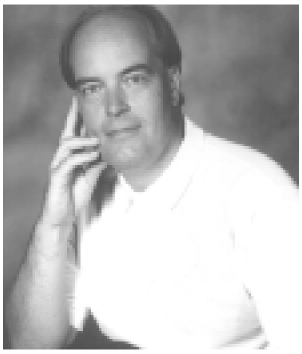
Solder Paste Stencils What Are The Options?



Stencils for Solder Paste printing are now a common commodity in the market place but what is available and what are the choices. Which are best and what are the advantages and disadvantages of each type. Here is your opportunity to find out for yourself and make the correct choice for your future production operation.

Brass Stencils

This used to be the most extensively used stencil material but in some areas this has changed to steel. The advantage of the material is that it is easy to etch and is readily available in the standard stock thickness required for the printing of Solder paste.

Brass is etched from both sides at once. This is done in order to avoid the opening in the stencil being much larger at one side of the aperture than at the other. The reason for this is that the etch system is a chemical milling process, and is done using an etch resist to expose the areas in the surface to be removed. The etching fluid fills the pattern in the mask which will end up as the stencil apertures and starts to etch its way through the metal.

Unfortunately however, because the top of the brass is contacted for a longer time than the bottom, apertures formed in this way are tapered from top to bottom, and are in fact larger than the original artwork. For this reason, the etching is done from both sides of the brass at once in order to minimise the effect. Control of the etch solutions, temperature of the etching agents and the effectiveness of the spray application can have a major effect on the quality output from a stencil supplier. The basic materials used can also affect the quality of the etching process.

In addition to the brass being chemically milled from both sides at once, the artwork is modified before use by the designer or stencil manufacturer, in order to make the artwork aperture smaller to compensate for the etching effect. This means that the apertures in the stencil will eventually be the size of the apertures in the aperture list.

If artwork is supplied to stencil suppliers it will normally be a 1:1 of the final printed board pad layout. In order to make this smaller, the stencil manufacturer puts the artwork through a process known as "wobbling" or micro modification. This is a photographic process which reduces the pad size but has the effect of rounding off the corners on square aperture pads.

In order to avoid this effect with very fine pitch devices, it is possible with some laser plot bureaus to have them compensate for the etch at the laser plot stage, and actually plot the pads smaller. The stencil supplier can of course also provide this service provided the design engineer has not already taken this into consideration on the artwork otherwise pads will be compensated twice and end up too small for printing.

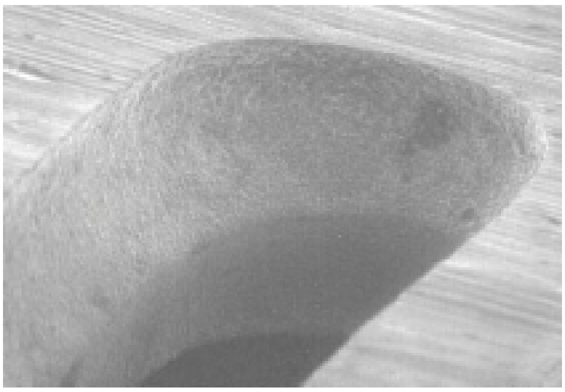
The advantage to this approach is that the artwork is modified, but the corners of the stencil pad apertures do not get rounded off. Over the years different viewpoints have arisen, in many cases not substantiated by scientific evaluations. The difference between rounded and square apertures has never been demonstrated to be a problem. The main issue is the visual appearance of the deposit after reflow. If you have a square pad and a rounded stencil aperture there may be evidence of no wetting on the corner of the pad. This will be due to the wetability of different surface coatings and the lack of paste in this area. It is not going to affect the reliability of the solder joints.

On stencils, there may have to be some allowance for a mixture of technologies on the board. Different pitches may require different volumes of paste. The classic answer to this is to differentially etch the stencil. In a board with a mixture of technologies, this would mean that a typical stencil thickness may be 0.006" in one area for 0.020" pitch devices and 0.008" thou overall thickness, to allow for the 0.050" surface mounted devices.

On the fine pitch devices the top of the stencil is locally etched away around the whole component footprint thereby locally reducing the stencil thickness from the squeegee side. This works fairly well, but generally, around 3 - 5 mm clearance is needed around the fine pitch component. The reason for this is that the localised reduction in thickness has to be larger than the component in order to allow the squeegee blade sufficient travel to settle into the locally reduced cavity in the stencil. In most modern designs this clearance around a fine pitch device is actually not possible, since the whole idea of using fine pitch in the first place is generally to increase the packing density of the circuit. There is another answer that works well with both 50 thou surface mount and fine pitch packages, and once again the answer is in the original designers software before this is laser plotted.

