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Trimming Embedded Resistors Using Available PWB Equipment Technology

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By using two existing pieces of common printed wiring board manufacturing equipment, embedded resistor manufacturers can obtain laser trim results similar to the trimming obtained using a specialized probe card based laser trimmer. Existing electrical test equipment can be programmed to first measure the values of plated additive resistors manufactured on circuit board inner layers. Next, this value information is programmed into the software of a laser routinely used to drill microvias for circuit boards. A computer routine calculates the amount of the resistor that needs to be removed to adjust each resistor to the required design value. This trimming is then conducted on the actual inner layer.

Advantages of this technology include eliminating the manufacture of probe cards for each new circuit design, and utilizing existing machines for this new technology task. While accuracy of trim with this "off line" machine may not be quite as precise as active trimming with probe cards, the accuracy is sufficient for many of the 5-10% resistor values needed for such design applications as digital signal termination. Plated additive resistors, with their uniform thickness across each resistor, are particularly easy for this technology combination to trim.

Background

Embedded resistors have been used in circuit boards for over 20 years. Embedded resistors have traditionally been made in the 25-100 ohm per square value range and at values of plus or minus about 15% of nominal resistance. While this is not the same accuracy as surface mount resistors, some companies, such as Motorola, have found that this accuracy is adequate for many applications, such as personal pagers.

However, it is in only the last three years that interest has been expressed in trimming these resistors to values more accurate than those "as produced". Laser trimming of resistors is well known, as surface mount resistors are typically trimmed to value, while still in the format of mass production. Probe cards are typically used in this application, as these probe cards easily and rapidly trim sheets of "all the same" resistors in mass production.

The location of resistors in circuit board production does not usually follow the grid pattern as when resistors are mass produced for surface mounting end use. Resistors embedded in circuit boards are located near the electrical components in their net. This means that embedded resistors are not in arrays that are easy to use probe cards. Also, flying probe technology has not yet been commercially demonstrated for embedded circuit board resistor trimming.

While circuit board innerlayers are more commonly optically inspected before lamination, full electrical test is easily done on these same layers. Finished bare circuit boards are routinely electrically tested, with data accumulation of resistance values in various circuit nets. Establishing the desired electrical resistance measurements for embedded resistors is done interactively with the plotted artwork of the inner layer through simulation of laser trimmed resistor values.

Thus, the investigation of this report was undertaken – to see if commonly available PWB electrical test equipment and laser microvia drilling equipment could be used in combination to trim embedded plated additive resistors for circuit boards.

Scouting Runs

During the initial scouting runs at Photomachining, the following problems were identified because of using a laser microvia drilling machine:

1. Cut smoothness
2. Absolute location
3. Machine problems
4. Software problems
5. Correct energy for trim, without damaging resin
6. Non uniformity across laser spot in this application

The following was done to improve the test vehicle and give better test results:

1. Decrease travel between pulses – more overlap, correct beam energy
2. Software issues, and recognize machine table limitations
3. Still under study – still some laser issues
4. Data portability. DXF and Gerber software version compatiblity
5. Trial and error correction
6. Still under study.

Program Test Parameters

To demonstrate the combination of independent electrical test and laser trim, a desirable circuit geometry was selected, and incorporated into a test vehicle. (Figures 1a, 1b, and 1c). The size of the circuit board chosen was 125mm by 175mm, and the "boards" were manufactured four–up in a panel size of 400mm by 600mm. Nominal resistor size was from 1.6 x 3.2 mm down to 0.3 x 0.6 mm. All the resistor designations in this paper refer to the size of the desired resistor in millimeters.

A total of 12 panels, each containing 480 resistors was used in the test program.

