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Automated, reliable lapping and polishing systems make light work of hard silicon carbide and sapphire wafers

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Overview

The lapping and polishing of wafers made from hard materials such as silicon carbide (SiC) and sapphire has always been problematic for a sector centred on high productivity and high quality.

Industry requirements are little short of demanding, and include increased material removal rate (MRR), finer and more consistent surface finishes, less sub-surface damage, and minimised total thickness variation (TTV), surface roughness and flatness. Furthermore, wafer materials such as SiC and sapphire do not come cheap, so it's extremely advantageous to optimise lapping and polishing processes to avoid expensive damage, rework and scrap.

While lapping and polishing techniques have become more predictable in recent years, there is often the need for significant user expertise, guesswork and development time in order to achieve optimisation. However, enhanced process control can be attained through the application of Preston's law, as this delivers a framework for predicting the amount of material that will be removed in a given time by lapping and polishing.

By controlling the variables using advanced automated sample preparation systems, process accuracy and repeatability can be achieved. For hard materials like SiC and sapphire, systems must offer capabilities such as precise parallelism control, high pressure polishing and variable plate speed. Sensors offering real time information for factors such as co-efficient of friction, pad/plate interface temperature and slurry temperature, are also beneficial.

The materials, sapphire

Sapphire substrates, optics and semiconductor wafers are an increasingly important industry segment. Notably, sapphire substrates for LED (GaN) light-emitting diodes are contributing to energy savings, meaning that the volume of sapphire wafers being produced has increased dramatically in recent years.

Synthetic sapphire is a hard, chemically inert, mono-axial crystal material offering excellent optical properties. It also provides thermal stability to 1600°C, a melting point of about 2045°C, and has one of highest hardness values of all materials, after diamond and SiC.

After growing, Sapphire crystals must be cut (or core-drilled and sliced) into the correct crystal angle. Typically LED sapphire wafer substrates are made using C-plane sapphire, although other applications exist for A-plane or R-plane wafers.

The materials, SiC

SiC is even harder than sapphire and has found its place as a popular material choice in fibre optics, LED and power electronics applications. This is because it can operate at a higher temperature, power level and voltage than other wafer materials, thus enabling improved energy efficiency in power devices, LED lighting and telecommunications.

Until the invention of boron carbide in 1929, SiC was the hardest synthetic material known to mankind. It has a Mohs hardness rating of 9, approaching that of diamond. Being so high on the Mohs scale makes lapping and polishing SiC wafers a real challenge without the right equipment.

The process

All wafers are subject to various common stages during production. Typically, these commence with slicing the wafer from the crystal and finish with thinning of the device through lapping and polishing techniques.

Lapping is a process that is typically performed using counter-rotating plates and an aluminium oxide abrasive with defined grain size distribution. The object of lapping is to improve the flatness and micro-roughness of the wafers.

The final material removal step in manufacturing wafers is CMP (chemical mechanical polishing), a process that allows users to generate a super-flat, mirror-like surface with atomic-scale roughness. The process is typically undertaken using the rotary or orbital motion of a chemical slurry between the wafer and a polishing plate.

In both lapping and polishing, a fundamental understanding of the process is necessary to ensure a quality result. After all, there are many variables, including different slurries and polishing pads, while parameters such as polishing rate, pressure and uniformity can all impact the surface of the wafer if they are not applied correctly.

Law and order

To accurately predict the amount of material removed from a sample in a given time, Preston's law needs to be applied. In fact, it is possible to analyse the Prestonian behaviour of MRR to confirm process stability.

According to Preston's equation, MRR is proportional to the product of the processing pressure/load/down-force and plate velocity. In the CMP process, the polishing rate and precision are impacted not only by the slurry flow and the characteristics of the polishing plate, but also by factors such as the mechanical action between the wafer and the plate, the chemical action resulting from the chemical components of the slurry, and the interactions between them. In short, timers based upon predictions from Preston's law can be used to accurately predict the amount of material removed from a sample.

