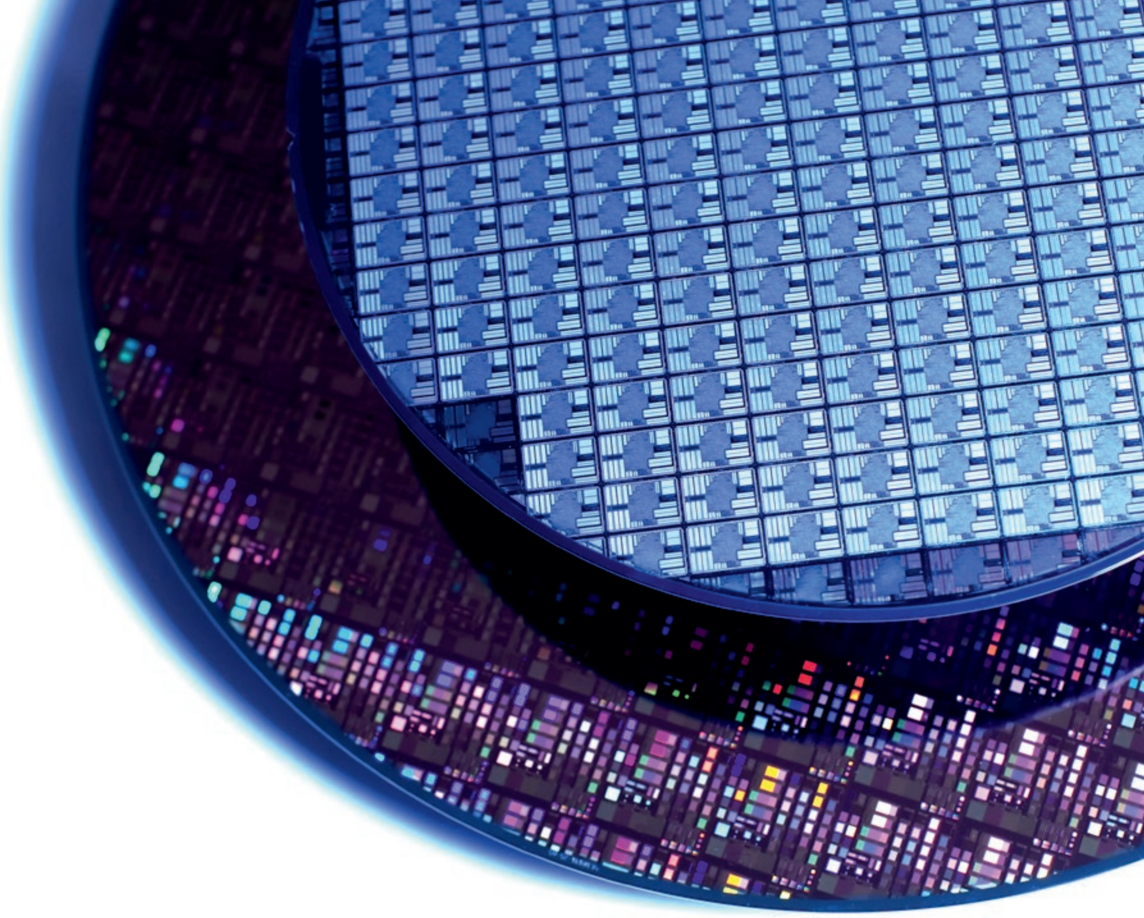


Since 1965
LOGITECH
Materials Technologists & Engineers
50
a tradition of excellence in precision materials technology

Finishing first – how automated systems improve the productivity and repeatability of wafer lapping and polishing

Author: Mark Kennedy

Overview

The lapping and polishing of wafers for use in semiconductors and optical devices is a time consuming task that can risk damage to expensive custom wafers worth in excess of $5000 each if things do not go to plan.

While lapping and polishing processes have become more predictable, there is often the need for a significant level of user expertise, guesswork and development time in order to optimise surface finish and repeatability. This can hamper the development of new technologies, especially as a process that is optimised at the pilot stage will often need to be revisited when transitioned to full production.

