The assessment of areal surface texture parameters for characterizing the adhesive bond strength of copper plated micro-machined glass

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Abstract

The micro-electronics industry is investigating glass as an alternative printed circuit board material and interposer. Electroless copper plating of glass is required for tracks and interconnects, but understanding of how the surface topography of the glass substrate affects the mechanics of the copper/glass bond quality is limited. Areal surface texture parameters provide the potential for characterizing key surface features associated with improving copper/glass bonding. Laser ablation techniques have been used to prepare glass surfaces with micro-scale structured features, and these features have been quantified using areal parameters. The copper/glass bond strength has been quantified using scratch testing techniques, with statistical analysis identifying strongly correlating areal parameters that may be used for predictive design of glass surfaces.

1 Introduction

Glass is attractive as an alternative substrate material for printed circuit boards and interposers, due to its relatively low cost, high thermal stability, similar thermal expansion coefficient to that of silicon, and transparency, which could simplify assembly and inspection of components with area array or hidden interconnects. The concept of using glass for high density interconnects has been explored by several research groups [1]. Previous work has examined the feasibility of the major process steps required to form a high density, multilayer glass circuit board: glass layer lamination, drilling of microvias, and electrical interconnect pattern formation. However, an issue of concern has been the quality of bonding of the electroless plated copper on the glass (required for tracks and interconnects). The complex relationship between surface topography and adhesion has interested researchers for more than fifty years. However, the quantified influence of surface topography has typically been considered in a superficial manner, with very little evidence for the use of the new ISO/FDIS 25178-2 areal parameters [2].

The research reported in this paper has involved the production of textures and structures on glass substrates using laser ablation, allowing a systematic study of the effect of surface topography on electroless plated copper adhesion. Key aims of the research have been to improve the mechanical copper/glass bond strength, and use areal parameters in a predictive manner, linking to bond strength measurement.

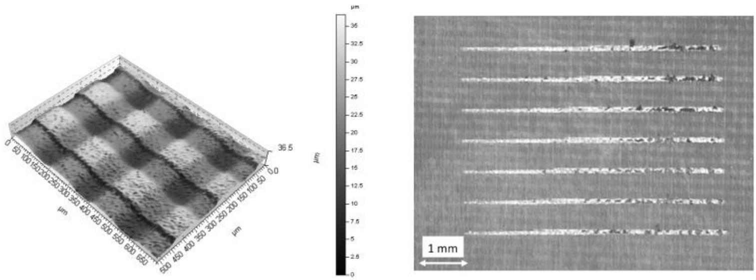
2 Glass processing and measurement

The basic methodology and techniques used here to correlate surface topography with adhesion performance can be summarized as follows.

- Laser machining with control of machining variables.
- Surface metrology to characterize the machined surfaces using areal parameters.
- Electroless copper plating with control of plating variables.
- Scratch testing to quantify plating critical load of failure (adhesive bond failure).
- Correlation of critical loads of failure with areal parameter values.

Cerium doped glass (40 mm × 40 mm × 500 μm) supplied by Qioptiq Ltd, was chosen as a substrate material due to its absorption characteristics at excimer laser wavelengths. Excimer lasers can generate micro-scale array structures on glass by using mask projection/dragging [3], and in this research complex micro-scale structures were typically produced via multiple passes of the laser across the glass in a grid fashion. A range of novel structures of various depths were generated by changing the mask geometry, mask dimensions and laser operation parameters.

Prior to copper plating, the glass surface topographies were characterized using coherence scanning interferometry (10× objective lens, lateral field of view 700 μm × 500 μm) as shown in Figure 1(a). Data sets were processed using areal parameters, with a range of filter variables being explored. Electroless copper plating procedures included substrate cleaning (Decon 90), catalyst dipping (Circuposit™ catalyst 3344/4444) and copper bath dipping (Circuposit™ 3350-1), with wash/dry cycles between each stage (the copper plating thickness was approximately 0.5 μm). Scratch testing was used for quantitative assessment of the copper/glass adhesion strength, using a test system (at NPL) with a 200 µm Rockwell C diamond stylus and a load range of 1 N to 15 N. A scratch tested sample is shown in Figure 1(b).



(a) (b)

Figure 1: (a) Ablated structure, (b) scratch testing of copper plating

3 Results and conclusions

Areal parameters for samples typical of those shown in Figure 1 were calculated with reference to the definition and relevance of each parameter. Figure 2 shows the relationships of four parameters (*Spc*, *Sq*, *Vvc* and *Sdq*) which showed clear trends when plotted against the respective mean critical load values, and demonstrate increasing copper/glass plating adhesive bond strength.

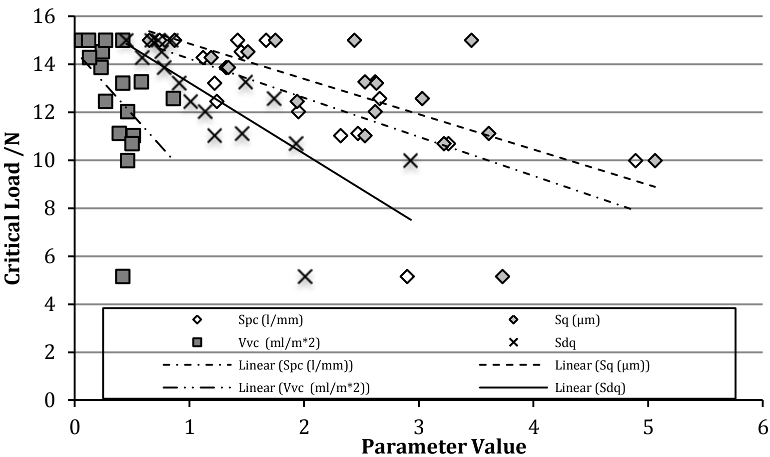


Figure 2: Critical load against areal parameter value

Two correlation coefficients were used to quantify the strength of the relationship between the parameter values and the mean critical load values: Pearson product moment correlation coefficient (ρ), and Spearman's rank correlation coefficient (r), with the strongest parameter correlations shown in Table 1.

The research reported here has demonstrated the ability to structure glass surfaces in a novel manner, and to improve electroless copper plating bond strength. The data demonstrates the strength of correlations, and reinforces the selection of these areal parameters as strong candidates for predictive design. It should be possible to use these parameters to assess structured glass and calculate whether the structure will improve plating adhesion. This removes the need for numerous electroless plating trials and scratch testing. Furthermore, the identified areal parameters could also be used in a modelling environment to assess the viability of modelled surfaces, without the need to machine numerous trial glass surfaces.

Table 1: Areal parameters and correlation coefficient values

Areal Parameter	Spearman (r)	Pearson (ρ)
Spc	-0.86	-0.81
Sq	-0.81	-0.76
Vvc	-0.80	-0.75
Sdq	-0.77	-0.73

References:

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