For a fine pitch surface mounted or TAB device it is feasible, and perfectly acceptable, to reduce the amount of solder paste locally by reducing the cross sectional area of the stencil aperture. This can be done most readily by reducing the size of the pads on the footprint on the CAD system for the solder paste artwork only. Alternatively, some laser plot bureau's are able to handle this requirement at the plotting stage. However, since it is a part of the board design, it is better to lay down these rules as part of the CAD system library for these components since that way there can be no question of whether the artwork needs modification or not.

In practice a 25% overall cross sectional reduction is best for devices at a pitch of around 0.025", and 0.030" to 35% for pitches lower than this. This means in effect that if we have a pad with a length of say 1.5 mm and a width of 1 mm, then for a 25 thou pitch device the artwork for the paste deposition would have the length of the pad reduced by 25% overall. This reduction should be done equally from both ends of the pad by taking 12.5% from each end. This would give us an aperture that, although smaller, is still on the original geometric centre of the pad but with a dimension of 0.5mm across the pad, and a length of 1.125 mm as opposed to the original 1.5 mm. This practice can be applied to any data that is destined for stencil manufacture for solder deposition on fine pitch devices.

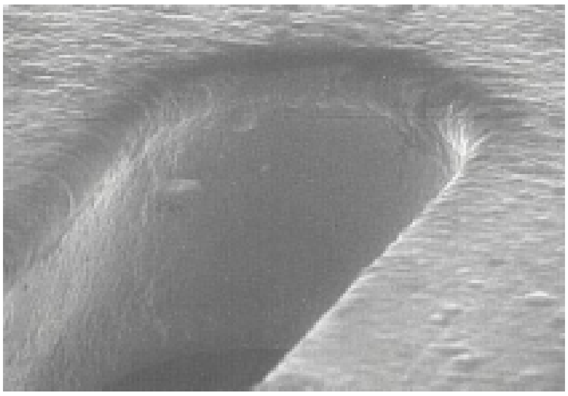


SEM view of stencil produced with the etched brass centre section pronounced. Most etching companies do not produce etched stencils like this any more, at leased the good ones do not.

Nickel plating after etching.

The Nickel plating, is said to give a smoother wall to the aperture, and for this reason, a cleaner break out of the paste from the stencil when it is separated from the board. Viewing the aperture walls the use of this technique does improve the appearance and reportedly the paste release due to the lower friction forces. The nickel does not, however, overcome poor etching process due to the thin coating applied. The quality of the aperture must be of the highest quality before nickel plating. In the paste the nickel has also been promoted to reduce oxides from the brass surface affecting the paste and causing problems of solder balling, this has never been proved.

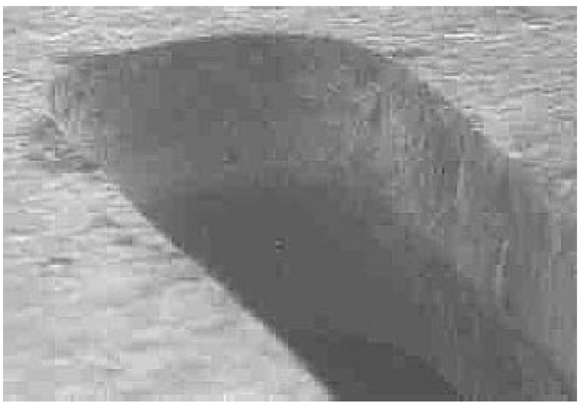
Care should be taken when evaluating any stencil surface for print compatibility; paste has been seen to skid across a surface rather than roll in front of the blade as a bead. Both nickel and stainless steel masks have suffered from this problem if the combination of paste and stencil are not considered together. Both materials may have a very smooth surface with lubricative qualities which can aggravate paste skidding.



Nickel plating can over come minor surface imperfections but a few micron can not over come under or over etching.

Stainless Steel

Stainless steel can be used for etched stencil manufacture, and all of the comments about artwork modification in the above paragraphs on the subject of brass apply. One thing to note however, is that brass is a fairly ductile material, and in use will coin to take up any localised board imperfections which will result in an intimate contact between the stencil aperture and the pad surface. In the case of stainless steel, however, this is not the case, and as such it is a very unforgiving material when used in a printer that has even the slightest of coplanarity problems.



Basically coining is the gradual distortion during use of the metal stencil. It will take up any uneven surfaces of the board and printer support table or tooling and leave a permanent mark. Examples of coining are:

The edge of the board when not supported by an edge plate
Any large cut outs in the board or on multi panels
Tooling pins protruding through tooling holes
Uneven plating or domed tin lead on large circuit ground planes

It is fair to say, however, if you use too much squeegee pressure you will always get coining on the metal stencil. There are some company technicians in high volume applications like their coined stencil so much that it is sent back for occasional remounting if damage occurs to the mesh or frame. The perfect coining to the particular board design provides a better gasket to the board surface during printing. It is effectively worn into the design.

