MEETING THE CHALLENGES OF MICROMACHINING 5G PHONE ANTENNAE

Key components in 5G phones are the miniaturised antennae that are smaller and physically more complex than earlier devices. This is due, in part, to the shift to a higher frequency (e.g., microwave) operation necessary for 5G. Also a key part of 5G will be the ability of mobile devices to simultaneously exploit signals from different transmitters. In a smartphone, this requires multiple miniaturised antennae with complex 2D, and even 3D, shapes. These shapes must also support so-called MIMO operation: multiple signals in, multiple signals out for the same antenna. Existing antennae already support 2x2 and even 4x4 MIMO function, but 5G is looking to increase this type of multiplexing further.

The antennae are fabricated from laminated substrates, with a layer of copper supported on an insulator (e.g., Liquid Crystal Polymer (LCP)) often including a bonding (adhesive) layer. During the fabrication process they have to be mounted on some type of sacrificial tape or other carrier.

Laser micromachining is the obvious choice to perform the necessary cutting/scribing (scribing involves selective removal of layers without damaging the under layers). Nanosecond (Q-switched) lasers could readily provide the required spatial resolution, but not in a single process. The problem is that copper and polymer have very different ablation thresholds. Optimised micromachining requires a laser fluence of ~7x the ablation threshold. Increasing the fluence toward 10x over threshold and beyond does not improve process speed, it just increases the width of the cut and the extent of the heat affected zone (HAZ). This is the material adjacent to the cut, scribe or hole that is degraded by thermal effects, for example charring in paper and plastics, creation of a glassy phase in ceramics, or melting in the case of semiconductors. With a small electromagnetic device like a phone antenna, the HAZ must be minimised to avoid functional damage, e.g. melting, which could lead to a short circuit. The HAZ can also reduce device reliability and lifetime. However, if a nanosecond laser process were optimised for ablating the copper, it would be very difficult to prevent significant HAZ damage in the polymer. As a consequence, with nanosecond lasers the antennae would have to be patterned in two separate processes with two different laser setups, adding to the process cost and requiring that tight registration is maintained throughout. Moreover, registration would be difficult because of material shrinkage after the first step.

Two well-proven ways to minimise HAZ are to use shorter (e.g. picosecond) pulse widths and/or shorter wavelengths. With ultra short pulse (USP) lasers, much of the pulse energy is carried away in the ejected material, before it has time to spread and cause a HAZ. Moreover, although the pulse energy is typically lower in USP lasers, they offer much higher pulse repetition rates which supports processing in fast multiple passes, further minimising HAZ issues.

The use of shorter wavelengths, i.e., ultraviolet, is also well-known to reduce HAZ effects. That is because the high energy photons can directly break interatomic bonds in most materials, so that some of the material is removed in a photolytic process, rather than a thermal process. The use of a shorter wavelength also supports a larger depth of focus, thereby increasing the process window. The combination of short pulse width and short wavelength therefore make the picosecond UV laser an ideal candidate for micromachining the copper/insulator laminates in this antenna application.

Recently, industrial USP ultraviolet lasers have increased in average power, which is necessary for high process throughput in applications like 5G antennae cutting. An example is the Coherent HyperRapid NX, which is available with up to 30 watts of output at a wavelength of 355 nm. This enables scan speeds of several meters/sec with typically about 10 passes needed to process the latest antenna designs.

The HyperRapid NX includes a novel pulse control feature called Pulse EQ, which further enhances its capabilities for complex shape cutting or scribing where the beam is rapidly scanned across the substrate. This inevitably involves finite acceleration and deceleration rates so that the motion in straight lines is faster than the motion around tight curves and corners.

This is potentially problematic, since excessive pulse-to-pulse overlap can lead to thermal accumulation and a HAZ, even with the small thermal load created by USP ultraviolet lasers. Instead, this new pulse control feature allows the pulse rate to be controlled in real time: in this case by slaving the pulsing to position/velocity feedback synchronisation signals from the scanners. This ensures that the pulse-to-pulse overlap stays at the constant amount that has been determined to be optimum for each application. Just as important, the pulse control includes active stabilisation of the pulse energy; with older pulsed lasers, changing the pulse repetition rate usually causes variations in the pulse energy.

Figure 1 illustrates how this works with a single pass with a 30 watt ultraviolet USP laser (Coherent HyperRapid NX) on a SiN on Si sample chosen to highlight the pulse ablation pattern in these microscope images.

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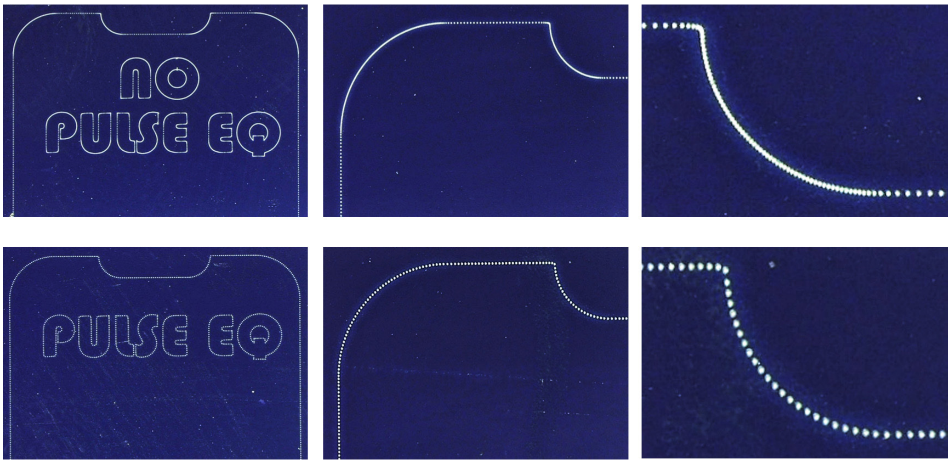

Figure 1: Demonstration of the benefit of active pulse rate control by real time feedback with a single pass over a sample of thin SiN on silicon.