It almost goes without saying that achieving the precision and surface finish required in hard wafer applications is a skilled job. This is due chiefly to the levels of manual set-up and control needed. The process is also laborious and not conducive to the high levels of throughput demanded by industry. After all, the quest for cost reductions in the manufacture of semiconductor devices are driven by volume and yield.

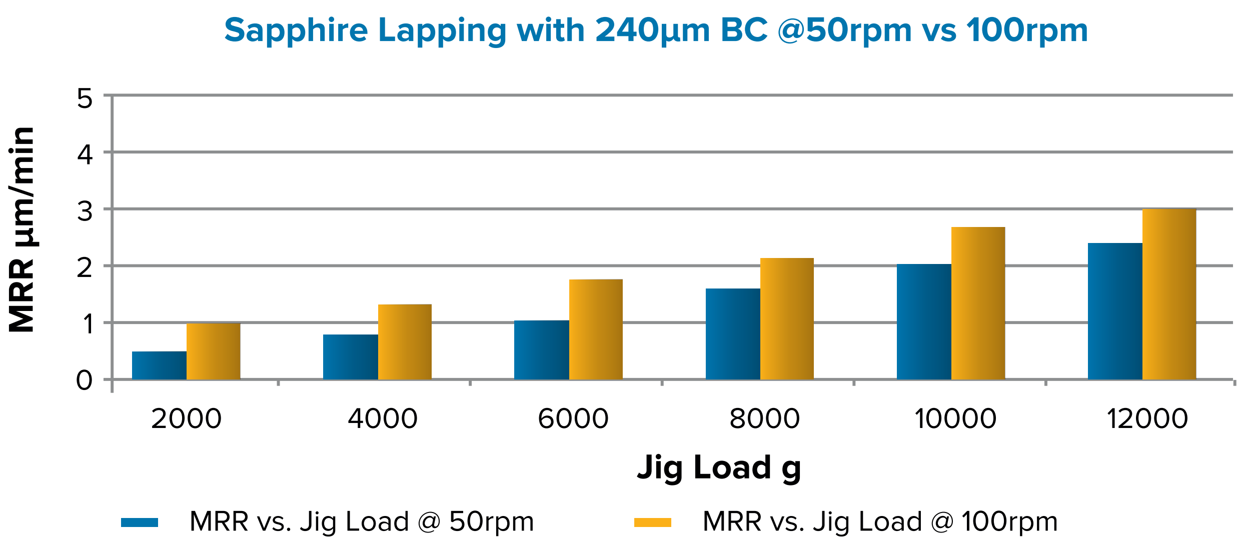
The trials

Tasked with overcoming these issues, Logitech created a process matrix to establish the stability and repeatability of a number of processes with the objective of guaranteeing conformance with Preston's law.

The company set out to confirm that advanced sample preparation systems such as Logitech's Akribis-Air can offer the accuracy, repeatability and control to confidently deliver optimum surface finishes and precise geometric tolerances on hard wafer materials such as SiC and sapphire.

The trials: sapphire

Trials involving the lapping of 50 mm sapphire wafers showed impressive results. Using 240 µm BC (boron carbide) abrasive, at 50 rpm versus 100 rpm, the typical removal rate with the Akribis-Air was boosted to 3-5 µm/min from 1-3 µm/min using the standard system. Changing the abrasive for 400 µm BC showed similar gains of 0.5-1.5 µm/min over 0.3-0.8 µm/min.

