Reversible Wafer Bonding; Challenges in Ramping up 150mm GaAs Wafer Production to Meet Growing Demand.

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Key Words: 150mm GaAs wafer, backend process, cycle time reduction, process capability, yield.

ABSTRACT

At Filtronic Compound Semiconductors' 150mm gallium arsenide wafer fab in Newton Aycliffe a reversible wafer bonding process has been developed to accommodate a significant increase in wafer production through the backend processes. This method of mounting and demounting wafers from sapphire substrates has produced mechanical and visual yield exceeding 99% while demonstrating process capability for wafer thinning >1.7 CpK. This paper will discuss the process development for wafer bonding and de-bonding in a volume-manufacturing environment along with the challenges experienced with rapid growth in wafer demand.

INTRODUCTION

Temporary bonding of wafers to their support substrate is a critical stage in the manufacturing of GaAs based devices as it enables wafers to be thinned while maintaining enough rigidity for further backend processing. Engineers face the challenge of selecting from a wide array of materials to mount the wafers to the supporting substrates [1-8]. The bonding material must be able to withstand the variety of back face processes that are required when addressing several product families. The challenge does not end there; key performance indicators such as cycle time, final wafer thickness, total thickness variation, mechanical and visual yield become of significant importance as wafer volumes increase. The product portfolio at Filtronic from the perspective of a back face process engineer can be simplified into two categories.

i) Wafers requiring through wafer vias, therefore bonding, thinning, via formation, back metal, and de-bonding.

ii) Wafers requiring bonding, thinning and de-bonding only.

The latter product has experienced a vast increase in wafer volumes in the past twelve months. Wafers requiring more complex back face processes are of lower volume but are high value and therefore mechanical and visual yield are equally as important.

WAX BONDING VERSUS ADHESIVE TAPES

Wax bonding has been predominant throughout the industry [3-6] and at Filtronic. A protective coat is applied to the active face of the wafer, a dry film wax is then utilised to temporarily bond the wafer to the support sapphire. This method proved compatible with all automated back face processing such as grinding, photolithography, dry etch and metalisation. Wax bonded wafers proved to demonstrate excellent final wafer thickness control and within wafer variation (figure 1). However, the lengthy solvent demount required has cost and environmental implications. To obtain wafer cleanliness post de-bonding, expensive solvents are required to remove the wax and photo resist protective coat. These expensive solvents must be frequently replenished which is costly and requires equipment downtime. The solvent de-bond process also necessitates handling of unsupported thin wafers increasing the risk of damage. It was therefore considered imperative to explore alternative solutions to accommodate a rapid expansion in wafer throughput. The back-face engineering team embarked on a project to develop a process compatible with existing fabrication processes that would enable increased throughput while improving visual and mechanical yield.

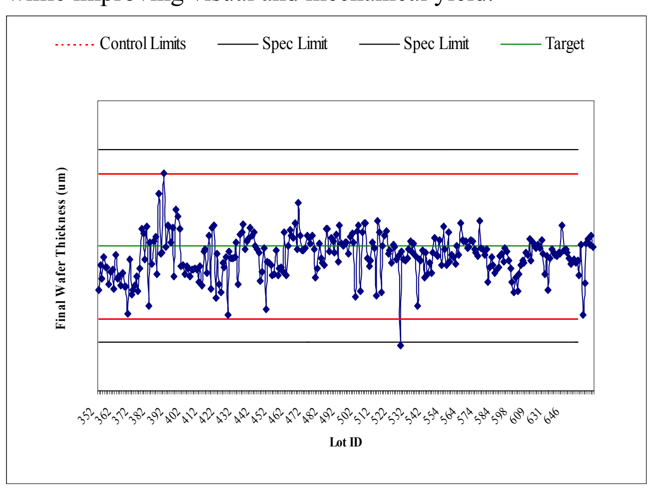

Figure 1. Final wafer thickness control for wax bonding process

Thermal release adhesive tape was proven to be an attractive alternative to wax bonding [7-8]. This process was investigated for the volume production routes with minimal investment in equipment. The wafer is coated with a protective coat to protect the active face prior to lamination of the double-sided adhesive tape (figure 2). The tape is applied with the thermal release adhesive towards the wafer surface, the protective liner is removed and the sapphire applied. Secure adhesion between wafer and support substrate can be achieved at room temperature capable of withstanding the mechanical grind process and subsequent processes. Once a wafer has received the back face processing it can be de-bonded rapidly from the sapphire by applying heat. Heating the adhesive tape above the release temperature initiates a foaming reaction in the thermal release adhesive side, within seconds adhesive strength reduces to near zero as a result of decreased contact area (figure 3). The wafer and the support substrate can then be separated easily.

