Improved Thin-Film Resistor Material

by Bruce P. Mahler
OHMEGA TECHNOLOGIES

SUMMARY: Improvements in resistive alloys now allow for the creation of very small resistor elements that can be built within a logic trace. This results in improved electrical performance, improved reliability, more routing area and greater flexibility for PCB designers.

Embedded resistors have been used for many years as replacements for discrete surface devices in order to increase circuit density, improve reliability and enhance electrical performance. For many of those years, circuit designs were able to accommodate embedded resistor footprints that were relatively large, typically with line widths greater than 250 microns (Figure 1).

The evolution to greater I/O densities and routing constrictions made it very difficult, if not impossible, to embed resistors with footprints of these dimensions, especially terminating resistors within the high-density routing area of BGA devices.

This lead to the development of a 10 ohm per square sheet resistivity "resistor built in-trace" technology, OhmegaPly ORBIT, that allowed termination resistors to be built within traces and eliminated the requirement for designing

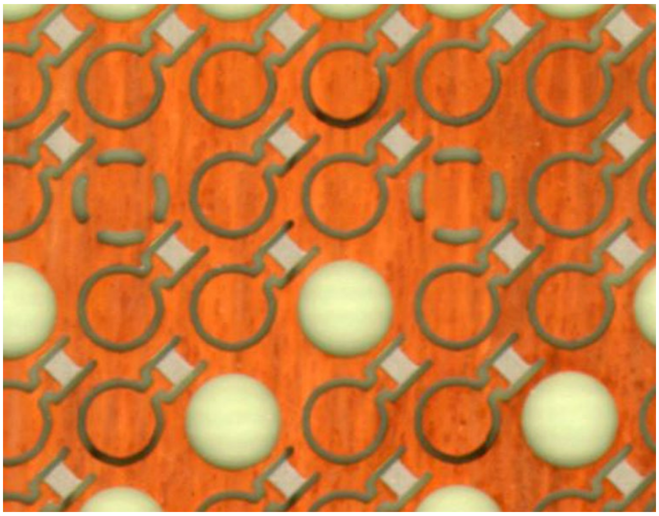

Figure 1. Parallel termination resistors.

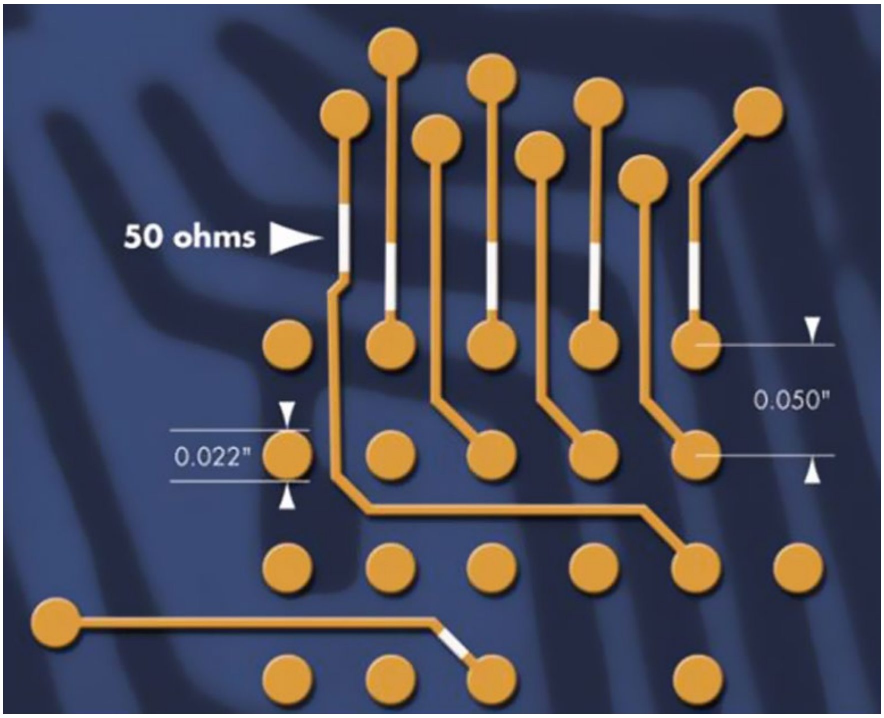

Figure 2. Resistor built-in trace.

resistor footprints by placing them within the circuit layout (Figure 2). These resistors are typically about 125 microns wide.

With increasing I/O densities, there has been a new need for embedded resistors that could fit within uBGA footprints with pad pitches of less than 500 microns. Resistors with line widths of less than 100 microns are necessary to accommodate these new requirements.

In order to achieve good tolerance and fine line resistors with line widths less than 100 microns, Ohmega Technologies began development work to enhance the standard OhmegaPly nickel-phosphorous resistive alloy. This effort focused on improving the chemical and physical stability of the resistive alloy. Success in this effort led to the creation of the patent-pending OhmegaPly Micro Trace Resistor (MTR) technology.

In addition to an improved resistive material, it is suggested that board shop processing include the use of laser direct imaging (LDI) for both the primary and secondary print operations. LDI has the advantage of greater precision, straight sidewalls and near perfect registration for the second imaging that defines the resistor length. This means that the overlap of the photoresist-defined window over the resistor element needed for the second print and etch operation can be smaller and becomes critical when working with lines and spaces of 100 microns or less using conventional print and etch processes.