The path to better process control lies with Preston's law, which provides a framework for predicting the amount of material that will be removed in a given time by lapping and polishing processes. By controlling the variables using advanced automated sample preparation systems, operator variability can be minimised and process accuracy and repeatability can be delivered.

The process

Every semiconductor wafer undergoes several common stages during manufacture, including slicing the wafer from the crystal, preparing the surface prior to fabrication and subsequent thinning of the device through the deployment of lapping and polishing techniques.

After slicing, wafers made from silicon, III-V, I.R. and similar materials.sapphire, silicon carbide and other semiconductor and optical device materials are lapped to remove the surface damaged by the cutting process. Typically, this is performed using counter-rotating plates and an aluminium oxide abrasive with defined grain size distribution. During lapping, the flatness and micro-roughness of the wafers are improved.

CMP (chemical mechanical polishing) is the final material removal step in manufacturing wafers. This process allows the attainment of super-flat, mirror-like surfaces with a remaining roughness on an atomic scale. Typically, CMP is achieved using a rotary or orbital motion of a chemical slurry between the wafer and a polishing plate.

Industry requirements

There are many reasons why wafer manufacturers need stability and repeatability when it comes to sample preparation. For instance, stringent quality requirements dictate that parameters such as total thickness variation (TTV), surface roughness and flatness must be minimised.

In all cases, a fundamental understanding of the process is required to ensure a quality outcome. Different types of wafer materials, slurries and polishing pads, along with polishing rate, pressure and uniformity can all impact the resulting surface. It is also important not to overburden the surface with too much slurry, as is the potential to detect when the polishing process is complete.

To put this in simple terms, it is vital to accurately predict the amount of material removed from a sample in a given time. Here, Preston's law can be deployed. Indeed, it is possible to analyse the Prestonian behaviour of material removal rate (MRR) to confirm that all-important process stability.

Preston's law

Preston's equation states that the MRR is proportional to the product of the processing pressure/load/down-force and plate velocity. In the CMP process, the polishing rate and accuracy are affected not only by the flow of the slurry and the characteristics of the polishing plate, but also by 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.

M	=	a * p * v * t * + C					(y = mx + c)			
Material Removed (µm)	=	Constant	*	Processing Pressure (g/cm2)	*	Plate Speed (rpm)	*	Processing Time (mins)	+	Constant

Preston's law can be used to accurately predict the amount of material removed from a sample and confirm stability in the process. The process stability is generated by using a stable / accurate / repeatable processing platform such as that available on the Akribis-air.

Needless to say, it's a very skilled job to achieve the precision and surface finish required in demanding wafer applications, due mainly to the required levels of manual set-up and control. It is also time consuming and not conducive to the productivity levels demanded by industry. After all, the search for cost reduction in semiconductor device production is driven by volume and yield.

With this in mind, the Logitech team set up a process matrix to establish the stability and repeatability of a number of processes to guarantee conformance with Preston's law. The aim of the trials was to confirm that advanced sample preparation systems such as the Logitech Akribis-Air can offer the accuracy, repeatability and control to confidently deliver optimum surface finishes and precise geometric tolerances.

Silicon Lapping and Polishing

Lapping and polishing trials using a typical silicon substrate deployed in semiconductor applications such as integrated circuits, solar and waveguides, proved extremely revealing.

In a typical silicon lapping and polishing process, a series of steps are used, each with a different slurry solution.

Firstly a coarse lapping process is undertaken, to remove material within 50 µm of the end point target. Previous experiments have shown that slurries containing Al_2O_3 particles measuring 20 µm provide the optimum balance between material removal speed and maintaining the integrity of the underlying silicon wafer.