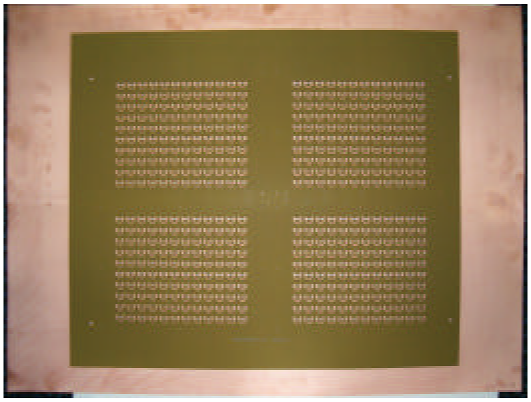

Figure 1a – Test Panel

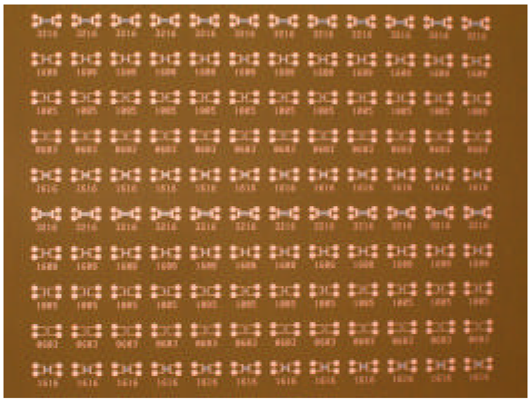

Figure 1b – Test Pattern

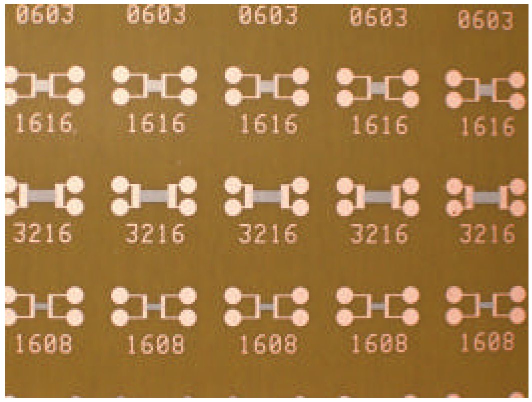

Figure 1c – Test Panel Section

A fiducial location system was set up at the corners of the panel for alignment of the microvia drilling laser and the electrical test fixture. In this test, the global fiducial system served as the orientation for both the probe testing and the laser activation. In final practice, it will be desirable to have a fiducial system that is more localized.

Next, a software routine for laser trim was developed, based on mathematical modeling of the electrical results expected upon trimming. Since the trim is not interactive, it is possible to set the trim to minimize the plunge cut effect on cross sectional area. Also, the plunge cut undertaken was set at some distance from the terminations, also to minimize resistor heating effects. Since the cut is mathematically derived, the "L" cut is frequently longer than would be expected in an interactive cut. Figure 2a is a picture of the graphical model of the trim undertaken on 1.6x1.6mm resistors, and Figure 2b is a picture of the graphical model of the trim undertaken on 3.2x1.6mm resistors. Both of these figures show the electrical path expected after trim.

