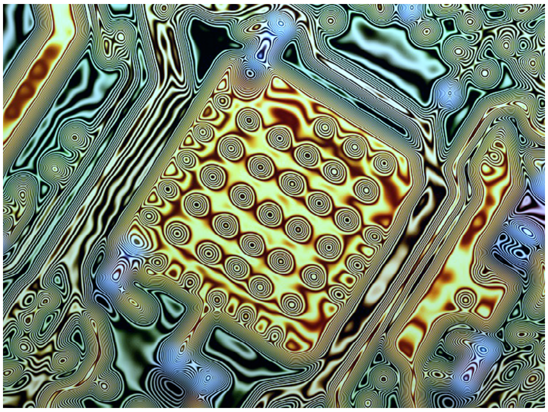
MENY GANTZ, VP marketing, PCB division, Orbotech,
www.orbotech.com

mSAP: The New PCB Manufacturing Imperative for 5G Smartphones

Modified semi-additive processes and advanced manufacturing techniques are enabling high-density interconnects in smartphones at lower costs and faster production speeds.



Manufacturers of consumer electronics are under ever-increasing pressure to design the sleek, compact devices that customers covet, balancing form and function in a manner that differentiates their products in a crowded and competitive marketplace. Nowhere is this truer than in the smartphone market, where corporate fortunes can rise and fall on the success of their newest generation of phones.

When it comes to smartphone designs, every millimeter of space savings achieved within the device enclosure can unlock significant value for the end customer. It makes possible the use of larger, higher-resolution displays, bigger batteries, and more sophisticated processors and components. All of this enhances the device's feature set, and improves the overall user experience.

These form-factor-driven design pressures have been relieved in part via the increased use of high-density interconnects (HDIs), which enable more functions per unit area than conventional printed circuit boards (PCBs). Leveraging finer lines, thinner materials, and laser-drilled vias, HDIs have played a crucial role in the ongoing miniaturization of smartphones and their embedded subsystems.

But as we evolve from 4G LTE to next-generation, 5G-compatible smartphones, the PCB industry's approach to HDI manufacturing must also evolve. Massive-MIMO (multiple-input multiple-oOutput) antenna configurations and increasingly complex RF front-ends will expand the RF content footprint within the 5G smartphone, and the processing power needed to support the staggering volume of 5G data will likely impact battery capacities and geometries, among many other factors. As a result, despite increased I/O demands, the amount of available space for HDI PCBs within 5G smartphones will be significantly reduced.

Moreover, the higher frequencies inherent to 5G will require much stricter impedance control. If not formed with extreme precision, the thinner traces of HDIs can introduce increased risk of signal degradation and data-integrity lapses.

ADDITION AND SUBTRACTION

PCB manufacturers can overcome these challenges by utilizing a modified semi-additive process (mSAP). Commonly used today in IC substrate production, mSAP is poised for widespread adoption in the advanced HDI PCB manufacturing industry.

Current line/space requirements have already reduced to 30/30 and are expected to decrease even further to 25/25, or even 20/20. mSAP is fully able to support these requirements, enabling 5G smartphone makers to achieve unprecedented device densities while leveraging superior conductor geometries for exacting impedance control at high-frequency operation.

mSAP is essentially the opposite—or reverse image, if you will—of conventional subtractive processes. In a subtractive process, fine lines are formed by coating the copper layer with an etch resist, applying photolithography to image the areas where the copper should be retained, and etching away the un-imaged material.

The rectangular shape enabled by the mSAP process is far more effective, maximizing circuit density and accurate impedance control with lower signal loss.

The main drawback of this approach is that the chemical treatment used to vertically etch the lines will also dissolve the copper in a horizontal direction along the trace walls. In a cross-section view, the resulting traces will appear trapezoidal in shape. This wedged-shaped trace can introduce myriad impedance anomalies, and compromise circuit density in instances where lines are formed wider than intended.

In contrast, with mSAP, a much thinner copper layer is coated onto the laminate, and plated in the areas where the resist isn't applied—thus, the "additive" nature of the process. The thin copper remaining in the spaces between conductors is then etched away. Whereas trace geometries are chemically defined during subtractive processes, mSAP allows trace geometries to be defined via photolithography. The traces are therefore formed with much greater precision, in straight vertical lines, yielding a rectangular-shaped cross-section that maximizes circuit density and enables accurate impedance control with lower signal loss.

ADVANCED MANUFACTURING TECHNIQUES

mSAP will help PCB manufacturers overcome the technical hurdles of advanced HDI production for 5G smartphones, but mSAP must ultimately be implemented in a manner that minimizes costs and maximizes production throughput and yield to ensure adequate return on investment. Whereas IC substrate production can comfortably absorb the higher costs typically associated with mSAP, the commercial-volume scale of smartphone PCB manufacturing is far less forgiving where costs and production efficiencies are concerned.

To effectively employ mSAP in mass production, PCB suppliers are increasingly investing in the advanced manufacturing tools and techniques necessary to maintain and extend their competitive advantage through the transition from 4G LTE to 5G smartphones. In this scenario, HDIs with higher densities and precisely formed lines will be a critical requirement.

These PCB manufacturers are adopting advanced direct-imaging (DI) systems capable of achieving 10-micron lines and 15-micron line spacing, with high registration accuracy down to 7.5 microns to ensure precise uniformity. These capabilities can encompass advanced localized-registration features designed to enable the registration of partitions within the individual PCB.

DI systems equipped with high depth of focus (DoF) and multi-wavelength light sources can produce sharper edge patterns across a wide variety of resists, while maintaining high throughput, high quality and consistent uniformity.

Leveraging advanced automated-optical-inspection (AOI) systems, PCB manufacturers can quickly and accurately identify HDI defects for enhanced quality assurance, and reduce the false alarms that may stall production processes. In addition, 2D metrology assessment capabilities can be employed to enable continuous automatic inline measurement of top and bottom conductor widths, ensuring accurate and repeatable measurement using streamlined sampling techniques, and enabling improved impedance control.

Where appropriate, PCB manufacturers may also employ automated-optical-shaping (AOS) systems to eliminate defects such as opens, nicks, and shorts. Using 3D-shaping capabilities that recreate the original design, AOS systems can be applied to inner and outer HDI layers. Whereas manual repair is less accurate and can cause damage to the panel, AOS enables highly precise, high-quality shaping, boosting yield considerably while virtually eliminating PCB scrap, thereby creating a competitive cost structure for the end client.

Ideally, these advanced HDI manufacturing solutions should be tied together via a software framework that collects data throughout the production process, identifying when, where, and how a PCB is handled at every touchpoint. This can help to ensure end-to-end HDI traceability for occasions where QA troubleshooting may be required, while providing a holistic view into manufacturing workflows.

The evolution of 5G smartphones demands a new approach to advanced HDI manufacturing that maximizes the density of onboard embedded electronics while reducing RF signal friction at high frequencies. mSAP is making it possible for PCB suppliers to meet these exacting requirements, while leveraging DI, AOI, and AOS technologies to help lower manufacturing costs, accelerate production throughput, and maximize yield.

MENY GANTZ is the VP of Marketing in Orbotech's Printed Circuit Board division, where he is responsible for the overall marketing strategy and product roadmap of the division. Mr. Gantz joined Orbotech in 2000 and has served in a number of product management and marketing positions within the PCB division, both at the company's HQ in Israel and in Asia Pacific. Mr. Gantz has an MBA from Tel Aviv University and an M.Sc. in Electro-Optics from Ben Gurion University.