Copper

Copper foil has been used for stencil production in the Far East and is normally always plated with nickel to provide a harder working surface equal to or harder than brass. It is available in a wide range of stock sizes. Copper has been used due to ease of etching fine apertures. It is, however, easily damaged during handling at the stencil manufacturing stage and in assembly and should be avoided. Its use is uncommon in Europe and the United States.

Molybdenum

Molybdenum often referred to as just "Moly" due to the difficulty of the pronunciation is a further choice in the base materials for stencils. The metal has been popular mainly in United States with very little interest in Europe. It is fairly easy to etch, producing very well defined apertures for fine pitch printing. The main concern in the use of Moly from the stencil supplier is the etching process chemistry. The process employs the use of etching solution which raises some further health and safety issues unique to the process. It is also an expensive process with limited availability of the required stock materials when compared to other base sheet materials.

Advantages of Chemical Etching:

Provided the correct supplier is selected the etching process can provide high quality and a very fast turn round. Not all etched stencil suppliers have the large knife edge in the center of the aperture as depicted in many trade adverts. Step etch capability is available from most suppliers in one facility and there are a wide range of materials which can be etched for stencil manufacture.

Disadvantages of Chemical Etching:

There are suppliers who are not very good at stencil etching, leaving over sized apertures or large knife edges in apertures. The thickness of the base material is a limitation to etching process however stencils are becoming thinner rather than thicker.

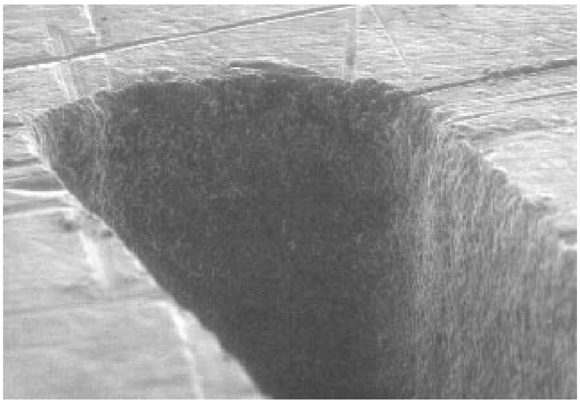
The apertures are affected by environmental changes in the photographic process. The repeatability between stencil is not as good as with laser cutting.

Laser Cut Stainless Steel

It is also possible to obtain laser cut stainless steel stencils although the cost of such a stencils is generally high, typically being two times the cost of the equivalent brass etched stencil. The stencil is cut using a YAG laser which literally cuts through the stencil material with a spot size of between 0.002-0.003".

The advantage is that the laser system works directly from the CAD disc without any filmwork stage in between. This means that a disc with a Gerber file can drive the laser system directly. This is not necessarily such an advantage as it may first seem, since circuit boards are, of course, produced from filmwork. The tolerances of both need to be considered when evaluating the printing process. No stencil can overcome a poor quality or dimensionally variable circuit board material.

The advantage of the laser system does is that, since the control system is software based, it is very easy to locally modify pad lengths by sending a marked up drawing along with the disc to the manufacturer. Another advantage to the system is that no etching allowances or artwork modifications need to be made. Also the side walls of a laser cut stencil are perpendicular to the face of the stencil, unlike the side walls of an etched stencil which may be hour glass shaped, and can tend to retain solder paste in the stencil. It is, of course, possible to modify the shape of the finished aperture as is now done to aid paste release. The apertures are now formed with a larger aperture on the base of the stencil to aid paste release just like wet sand in a child's bucket at the seaside. This is generally referred to as trapezoidal apertures.



Combination stencils may be used for fine pitch designs with a reduction in the total stencil price by combining laser cut apertures and etched stencils. This will depend on the way in which the stencil is costed. It is more common to have a combination of laser and etch when a step stencil is required.

Advantages:

Aperture size is very repeatable and controlled from aperture to aperture. The positional accuracy of the apertures and the apertures themselves are very accurate due to the CNC control during cutting. Taper of the aperture can be adjusted along with no practical size limitations. It is also considered to be more environmentally acceptable.

Disadvantages:

A chemical process will be required if any step down sections are needed in a laser cut mask. Some of the laser systems currently used can produce different quality apertures and affect the aperture wall. The laser is affected by the choice of basic material just like the etching process. The laser cut stencil is more expensive than an etched mask.

New techniques in stencil manufacture can produce support mesh patters which eliminate solder paste scooping even on large area prints which can be a problem on conductive adhesives.