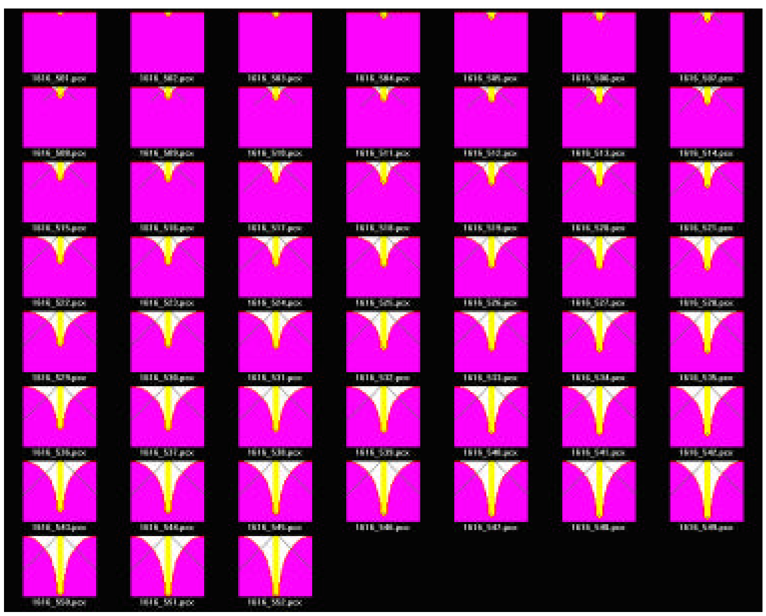

Figure 2a - Modeling of Trim of 1.6 x 1.6 mm Resistors

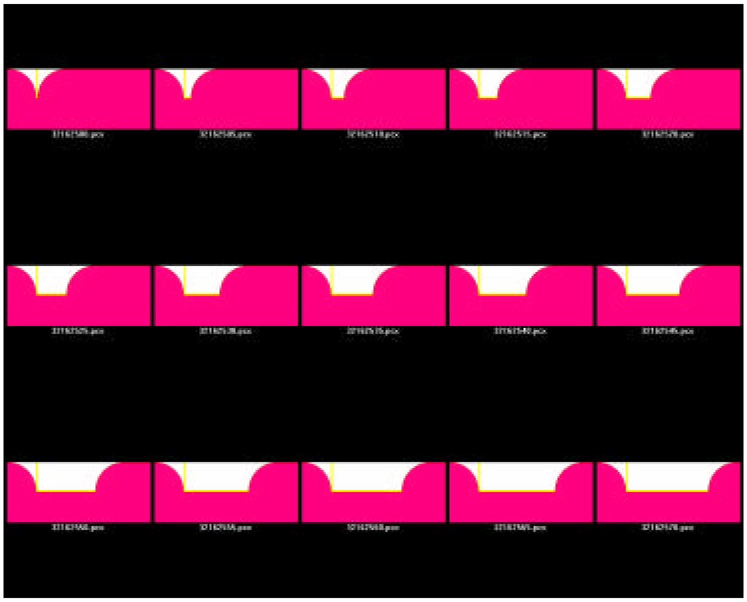

Figure 2b - Modeling of Trim of 3.2 x 1.6 mm Resistors

Key undertakings of the trim model were as follows:

1. Evaluating the dimensions of the "L" cut to get the resistor value desired (see Figures 2a and 2b)
2. Modeling of the spot size for trim – based on the capabilities of the laser drill.
3. Modeling of the travel of the pulsing laser source, to determine movement between each pulse
4. Modeling of the desired resistor starting value range to give acceptable final resistor values.
5. Summarizing parameters for the laser via drill to cut the resistor to give the desired value.

Next the Gerber artwork was plotted to give the locations for starting laser trim. This global alignment format is accurate to 25 microns, giving an expected trim accuracy of 8% on the smallest resistors (2% on the largest 3.2x1.6mm) and a 3% final error is due to resistor plating. This total could be as much as 5% on the larger resistors used in this study.

The same Gerber plot of resistor locations gave the test points for the electrical test equipment. Many of the resistor pictures here will show the mark from either manual or automated test probes.

The first run of resistors resulted in a plot of resistor values. All resistor terminations were able to be tested with the ECT equipment, using a standard probe test fixture.

Figure 3a and b show the 1.6 x 1.6 resistor before and after trim, and Figure 4a and b show the actual 3.2 x 1.6 resistor before and after trim.