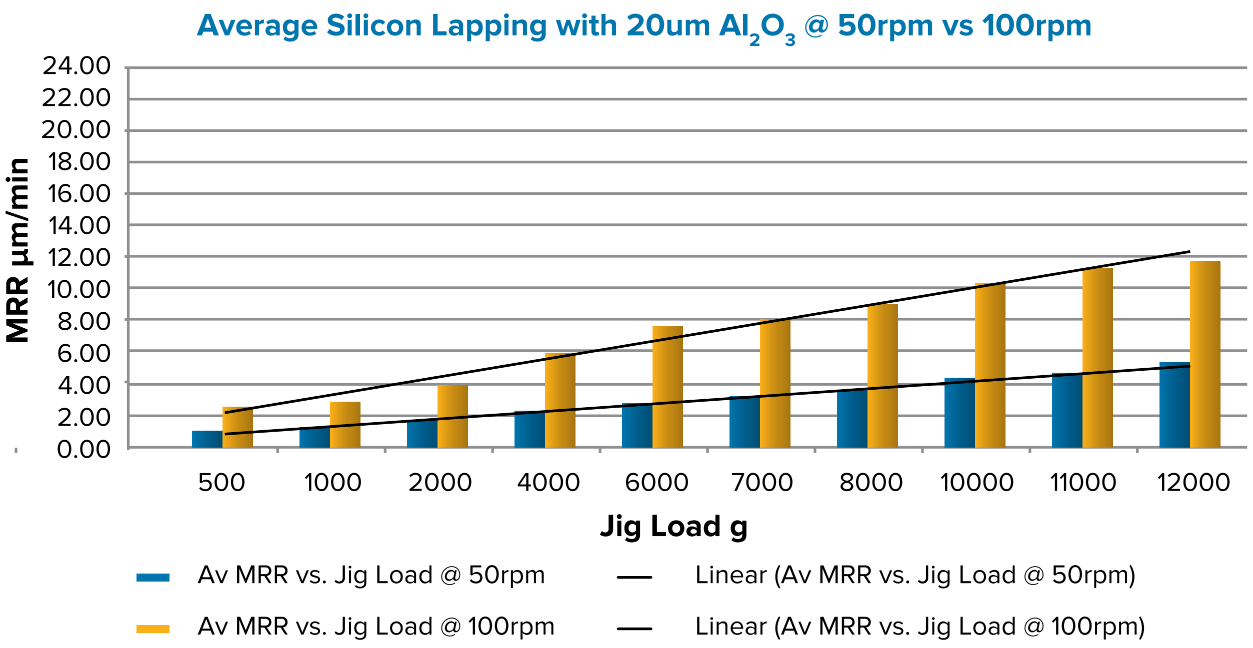
In a second stage, a medium / fine lapping process is conducted, during which a finer, less abrasive 9 µm Al_2O_3 slurry is used to remove materials to within 10 µm of the end point target.

The final stage involves removing the final micrometers of material and any damage caused to the wafer during the lapping process using 32nm colloidal silica, Logitech SF1 polishing slurry. After undergoing all three stages, a typical surface roughness of Ra < 1nm is achievable.

In short, tests to determine average silicon lapping at 50 rpm versus 100 rpm, showed an average MRR of 18-22 µm/min with the Akribis-Air compared with just 7-9 µm/min using a standard Logitech lapping and polishing system. When added to the substantial time savings and accuracy provided with the automated set-up and control platform, and the internal clean-up facility, total process time savings were in the region of 40%.

Coarse lapping stage

During the coarse lapping stage, 100 mm silicon substrates were processed using 20 µm Al_2O_3 abrasive and a radial grooved cast iron plate. The slurry flow rate, abrasive type, plate type and plate speed were kept constant. Only the pressure (jig load) was varied, between 500 and 12,000 g of down force.

