Increased Miniaturization with Trench Filling Technology

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Abstract

Increasing requirements for line and space dimensions are driving developments to improve both production yield and capability. In particular for the production of IC substrates line and space dimension below 15 µm is required for the next level of integration. However traditional production techniques using dry film image transfer are already reaching capability limits and are unlikely to achieve satisfactory future production requirements.

This paper presents a system for the production of structures based on the filling of trenches on a dielectric substrate. The trenches can be produced by methods such as laser ablation and subsequent metallization processes are used to complete the circuitisation.

The system utilizes copper metallization technology enabling complete filling of the trenches with minimum surface plated copper. Best possible copper plated surface distribution is a prerequisite for the process and this is achieved using an insoluble anode production module.

Introduction

In the last years extensive efforts have been made to minimize structures and feature sizes on the PCBs driven by the increasing miniaturization of wafer technology. New technologies like SAP, Semi Additive Process, have been developed and used to produce chip substrates with L/S of about 17 / 17 µm. The decreasing Cu line thickness in the SAP process inherits one potential drawback for the processing step: The active contact area between a Cu line and the underlying Cu basis becomes so small that the adhesion strength may not be sufficient. Lines may peel of during production. This could restrict this technology to a certain feature size.

A technology to circumvent this problem should build up Cu within permanent trenches during the production sequence. This would use 3 walls to improve adhesion instead of 1 underlying contact (see fig. 1)

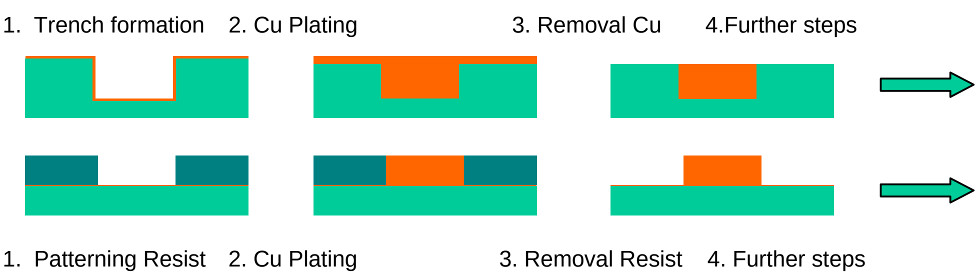

Fig 1: One difference in processing steps between a trench filling technology (top) and SAP technology (bottom) showing the benefit of 3 wall contacts of Cu for further processes.

Another difference of this technology is the trench formation itself. The structure formation is not based on a resist process thus reducing the number of process steps. Several new technologies are used to directly form trenches by embossing technology or laser writing technologies. Especially, the latter technology has been improved significantly over the last decade. Improvements are not only achieved in the resolution of the laser but also in methods to substantially increase the line speed which is now potentially production suitable. Trenches, pads and Blind Micro Vias (BMV) can now be produced in parallel on one board. Trenches with depth of about 10 - 20 µm along with pads of same depth and diameter ranging from 50 - 250 µm are easily produced together with BMV of different depths.

The critical steps of this technology are

1. The laser structuring for various base materials
2. The plating step to generate the best surface distribution with consistent filling of the trenches and at the same time the smallest amount of Cu on the surface itself
3. The subsequent etching step to remove the superfluous Cu from the surface leaving Cu in the trenches. This process step is extremely depending on step 2

As stated above the laser technology and also embossing technology has made already major advances but how about the plating and etching step? Since the etching step is so depending on the plating step we will focus in this publication merely on the technology to generate even Cu surfaces.

Technologies for an even Cu plating

Starting point for the Cu plating technology was the traditional BMV filling technology in vertical standard hoist type machine and soluble anode technology. The first results were promising in terms of filling structures but it became quickly apparent that this technology has its limitations. Small structures could be easily filled whereas larger pads showed incomplete filling and the plated Cu surface was too thick. Moreover, often 30 µm Cu or more had to be plated leading to enormous trouble in the subsequent etching step. Thus a new trench filling technology had to be applied.
The conveyorized horizontal Uniplate approach with PTH and Cu plating process gave significant improvements. Reasons are

1. The surface distribution in a conveyorized line is usually superior to a hoist type plating machine. This is especially true for our Uniplate systems both in the desmear / activating/e'less sequence and the plating steps
2. The plating step in an Uniplate Inpulse2 unit is requiring less copper on the surface than any other plating technology making it easier and faster to etch
3. The Inpulse2 unit gives the best possible surface distribution by using reverse pulse technology plus segmented and individually controlled inert anodes.
4. The Uniplate system allows significantly higher current densities as standard applications

The technology to reduce the amount of Cu for filling application has been developed in the past 2 years. An example for the enormous potential is given in fig. 2 where a BMV is filled with this technology in a panel plating mode.

