SINGLE SIDED WAFER THINNING FOR 3D INTEGRATION

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ABSTRACT
High uniformity, single-sided wafer thinning is an enabling step for 3D wafer-level integration and for next generation 3D packaging solutions. We will present field results from a new wet etch thinning technology that allows for the thinning of wafers down to 50 um or less, with better uniformity, and at a lower cost than conventional thinning—without the need to protect the non-process side. The technology produces smooth edges without encroaching onto the non-process side. The method is intrinsically uniform throughout the entire surface, including the edges of the wafer. The linear scan technology exposes every area element of the wafer to the same chemical environment, thus avoiding gradients and centrosymmetries that result in large total thickness variation (TTV). In contrast, conventional thinning technologies that spin, spray or grind the wafers have inherent limitations on both uniformity and the final thickness that is practical and cost-effective to achieve with them. Linear scan processing is accomplished by scanning the wafer over a thin meniscus of etching chemicals. This technology also makes the process size and shape independent, and significantly reduces chemical and rinse water consumption. The backside is protected by a gas dynamic confinement method that effectively keeps chemicals and vapors away from the non-process side, thus eliminating the need for any kind of backside protection, such as resist or tape. The technology is suitable for virtually any material, such as silicon, germanium, glass, quartz, III-V, II-VI, among others. Also, wafers with tape or carriers can easily be etched by this method. The etching technology presented herein makes no contact with the wafers and does not spin them; it is thus very gentle and suitable for very thin or very distorted wafers. The same wet processing system can effectively clean packages with low standoff heights and remove polymer or tape residue. Optional application of megasonics to the cleaning or stripping operations enhances the process throughput and efficiency.

Keywords: Chemical Thinning, Etching, Stress Relief, WaveEtch, Linear Scan.

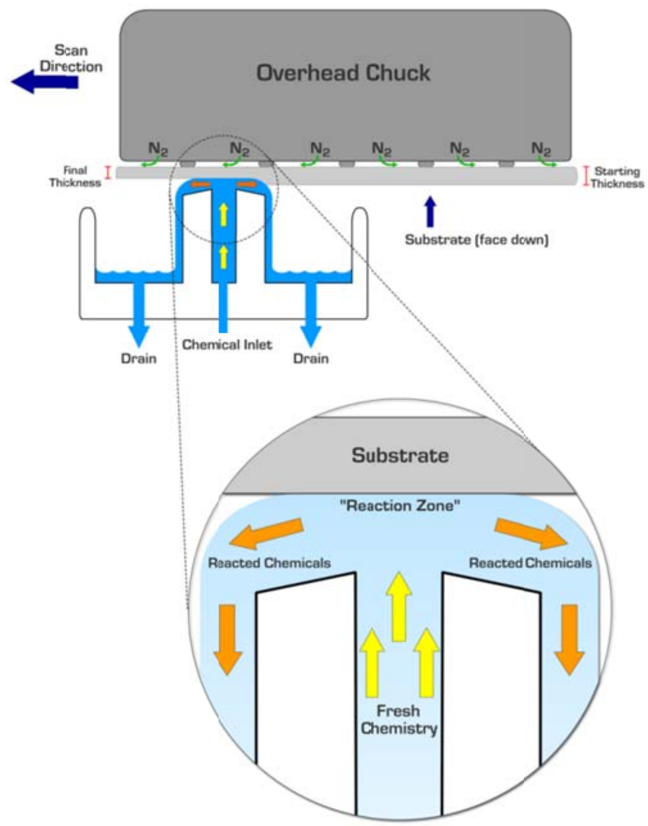


Figure 1a. Schematic representation of the LinearScan process depicting the substrate (held process side down) material being removed by the etching process, as well as the orthogonal paths of the reactants and the byproducts. The shaped flow of gas (DynamicConfinement), preventing the encroachment of fluid and vapors onto the non-process side (top), is also shown. Note the removal of material (etching) after the wafer has passed over the fluid meniscus and the different paths the reaction byproducts take to avoid interference with the supply of fresh reactants to the reaction zone.

INTRODUCTION
Wet etching involves the interaction between a liquid and a solid substrate and it is often the fastest and most cost-effective way to remove material[1], selectively or across an entire surface, as is required in packaging applications as well as many other steps of semiconductor fabrication.