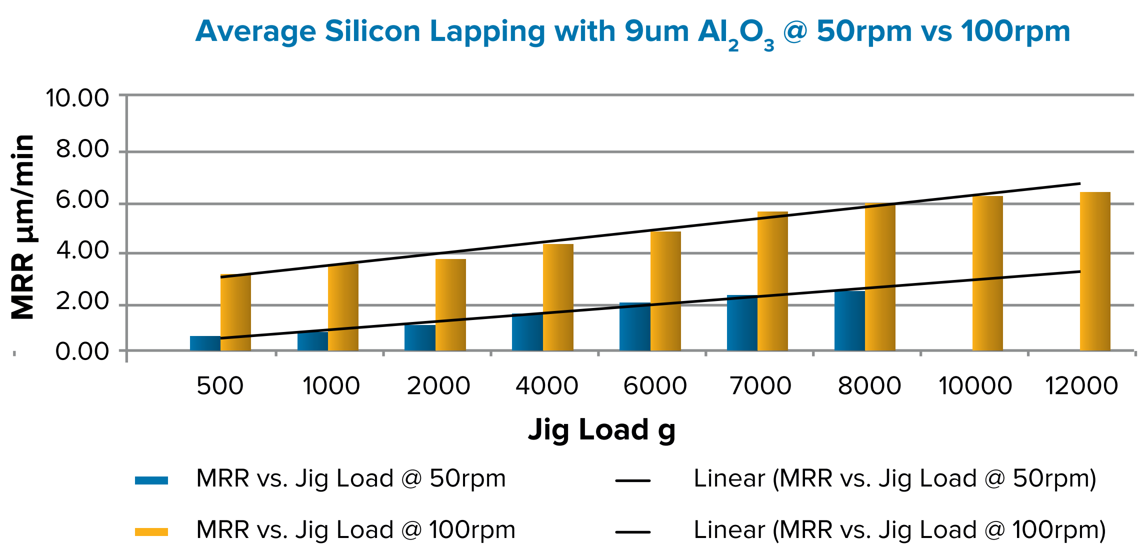


The trials showed experimental evidence of the relationship between pressure, plate speed and MRR. Moreover, the system demonstrated precise control of the processing pressure and plate speed to ensure accuracy and repeatability.

This precise control also enables accurate modelling of the system, and parameters can be controlled to provide the optimum conditions for a desired MRR.

Medium / fine lapping

During the next stage, a finer, less abrasive slurry was used that contained 9 µm Al_2O_3 particles. Here, average MRR using the Akribis-Air was 4-6 µm/min in comparison with just 2-4 µm/min using a standard system.