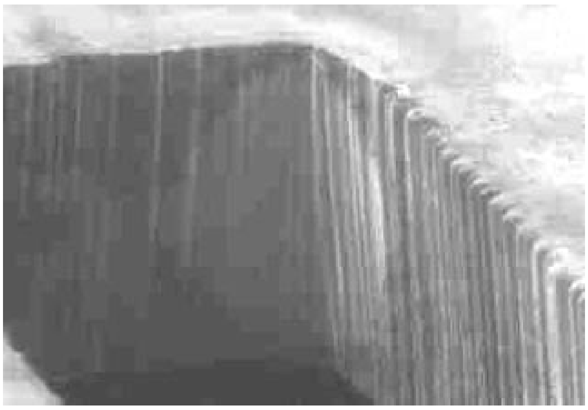
Electro Deposition Stencils

It is becoming more common to manufacture a stencil by plating up metal as opposed to etching it out. This is known as electro deposition or electroforming and is becoming a popular choice in the industry both in Europe and the United States. The cost of such a stencil lays part way between the cost of a laser cut and an etched stencil.

Electroforming technology has been used in the industry for many other applications before it was used for stencils. Application like shaver foils, diaphragms and encoder disks were some of the first using the chemical forming. Normally a stainless steel sheet is used as a base to plate which is coated with a dry film photo resist, commonly used in the printed board industry for defining copper circuitry. The resist is approximately 0.004" thick and is hot roll laminated on to the metal support sheet. Some application for electro forming use a liquid coating process which may reduce the cost of the process but the film will have a defined thickness.

The photographic master artwork is then placed on to the surface of the dry film and exposed to ultra violet light which polymerises the resist coating. The artwork consists of a completely black surface, normally referred to as negative artwork with only clear areas corresponding to the required apertures in the final stencil pattern. During exposure the ultra violet light causes the film to become hard and resistant to chemical development.

After the film has been developed the only areas of resist remaining on the steel plate are the resist shapes corresponding to the apertures and their final locations. The plate is then placed in a nickel plating solution until the required stencil thickness is achieved on the plate. The resist can then be striped and the mask removed from the support plate. The stencil then resembles a standard etched foil prior to mounting in a frame.



As the scanning electron microscope photograph shows there is a characteristic swirl shape to the aperture wall on all electroformed stencil which is caused by the surface of the resist. After the imaging and development of the resist a pattern is left in the surface which is transposed on to the stencil wall. The pattern is left on the stencil aperture wall because the resist is used as a mould for nickel formation. It is also possible to produce multi level stencils using electroform technology in the same way that a two stage etching or laser cut and etching can do for printing different thickness of paste on the board surface.

For some applications where a thick electroformed stencil is required laser cutting can be used after the nickel forming operation introducing yet another choice to the process engineer. The standard thickness of nickel formed stencils are 100, 125 and 150 microns with a hardness of 200 or 650HV.

Advantages:

Excellent dimensional accuracy and side walls with the possibility of tapered aperture control with any shape of aperture. Almost any thickness of stencil can be produced and the material properties can be changed with the plating bath chemistry.

Disadvantages:

A limited number of suppliers currently provide this service but this changing fast. Any defects in the aperture or the wall are due to photographic process or the mask material being used for the stencil. The cost of the stencil is more expensive than etched but equal to laser cut.

Electropolishing

Basically the electrolytic polishing process is used to overcome uneven surfaces after etching or laser cutting. The need for this process stage is very dependent on the ability of the stencil supplier to control his process in the first place. The process removes some material from the surface providing a smoother wall surface. It does not, however, overcome poor manufacture. It is a common process specified in the USA but not very common in Europe.

Pocket/Recessed Stencils

Although unusual it may be necessary to print paste on to a board which already has some known obstructions on the print surfaces. This requires that cavities are etched into the base of the stencil to allow projections on the board to be present without contacting the stencil during printing. An example of this may be the use of a thick stencil employed for solder paste printing during through hole or intrusive soldering. The original printing process for surface mount parts may be supplemented with an additional print on to the surface of the holes. It is, however, more sensible to print the paste into the through holes first, then conduct the normal print for the surface mount parts. On the second print an over size aperture will only be required for the through holes in the second print operation. Experimentation with different stencil designs should be able to eliminate a two stencil operation and also obtain effective through hole joints as the example below. This approach has been successful in many facilities in achieving satisfactory solder joints as the one shown below.

Bob Willis is a process engineer providing engineering support in conventional and surface mount assembly processes. He runs production lines for suppliers at exhibitions and also provides seminar and workshops world wide. Bob has one of the largest collection of training videos, interactive CD-ROMs and training material in the industry. Bob will be presenting four Master Classes at APEX in California, he will also be presenting classes at SMT Nuremberg in Germany for those engineers visiting the show. For further information on how Bob may be able to support your staff contact him via his web site **www.bobwillis.co.uk**