The demand for lower package heights, higher power requirements, and the development of higher-functionality systems-in-a-pack (SiP) are driving the need for more robust, lower cost, higher yield thinning technologies[2]. When the substrate can be wetted on both sides, immersion is a common choice for etching and thinning. If the substrate can only be exposed to the chemicals on one side, spin or spray become reasonable candidates, but both have their

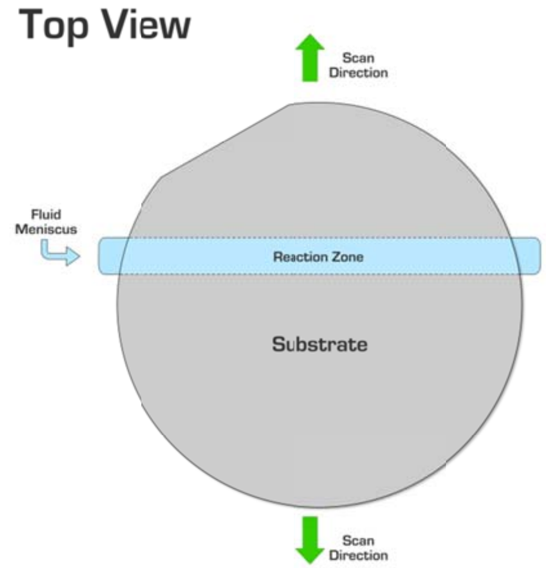


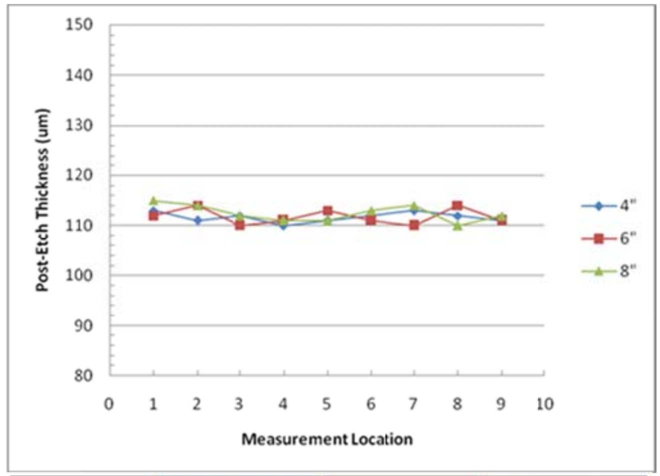
Figure 1b. Top view (wafer is being etched from below) of a wafer being scanned repeatedly in alternating directions, as necessary, over the fluid meniscus showing the narrow reaction zone where thinning is in progress.

shortcomings, such as radial and transport-induced non-uniformities. Depending on the particular package or device requirements, improved uniformity (in terms of total thickness variation, or TTV) is often an important consideration and conventional technologies have clear limitations in terms of how much material they can remove while staying within the allowed TTV requirements. Also, conventional technologies often result in undesirable exposure of the non-process side to residual liquid or vapors.

While immersion etching and spin/spray systems are still common in the industry, the need for better etching processes has become apparent. New device manufacturing techniques are becoming more demanding, which typically mandates the use of single-wafer, single-sided processing. In addition, thinner, denser packages, tighter TTV specs, and the push for increased functionality are driving this trend with no end in sight[3].

LINEAR SCAN ETCHING

A new technology: WaveEtch LinearScan etching provides high uniformity as well as true single-sidedness on ultra-thin, large substrates. It addresses the main shortcomings of conventional wet processing by providing a consistent and uniform supply of chemicals throughout the liquid-solid interface while making available an orthogonal path for the



Location	4" Post-Etch Thickness (um)	6" Post-Etch Thickness (um)	8" Post-Etch Thickness (um)
1	113	112	115
2	111	114	114
3	112	110	112
4	110	111	111
5	111	113	111
6	112	111	113
7	113	110	114
8	112	114	110
9	111	111	112

Figure 2. The material removal uniformity (Total Thickness Variation or TTV) typical of the WaveEtch LinearScan thinning process is illustrated above. TTV ranges from ±1.5 um for 4" wafers to ±2.5 for 8" wafers after the removal of 75 um to reach a final thickness, in this case, of 112 um.

byproducts, such as gases and vapors. Exposure of every surface element to the same chemical and transport environment makes the process intrinsically uniform (Figures 1a and 1b). The solid-liquid interface (boundary layer) is not subject to speed gradients, convection, or other transport-related gradients that may cause variations in its thickness and its concomitant impact on uniformity. The system eliminates virtually all transport-related and centrosymmetrical non-uniformities, which plague spin/spray and immersion processes. Figure 2 shows the uniformity of 4", 6" and 8" wafers (as total thickness variation or TTV) after the removal of 75 um. Substrates are held on their non-process side by conventional vacuum or noncontact chucks, while being gently scanned over a narrow pool of chemicals. Reactants enter the reaction zone through the bottom of the pool while the byproducts exit in