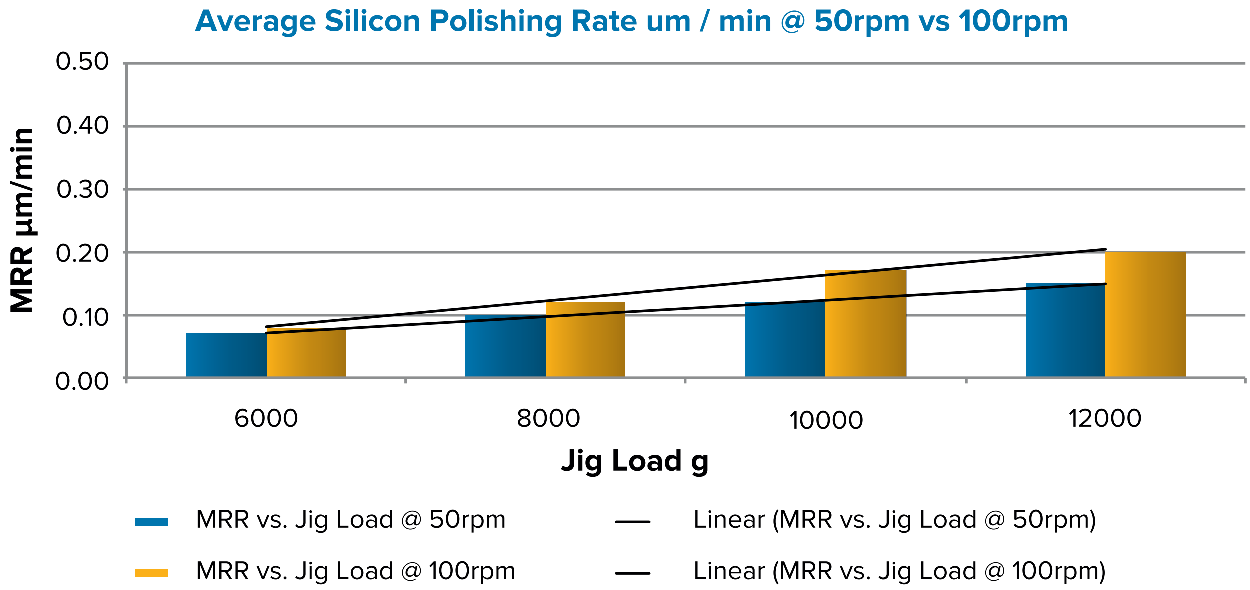


Again, the experimental results provided solid evidence of the precise control of processing parameters by the Akribis Air, which enabled accurate and precise material removal.

By extrapolating system constants material removal rates could be accurately predicted, for Jig loads between 500g and 12000g.

Polishing

The final polishing stage utilised an SF1 polishing slurry containing 32nm colloidal silica particles. Here the aim is to remove the final 10 µm of material along with any wafer damage caused during the lapping phase.



Due to the nature of the polishing stage, material removal rates of between 10-12 µm/hr were achieved at both 50 rpm and 100 rpm. The speed of material removal is considerably faster than the 2-4 µm/hr achieved under the same conditions using a Logitech PM5 /LP50 a set-up previously considered to be best-in-class.

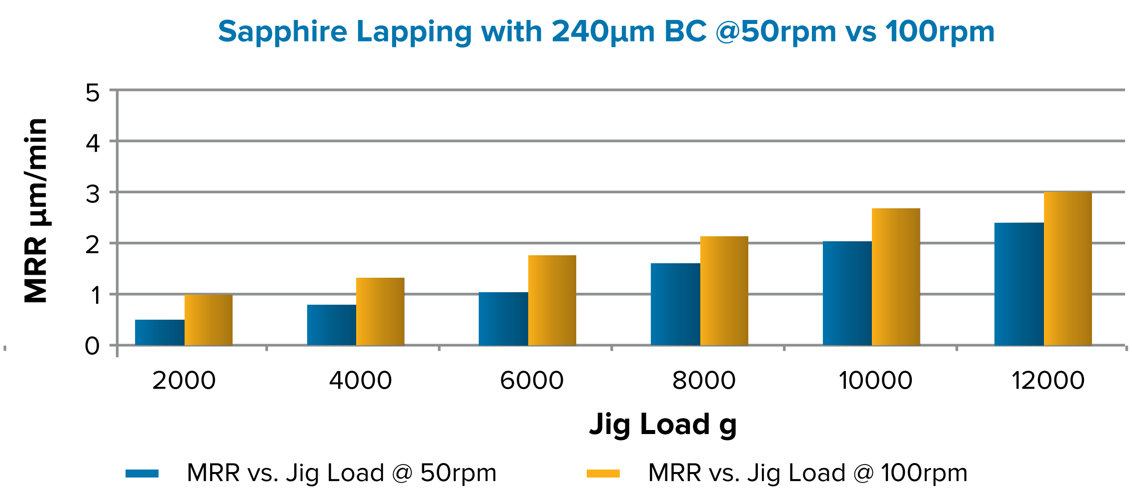
Despite these impressive removal rates, nothing was achieved at the detriment of quality. Indeed, the average TTV over the 100 mm silicon wafer was less than ±2 µm. Likewise; the average polished surface roughness was 1-2 nm, while average flatness was less than 2 µm.