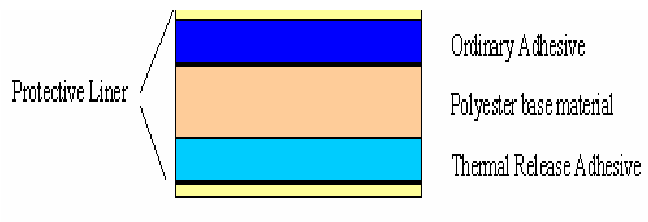

Figure 2. Construction of Thermal Release Adhesive Tape

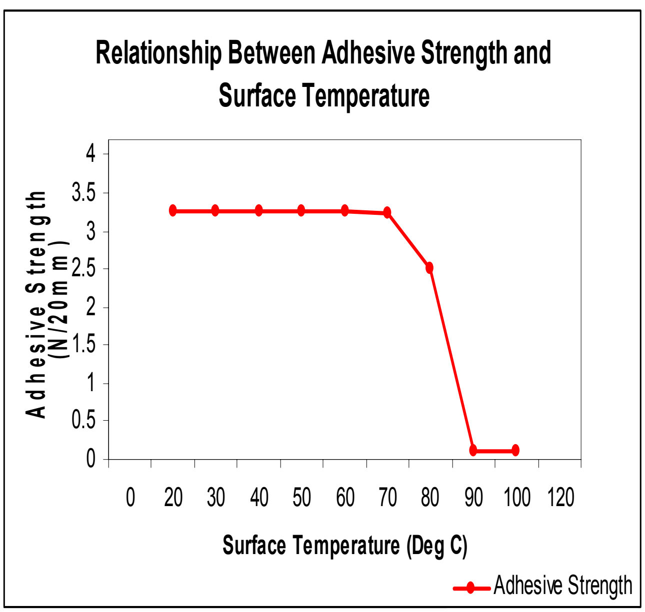

Figure 3. Effect of Temperature on the Adhesive Strength

The ability to maintain a uniform and repeatable bond thickness is deemed process critical when thinning wafers in a volume environment. Wafers are processed in batches of up to 18, therefore any within wafer thickness variation or wafer-to-wafer inconsistency of the bond will result in poor control of final wafer thickness. Bonding wafers with adhesive tape successfully enables temporary wafer bonding with exceptional final wafer thickness process capability. The process demonstrates a Cpk greater than 1.7 (figure 4).

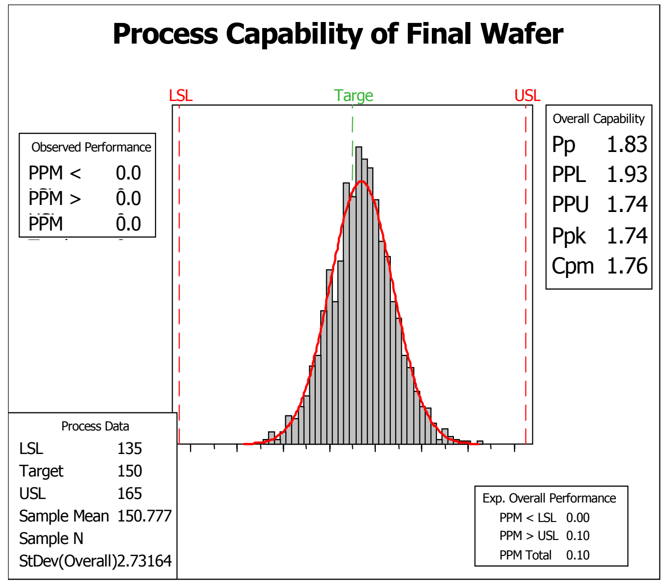

Figure 4. Process Capability for Adhesive Tape Bonding Process

Of equal importance is wafer cycle time. Utilising adhesive tape enables throughput of the wafer-thinning module to increase significantly without the necessity to invest in expensive de-bonding equipment. The process cycle time for a wax-bonded wafer in contrast is lengthy due to the time consuming solvent demount stages. These processes utilise expensive solvents, which are used at an elevated temperature. The chemical exchange frequency required to ensure wafer cleanliness makes the wax bonding process impractical for very large volume operation. During this high temperature solvent process the thinned wafer is predominantly unsupported posing mechanical yield concerns. Whereas utilising adhesive tape allows for the wafer to be mounted to film frame immediately after the sapphire is removed. The supported wafer will progress for cleaning, on wafer test, and die singulation. Given that the thinned wafer is almost always supported the resulting mechanical yield exceeds 99% (figure 5).