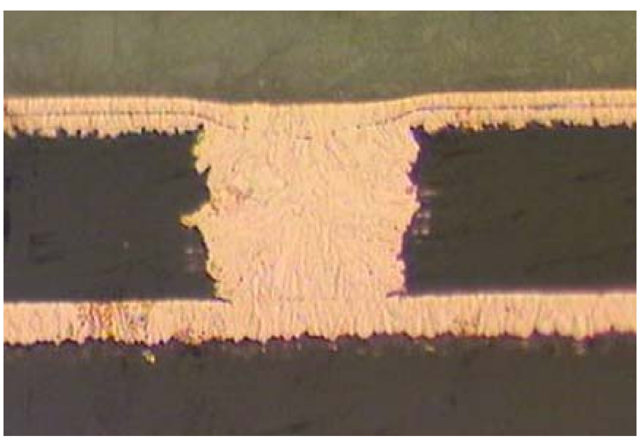

Fig. 2: 90 µm x 60 µm BMV with Inpulse2 technology. Only 12 µm Cu is being plated within 22 min. by 2 Inpulse2 platers (2 Cu layers visible)

With this technology often more than 40 % less Cu needed to fill up trenches and BMVs.

The application of this technology on a trench filling board is given in fig. 3 where trenches, BMV and a pad are filled in parallel.

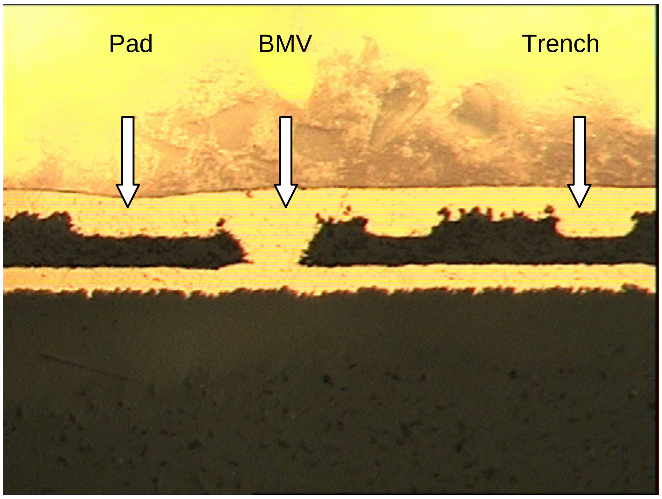

Fig. 3 a filled laser ablated structure plated by Inpulse2 technology. A via and a pad is seen on the left side by plating only 14 µm Cu.

Surface variations are comparatively small with only 14 µm Cu on the surface. The dimple in this example is about 5 µm. Increasing the plated Cu surface may even further improve the dimple.
This is only one example of various types of trench filling technologies including different base materials, trench and hole types and sizes etc. Within our development project we have seen successfully filled structures but as always certain restrictions and limitations have also been identified

Limitations:

1. Base materials have to be process able either by laser or embossing or other technologies. There are now some few base materials (incl. standard materials for conventional SAP technology) available
2. The technology is best suited for trenches and BMVs. If through holes are being used a significantly higher Cu plating layer is resulting along with decreasing surface distribution homogeneity.

Summary and outlook:
Substantial improvements have been made in the past years to realize the trench filling technology for smaller application. A key performance step is the Cu plating to generate the best possible surface evenness. The conveyorized Uniplate with its Inpulse2 plater systems has significantly improved both the surface distribution and the required Cu thickness. This may enable in future the subsequent etching step to generate the fabrication of smaller features sizes.
Since this is still a relatively young technology we may expects further improvements in the near future
At the moment further improvements in etching technologies and the parallel processing of through holes are still under development and shall improve in due course.