Applicability to other materials

The trials: sapphire

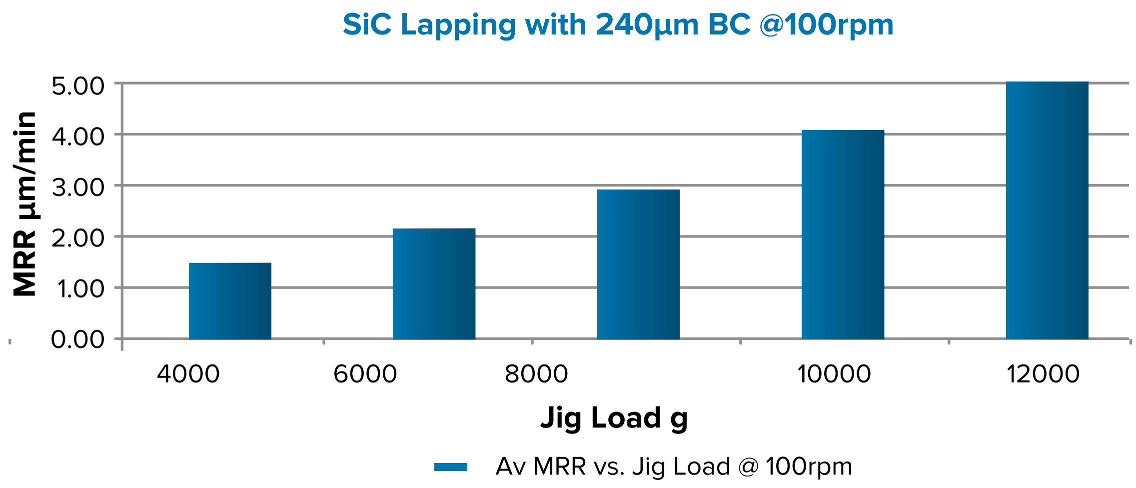
To test the theory further, trials were also conducted on 50 mm sapphire wafers, which is typically the material of choice in LED substrate and optics applications.
In Sapphire lapping with 240 µm BC (boron carbide) abrasive, again at 50 rpm versus 100 rpm, typical removal rate with the Akribis-Air was 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.

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 ±1 µm. Similarly, the average polished surface roughness was 1-2 nm, while average flatness was less than 2 µm.



The trials: silicon carbide and gallium arsenide

Akribis-Air trials on 100 mm silicon carbide substrates found in fibre optics, LED and power electronics applications demonstrated an average lapping MRR of 4-6 µm/min, and 4-6 µm/hr when polishing. The results were equally impressive on 100 mm gallium arsenide wafers, a material popular for solid state lasers, microwave frequency integrated circuits, monolithic microwave integrated circuits, infrared light-emitting diodes, laser diodes, solar cells and optical windows to list but a few. Here, lapping removal rates were controlled in the range of 7-10 µm/min, with polishing at 3-7 µm/hr.