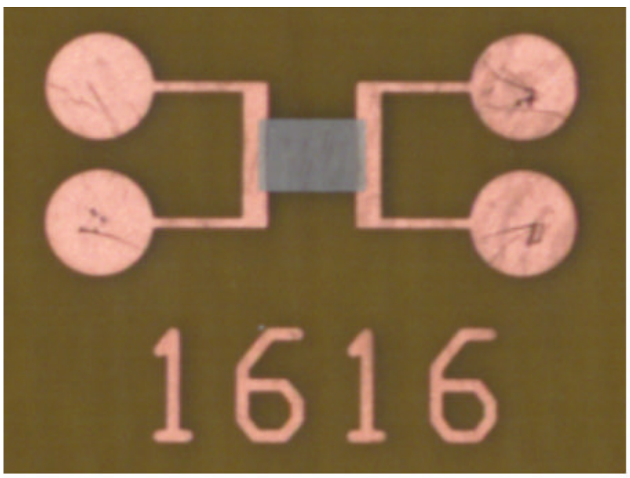

Figure 3a - 1.6 x 1.6 Resistor before Trim

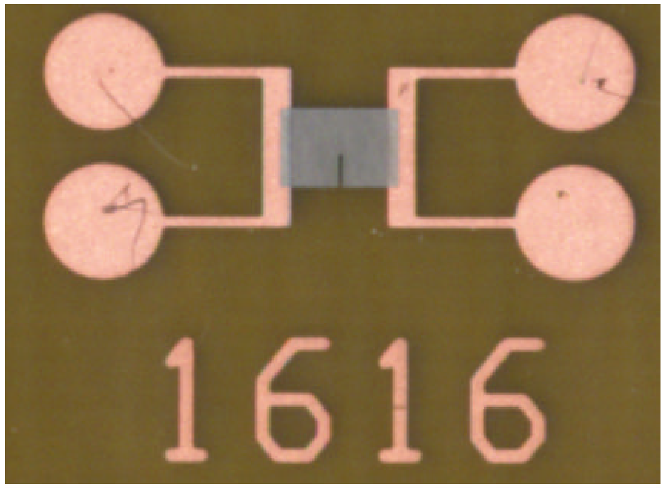

Figure 3b - 1.6 x 1.6 Resistor after Trim

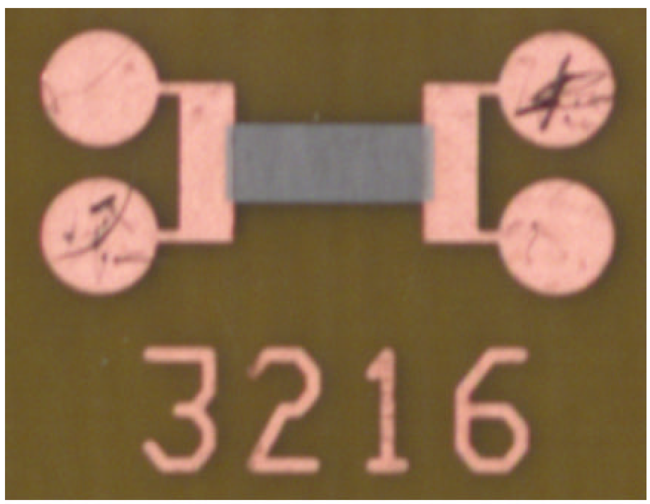

Figure 4a - 3.2 x 1.6 Resistor before Trim

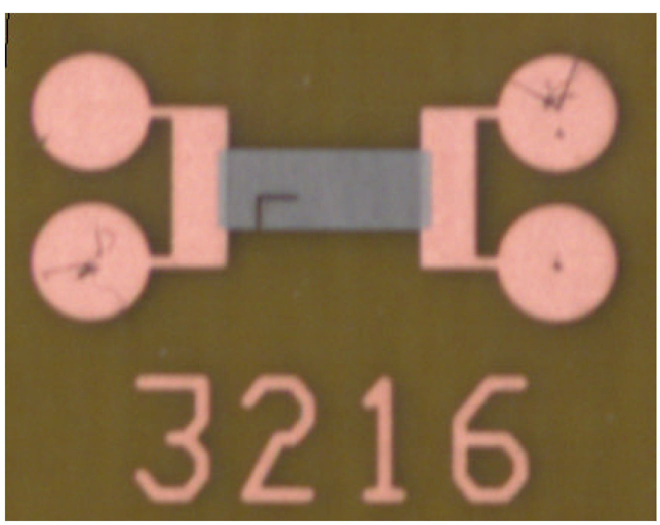

Figure 4a - 3.2 x 1.6 Resistor after Trim

Statistical plots of the values of the initial run of trimmed resistors are shown in the plots (next).

Figures 5 and 6 contain electrical test results from the ECT A6S before and after trim. The resistors were plated to a thickness where the desired nominal trim would be to a depth of about 0.5 mm. This was compared to the measured electrical starting and ending values of these resistors.