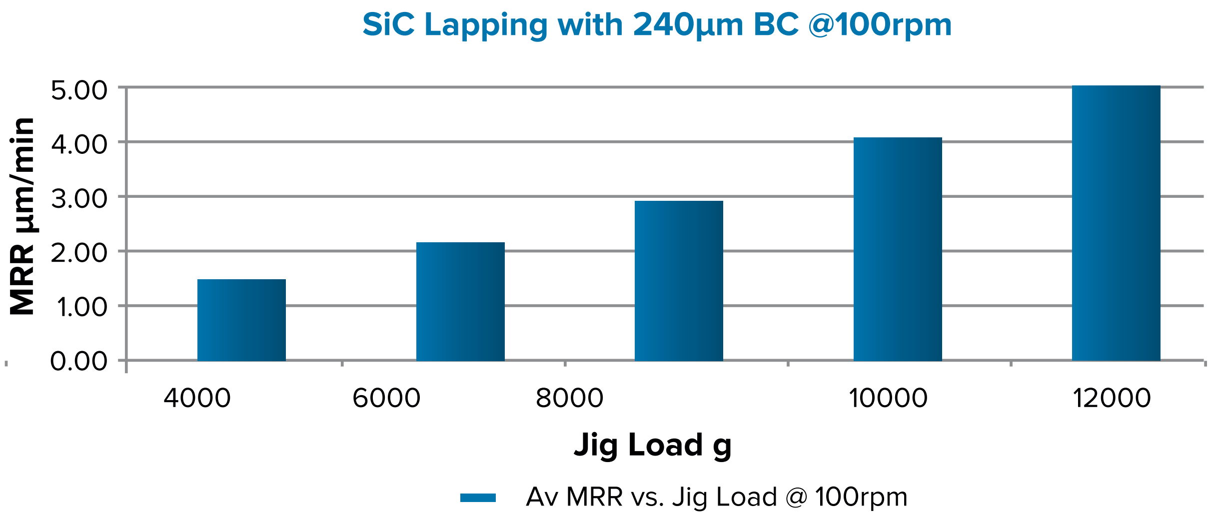


In short, the trials showed experimental evidence of the relationship between pressure, plate speed and MRR. Moreover, the system demonstrated precise control of the processing pressure and plate speed to ensure accuracy and repeatability.

Regarding sapphire polishing at 100 rpm, the Akribis-Air was able to remove material at a rate of 1-3 µm/hr – precisely double that achieved with the standard system. The average TTV over the 50 mm sapphire wafer was less than ±2 µm. Similarly, the average polished surface roughness was 1-2 nm, while average flatness was less than 2 µm.

The trials: SiC

Akribis-Air trials on 100 mm SiC substrates demonstrated an average lapping MRR of 4-6 µm/min, and 4-6 µm/hr when polishing. Moreover, the average TTV over the wafer was less than ±2 µm, the average polished surface roughness was 1-2 nm, and the average flatness was less than 2 µm.