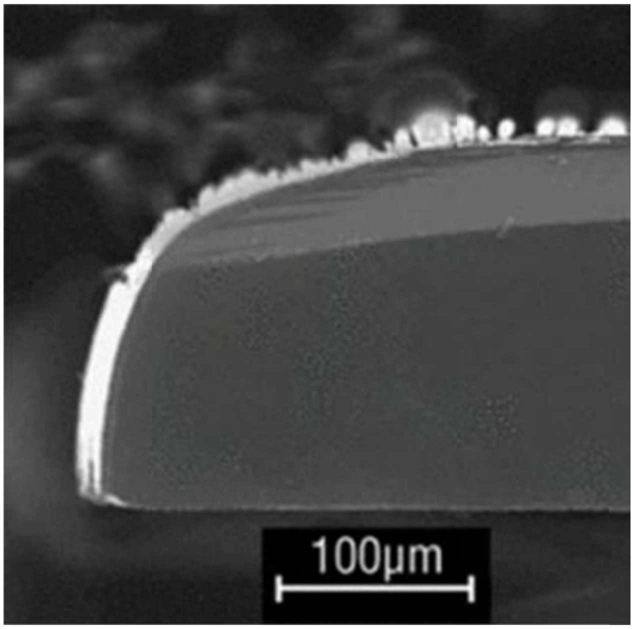


Figure 3. This figure illustrates the excellent confinement of the etching process exclusively to the process side of the substrate with no incursion to the non-process side. It also shows the fine control that the process exerts over the amount of "climb" of the etchant over the side wall of the wafer, as well as the smooth edge it produces.

a plane parallel to the substrate surface; this delays bath saturation, extends bath life, and insures a consistent supply of fresh chemicals to the surface. The substrate is not immersed, but merely put in contact with the top of the pool's meniscus, as also illustrated in Figure 1.

Chemicals and vapors are kept away from the non-process side by a proprietary gas sealing technology called DynamicConfinement (Figure 1), which forms a gaseous O-ring around the periphery of the substrate to prevent any liquid or vapor incursion. In this way, the non-process side is not subject to physical or chemical contact.

Wafer thinning is one of the native applications of the LinearScan etching technology. It allows for thinning of mounted or un-mounted, taped or un-taped substrates down to 50 um or less with superior uniformity, no edge damage, and without requiring any form of backside protection. Substrate assemblies, at any point in the packaging process, of virtually any thickness, structure, and size are all compatible with the LinearScan etching process.

The final thickness for modern IC device substrates continues to decrease, with 50µm being the current state-of-the-art target for many modern devices[4]. LinearScan etching systems are particularly well suited to handle and process very thin substrates. The unique process is carried out with no violent spinning, no need for lateral confinement by pins or other hard devices that may damage the wafer's edge, and no dynamic loading due to high rotational speeds. In the

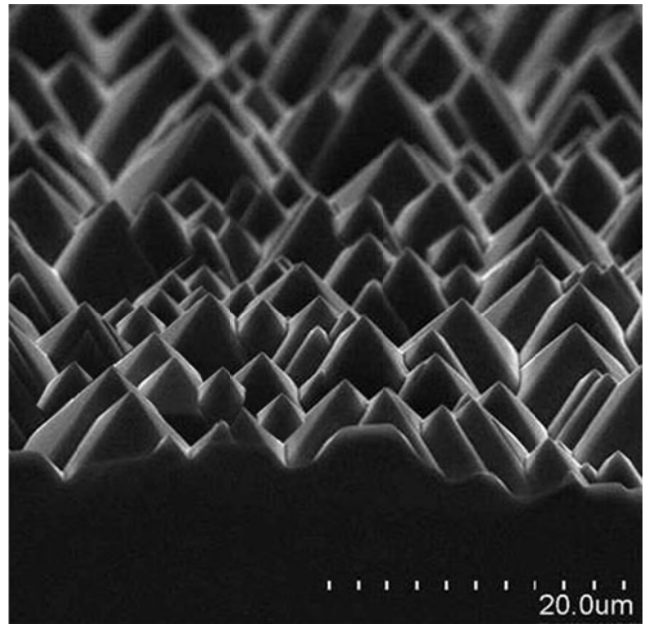


Figure 4a. The fine control that the LinearScan process exerts over the solid-liquid interface allows the production of surfaces that range from mirror-smooth to textured surfaces such as the above.

absence of hydrodynamic edge effects, the edges of the wafers are free of edge sharpness and the formation of "teeth," or other features common in spin/spray etch systems that significantly weaken the substrates[5]. See Figure 3 for a typical wafer edge profile after LinearScan thinning.