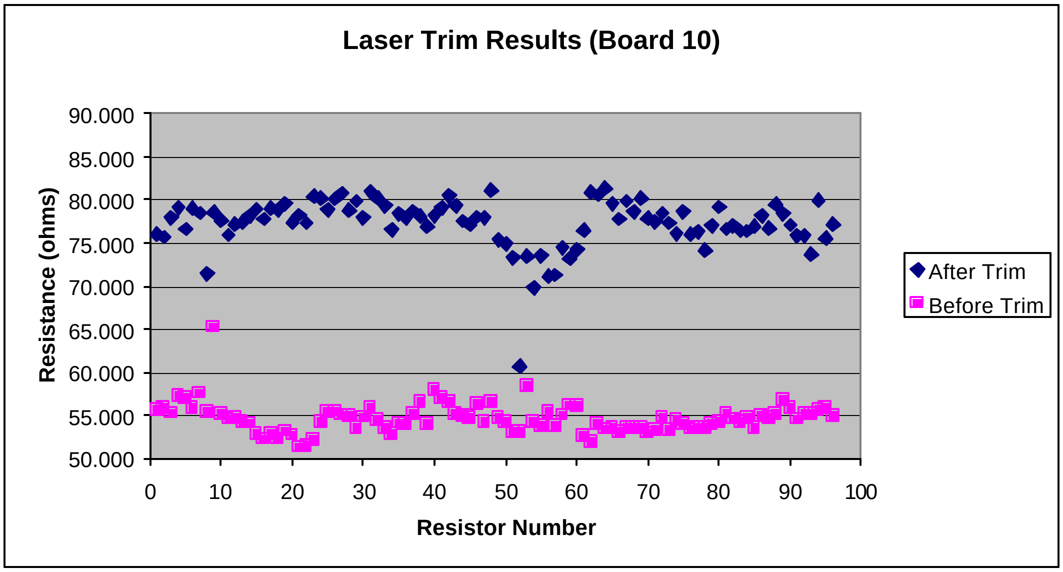

Figure 5 – Results for Board 10 – 55 Ohm Resistors Trimmed Up – Target 75 ohms

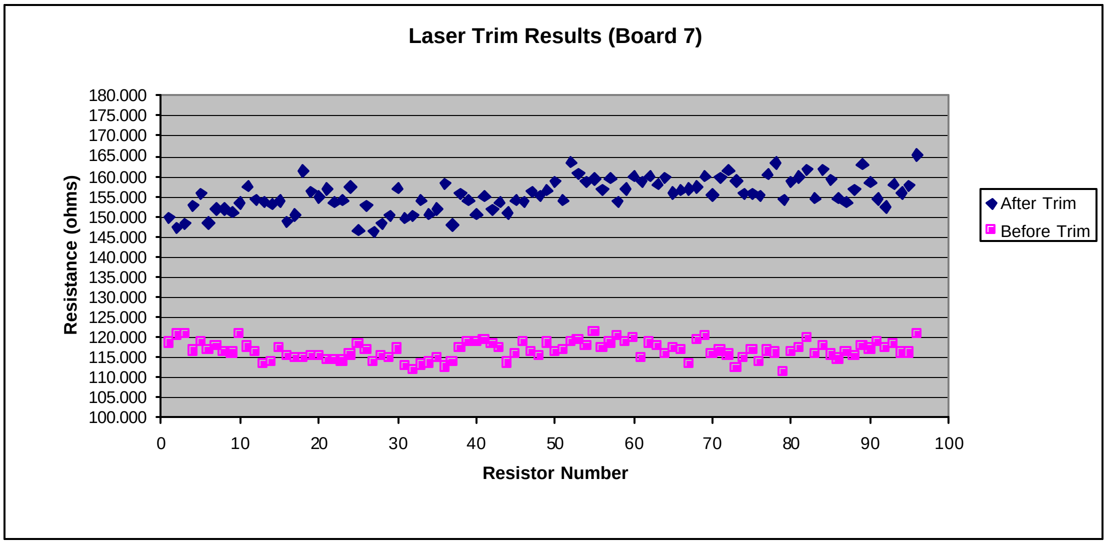

Figure 6 - Results for Board 7 – 110 Ohm Resistors Trimmed Up – Target 150 ohms

Electrical Test Equipment

Electrical testing of "before trim" and "after trim" inner layers in this study was quite successful. The machine used was the Everett Charles A6S with capability from 1 ohm to 50 megohm. This machine Figure 7 is capable of 35 micron (1.4 mil) probe point size, so it can virtually test on common conductors, without special probe test points. This shows that the presently available electrical test equipment can function in individual shops to measure embedded resistor values successfully. The data can be stored and successful laser trim can be demonstrated

Existing laser microvia drilling equipment – a custom designed machine at Photomachining, and an ESI unit at Tech Circuits both successfully were "turned down" to the intensity needed to ablate thin films of embedded resistors, such as those from the plated additive technology. This drilling equipment does not significantly decompose the epoxy underneath, or alongside, the resistor plating.

Plating can successfully give a consistent deposit across inner layer panels, as shown by the “as plated” data (Figure 5 and 6 starting data). Also, the use of existing laser microvia drilling equipment has been shown capable to trim resistor formulations, such as plated additive resistors, to an accuracy of about 7%.

Figure 7 - Everett Charles A6S

Laser Trim/Electrical Test Results

The results of the laser trim runs show that:

1. The principle of using existing circuit fabrication equipment for resistor laser trim was demonstrated as feasible
2. Accuracy is reasonable for the beginning test work – trim to about 7 % accuracy
3. Plan to improve the accuracy by exploring both location/fiducial issues, and by improving the laser operation in this application
4. Further results are to be presented at WECC Conference, as work continues after publication.

Plan Forward

Existing printed wiring board microvia drilling and electrical test equipment has been shown capable to produce trimmed resistors in the accuracy range of 5-9% range. This is better than a previously expected “as manufactured” range of 15%.

It is intended to solicit a field evaluation of the resistors trimmed with the “in house equipment” process. The key piece of that demonstration will be functional operation of the electrical device, based on resistors more accurate than those “as plated”. However, these resistors are not expected to have the accuracy of purchased surface mount discrete components.

The marketing plan for the software for this “in-house trimming” of embedded plated additive resistors is being determined. It is expected to be made publicly available.

Acknowledgements

1. PhotoMachining
2. Tech Circuits, Wallingford, CT
3. Everett Charles, Pomona, CA

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