At Filtronic the visual inspection regime is intensive. To ensure no defects are induced as a result of the wafer thinning process the protective coat remains in place until the entire process is complete. Once mounted to film frame the final process step is to remove the protective film along with any particulates. This technique ensures no damage to active device structures as well as exceptional visual quality. After cleaning the wafer is progressed to end of fab final automated inspection (figure 6). Every wafer is inspected and defects classified. The visual inspection sampling rate varies as a consequence of a number of parameters these guarantee a quality level agreed with the customer.

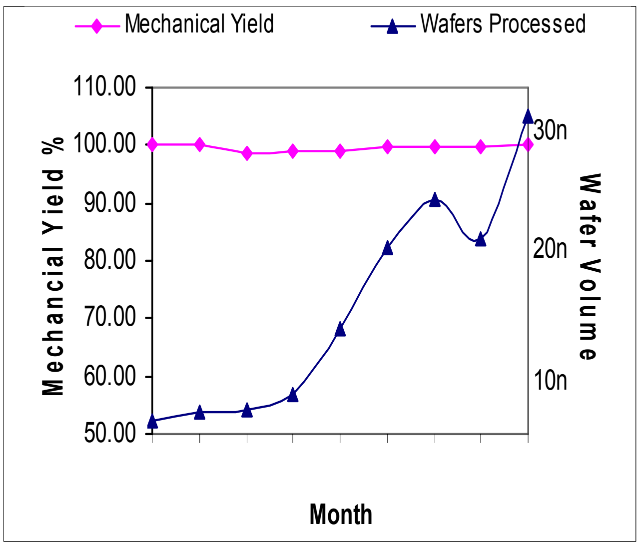

Figure 5. Mechanical yield as a % of wafer throughput

Figure 6. Automated Inspection at Filtronic

Investigation into the use of the thermal release adhesive tape for wafers with through wafer via processes have introduced a number of complications. Certain automated processes such as via formation or seed layer deposition can reach elevated temperatures for extended periods of time. Such processes have shown to initiate the thermal release reaction during the wafer processing. The wafer is no longer securely adhered to the support substrate hence further processing results in significant wafer damage. For this reason the adoption of the adhesive tape bonding method for all processes is in abeyance. To maximise the effectiveness of an automated bonding and de-bonding solution a common mount medium is required for all product routes prior to significant capital investment. Potential exists to develop the adhesive tape process such that is it is compatible with all automated through wafer via processes.

ONGOING DEVELOPMENT

Filtronic continues to increase its wafer throughput to meet the needs of its customers. To meet these needs the back-face engineering group continues to explore improved processes. Fully automated bonding and de-bonding equipment offers significant advantages over the semi-automatic equipment employed today and a number are being explored. There are several systems that are becoming available on the market (figures 7&8). These machines offer cassette-to-cassette bonding/de-bonding with adhesive tapes such that the wafer is never unsupported and wafer output is in the region of 40wf/hr [9-10]. Similar equipment is available for wax bonding.

The immediate aim is therefore to streamline the end process flows enabling the use of a common temporary bonding solution. This project has led to evaluation of a number of newer adhesive tapes whose release mechanism is activated by a number of different stimuli and where process temperatures are less of a concern. These solutions include higher temperature thermal release tapes, and others, that utilise different thermal release mechanisms from those already investigated.

The equipment tools presently being evaluated are adaptable to the different adhesive tapes that are available enabling the optimum release procedure to be chosen for the requirements of the Filtronic product portfolio to ensure continuous improvements in the key performance indicators such as cost, mechanical yield and de-bond cycle time.

Figure 7. Takatori WSM100 Bonder (with kind permission).

Figure 8. EVG850 bond and de-bond systems (with kind permission).

CONCLUSION

A significant improvement to bonding and de-bonding methods has enabled Filtronic to meet the demands of a diverse product portfolio. At the same time achieving the cycle time requirements, excellent yields and process performance in the wafer thinning process that are expected of a high volume wafer manufacturing facility. Future process development will be to explore emerging technology to facilitate further increase in wafer demand while maintaining key performance indicators. Additionally emphasis will be placed on further developing wafer bonding processes that are fully automatic.

ACKNOWLEDGEMENTS

The authors would like to thank all the staff at Filtronic Compound Semiconductors. Thanks also to EVG, GTI Corporation, Sekisui, and Adhesives Research for their ongoing support in process development activities.

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