Another key aspect to the creation of micro trace resistors is the use of a unique NiP differential etch technology. As line widths become narrower, the effect of undercut on the circuit becomes more pronounced, resulting in more line variation and larger resistor value tolerances. Over-etched line edges become ragged or uneven. This contributes to wider tolerances and degrades electrical performance in high frequency applications. When micro trace resistors of 100 microns or less are etched in the primary

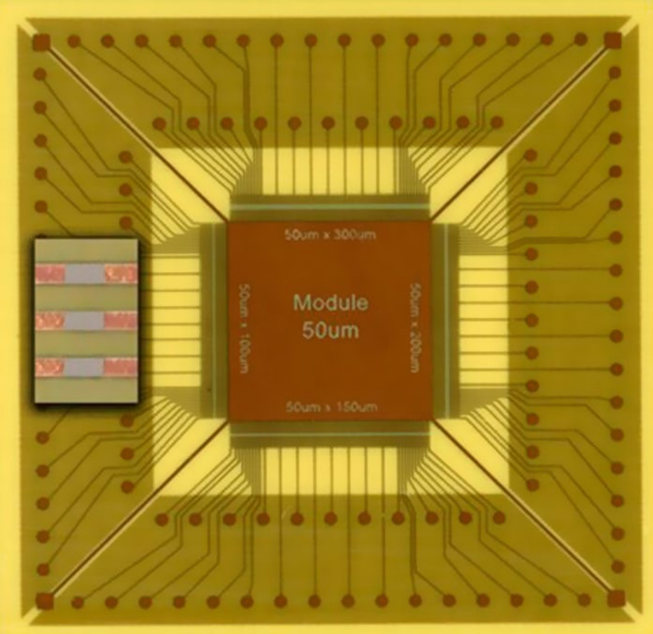

Figure 3. Example of Micro Trace Resistors.

	Standard OhmegaPly®		**OhmegaPly® MTR®**	
	25 ohm/sq	50 ohm/sq	25 ohm/sq	50 ohm/sq
Sheet Resistivity (after final alkaline etch)	28	50	25	50
Tolerance for a 100μ wide resistor	15%	15%	10%	10%
Micro Etch Exposure ΔR%	10%	4%	1%	1%
240 Hours 95% RH/40C ΔR%	2%	2%	1%	1%

Table 1. Comparison of Standard OhmegaPly and OhmegaPly MTR.

copper etchant, whether acid or alkaline, the dwell time is especially critical because the narrower the resistor element, the greater the variation in width has on the ohmic value of the resistor.

After primary copper etching, the exposed NiP layer must be stripped to limit the resistive layer to the boundaries of the etched copper features. The NiP differential etch is a selective copper sulfate solution that will strip the exposed resistive material without etching the copper features. In addition, it is a self-limiting bath that ceases to work after all of the exposed NiP resistive material is stripped away. It does not undercut copper to etch any underlying NiP resistive material. The importance of the congruence of the resistive trace to the copper trace is that as the resistor widths become narrower, the width variation has a greater effect on the resulting percent tolerance in ohmic values. After the differential strip, the use of LDI for the second print enables precision copper etching and tight tolerance miniature resistor elements (Figure 3).

Improvements in the chemical and physical stability of the NiP resistive alloy resulted in improved properties of the embedded resistor when compared to standard NiP resistive films (Table 1).

With greater material stability in the PCB chemical processes, a significant improvement in the final resistor tolerance is achievable with MTR.

Another concern with very small Micro Trace Resistor footprints is the power carrying capability of such small size elements. The power dis-

OHMEGAPLY MTR ® MICRO TRACE RESISTOR® TEST RESULTS

Resistivity	**Resistor Width**	**TWO SQUARES**		**FOUR SQUARES**		**SIX SQUARES**	
		Resistance (Ohm)	Power rating (mW)	Resistance (Ohm)	Power rating (mW)	Resistance (Ohm)	Power rating (mW)
25 ohm/sq.	**50 Micron**	50	40	100	50	150	55
	75 Micron	50	60	100	80	150	80
	100 Micron	50	70	100	100	150	125
	125 Micron	50	90	100	125	150	165
50 ohm/sq.	**50 Micron**	100	30	200	45	300	55
	75 Micron	100	45	200	65	300	80
	100 Micron	100	60	200	85	300	115
	125 Micron	100	80	200	100	300	120

Table 2. Power ratings of Micro Trace Resistors at 25°C.

sipation of the resistor is a function of thermal management, film thickness and element size. The NiP resistive alloy, both the standard and improved MTR versions, have a relative alloy thickness of approximately 0.4 microns for the 25 ohm per square product and 0.2 microns for 50 ohm per square sheet resistivity product, respectively. This is approximately twice the film thickness of other thin film alloy materials that are commercially available. This added thickness results in a lower temperature rise for a NiP resistive alloy when compared to other resistive alloys of the same sheet resistivity.

Testing of MTR resistors resulted in very good power ratings for such small element sizes, more than sufficient for most uBGA termination applications (Table 2).

Conclusion

Improvements in the basic OhmegaPly NiP resistive alloy has resulted in an enhanced version of the product that is especially suited for the high-density footprints of uBGA modules. These improvements allow for the creation of very small resistor elements less than 100 microns wide that can be built within the logic trace, resulting in improved electrical performance, improved reliability, more routing area and greater flexibility for the PCB designer. **PCBDESIGN**

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Bruce P. Mahler is vice president of Ohmega Technologies. He has been awarded four patents for improvements in embedded resistive materials and other packaging technologies over the past 35 years.