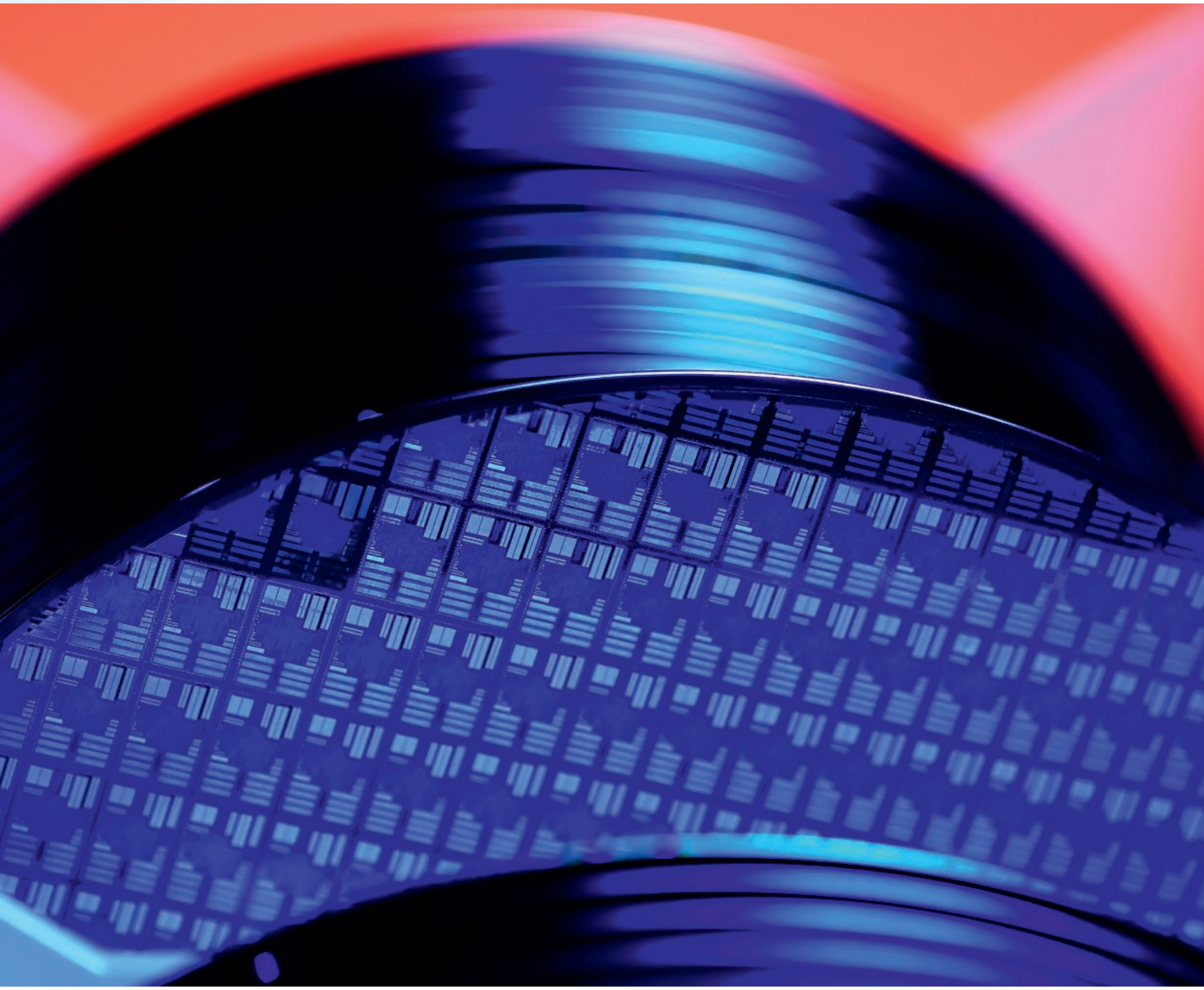
For both wafer materials, SiC and sapphire, the trials witnessed ±1 µm on end point thickness target values.

Automation

While MRR is improved with Akribis Air for both SiC and sapphire, the inherent hardness of these wafer materials means that cycle times are slower than for standard silicon for example. As a consequence, it is vital that automated technology is deployed for polishing and lapping as this will allow the machine to run unattended, thus negating labour costs.

Without doubt, automation can also help semiconductor and optical device manufacturers to optimise the sample preparation process. For example, automatic wafer thickness control on the Akribis Air provides a high level of geometric precision, flatness and parallelism, while software-based set-ups permit faster cycle times (in combination with plate speed up to 100 rpm) and more reliable results. Parameter control for the processing of complex and fragile materials/devices, and metered abrasive feed supply for optimal processing and reduced waste, are also hugely beneficial.

Workholding is another area of lapping and polishing systems that requires attention. This is why Logitech has introduced air-driven jig technology to the Akribis Air to hold the sample or substrate securely in place during processing. Among its principal features is dynamic load control for quicker, more responsive processing, while Bluetooth connectivity offers real-time data provision and enhanced control. In addition, there's an increased load range for higher removal rates while ensuring TTV remains low.



Conclusion

Semiconductor, optical device, LED and power electronics manufacturers need to achieve greater process control and exploit real-time data in their drive towards better productivity and reliable, repeatable quality.

When processing hard wafer materials such as SiC and sapphire, the Logitech trials demonstrate that automated sample preparation systems like the Akribis-Air can deliver faster total cycle times and MRR up to three times that of existing Logitech systems. What's more, low surface roughness values can be attained more efficiently, together with impressive process repeatability, precision, TTV and flatness control.

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