree of cleaning, oxide and antitarnish removal	Timing of conveyor speed (weekly)	Conveyor speed adjustment
Cleaner spray nozzle type & array (e.g., cone, fan)	Depending on equipment design		Spray impact, uniformity, and coverage pattern	Visual check for clogging (daily)	N/A
Cleaner spray pump pressure	15-30 psi (about 1-2 bar)	+/-20%	Spray impact, cleaning rate	Visual pressure gauge check	High/low pressure alarms
Rinse temperature	60-80°F (about 15-26°C)	+/-2°C	Rinse is more effective at higher temperature	Hand-held thermometer (daily)	Thermocouple: heater on/off; high/ low temp. alarm
Rinse pressue	15-30 psi (about 1-2 bar)	+/-2°C	Spray impact., rinse rate	Visual pressure gauge check	High/low pressure alarms
Drying (temp., time, air flow rate)	Depending on board type				

Surface Prep. Example #2: Pumice (or Aluminium Oxide) Brush or Jet Scrubbing

VARIABLE OR FEATURE	RANGE/ SPEC.	PRECISION	PROCESS EFFECT	TEST METHOD (FREQUENCY)	CONTROL METHOD
Grit type: size (freshly charged)	3F or 4F Fused pumice for brush; unfused for jet		Coarser grit yields rougher surface; chance of entrapment in through-holes; smaller particles have less surface impact	None	None
	With or without citric acid additive (per resist processing recommend.)		Citric acid additive slows retarnishing; also neutralises small amounts of alkali from pumice/ Al_2O_3 hydrolysis	Appearance of copper surface after contact with wet pumice	None
Particle size	Pumice: average about 60 micron (Al_2O_3 slightly larger)		See above	None (Vendor may test with classifying sieves or laser dry dispersion analysis)	Indirect control for removal of fines by solids replenishment and rebatching Fines are more likely to be dragged out and removed by cyclone; % solids maintained by addition of fresh grit Also: Rebatching of pumice after 1500-2000 panels. Rebatching of Al_2O_3 after 102 months

Surface Prep. Example #2: Pumice (or Aluminium Oxide) Brush or Jet Scrubbing (cont. 1)

VARIABLE OR FEATURE	RANGE/ SPEC.	PRECISION	PROCESS EFFECT	TEST METHOD (FREQUENCY)	CONTROL METHOD
Particle shape	Irregular, with sharp corners and edges		For best micro-roughness of surface	Pumice: none required. Indirect control: through normal replenishment Al_2O_3: particles wear 'round' Test: eg., SEM of particles Or: indirectly through R_z, R_a surface measurements (e.g., 2 X/month)	Pumice: see replenishment Al_2O_3: in addition to normal solids replenishment, establish a dump schedule (e.g., monthly, bimonthly) according to dry film adhesion performance history
Solids concentration	10-20% (typically 15%)	Normal	% Solids are chosen to maximise surface structuring: lower % solids reduces number of impacts; higher solids reduces flow speed and impact	Sedimentation in graduated cylinder (twice per shift)	Addition of fresh grit (or water) Or: Automatic rebatch after a certain board throughput
Brush pressure (N/A for jet)	Indirectly specified: 6-12 mm (1/4-1/2 inch) 'footprint'		High brush pressure may cause nylon smear; low pressure will reduce scrub efficiency	Footprint check (daily, or per lot, or upon laminate thickness change – whichever comes first)	Brush clearance adjustment

(Cont.)