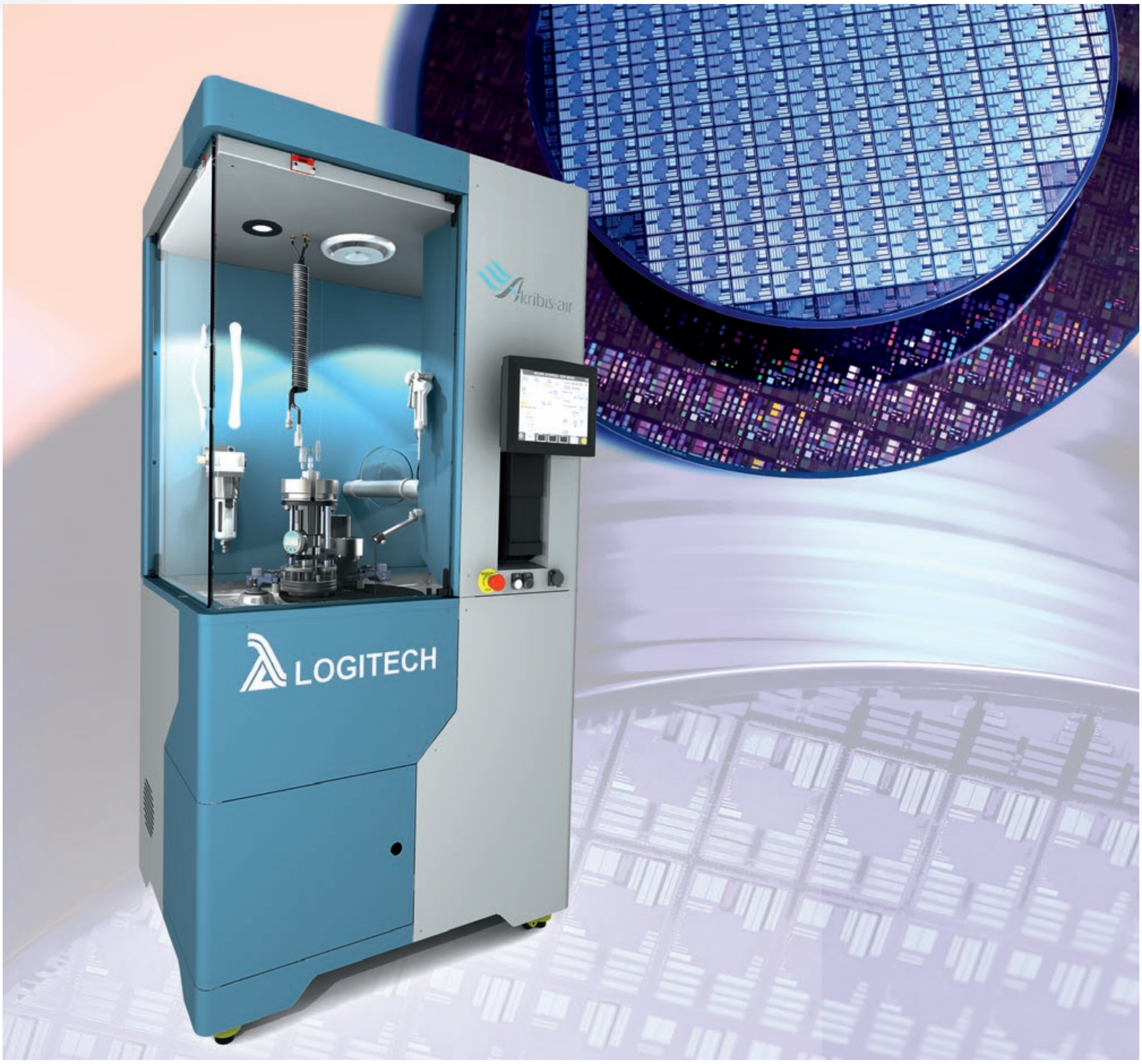
For both silicon carbide and gallium arsenide, the average TTV over the wafer was less than ±2 µm, the average polished surface roughness was 1-2 nm, and the average flatness was less than 2 µm. For all wafer materials, including silicon and sapphire, the trials witnessed ±1 µm on end point thickness target values.

Automated controls and air jigs

To comprehend how such impressive results have been achieved, it is necessary to consider the differentiating features of automated systems such as the Akribis-Air, in particular features like automated controls and air jigs. It is clear that these technologies can help semiconductor and optical device manufacturers to precisely optimise the sample preparation process.

For instance, automatic wafer thickness control helps deliver a high degree of geometric precision, flatness and parallelism, while software-driven set-up permits faster processing times (in tandem with plate speed up to 100 rpm) and more reliable results. There is also extensive parameter control for the processing of complex and fragile materials/devices, and metered abrasive feed supply for optimal processing and reduced waste.

Another key aspect of the system is air-driven jig technology, which holds the sample or substrate in place during processing. Importantly, this delivers dynamic load control for faster, more responsive processing, while Bluetooth connectivity offers real-time data provision and improved levels of control. There is also an increased load range for higher removal rates while maintaining low TTV.



Conclusion

Semiconductor and optical device manufacturers demand greater process control and real-time data in their quest for improved productivity and reliable, repeatable quality.

Evidence from extensive trials demonstrates that automated sample preparation systems such as the Akribis-Air can offer significant process improvements, specifically relating to faster overall process times, and MRR up to three times faster than existing Logitech systems. Furthermore, low surface roughness values can be achieved more efficiently, along with high process repeatability and impressive accuracy, TTV and flatness control.

Since 1965

LOGITECH

Materials Technologists & Engineers

50

a tradition of excellence in precision materials technology

For further information please visit our website:

www.logitech.uk.com