Also, the chemistries used do not require surfactants and are used in smaller volumes at lower flow rates, allowing for more efficient chemical usage. Chemicals can be used to a process-dictated end-point without regard to surfactant depletion. Together, these features lower chemical usage and its associated purchase and disposal costs, as well as often easing environmental regulatory compliance, resulting in overall production and costs-of-ownership reduction. Chemical usage reduction can range from approximately 20% to a factor of two or more, depending on the process, method, and tooling used to perform it.

LinearScan etching processes are size- and shape-independent. Since all areas are exposed to the same chemical and transport environment, the size and shape of the substrate are largely irrelevant. A process developed for a given substrate geometry can be readily used for another substrate geometry, thus making product process migration effortless and cost effective. LinearScan etching systems naturally accommodate odd, noncircular, thick shapes, and structures larger than 300mm.

To take greatest advantage of the tool's chemical flexibility, each process module has a full-function chemical handling unit that precisely meters, mixes, stores, ages, and monitors

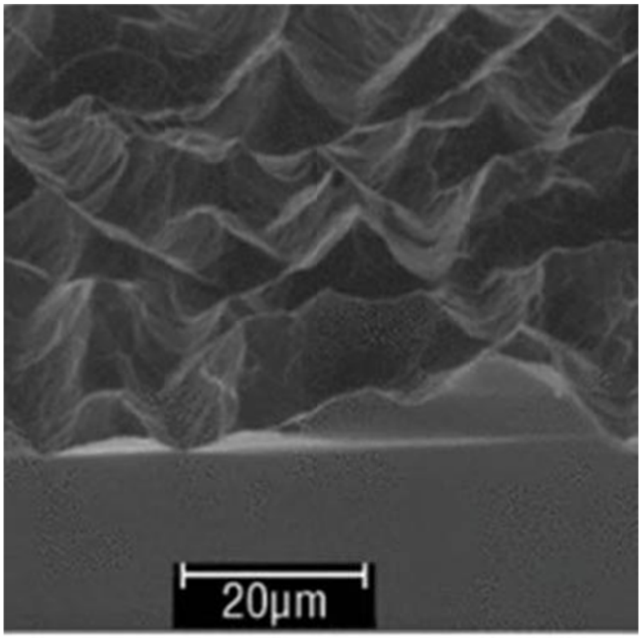


Figure 4b. Acidic textures, as shown in this figure, of a wide range of scales are possible with linear scan etching. A surface with peak to valley roughness of approximately 15 um is shown above. Roughness levels can range from the above to sub-micron levels.

up to three different chemicals prepared within the tool from relatively inexpensive bulk or bottled sources (as opposed to more expensive pre-mixed proprietary formulations). The rinse is also linear scan and typically a rapid step since the rinse water flow under the substrate is concentrated in a small area, and the contaminated rinse water exits the rinse module immediately, without being diluted into the incoming fresh rinse water.

For cleaning applications such as sometimes required in 3D's low standoff height structures or to remove residual polymer, the chemical process as well as the rinse step can be combined with the application of megasonics to alter the behavior of the boundary layer, promote transport to reach crevices in complex or high aspect ratio structures[6], as well as to speed up the process and rinse steps. The interfacial control allowed by this technology enables unprecedented manipulation of the liquid-solid interface. Figure 4 shows an example of a highly textured silicon surface. Engineered surfaces like this are helpful in improving adhesion, or reducing reflectivity, depending on the application. A large range of roughness and morphologies can be obtained by these methods.

The ability to exert control over the events that influence surface development is crucial in the formation of textured surfaces. The separate paths that reactants and by-products (including gaseous byproducts) take during linear scan etching allow for a variety of surfaces to be engineered, suitable for applications ranging from solar (Figure 4a) to metallization adhesion improvement. Acidic (Figure 4b) as well as alkaline textures (Figure 4a) are equally possible.

THINNING SUBSTRATES

As mentioned above, the systems are well suited for thinning and stress relief after grinding operations for packaging applications of very thin wafers since there is no mechanical contact with the surface or edges of the substrate. The process offers superior uniformity (Figure 2) and thus the ability to tune grinding operations for optimum yield, picking up more chemical removal if necessary, while staying within the TTV budget and lowering the cost of the whole operation. The systems can handle the single-sided wet etching of ultra-thin wafers (≤50µm), due to superior uniformity avoiding the risk of punch through. Intrinsic limits of grinding operations and downstream yield losses (from de-taping or de-bonding) usually prevent grinding to thicknesses below 150 um. The gentle and uniform nature of linear scan wet processing can easily thin well below 50µm. Figure 5 shows a 50µm wafer—thinned down, using a WaveEtch tool, from 125µm—with a TTV of 5% with its intact bonding layer and carrier wafer. Notice that there is no need to protect the non-process side of the wafer thus eliminating one more step in the overall packaging process.

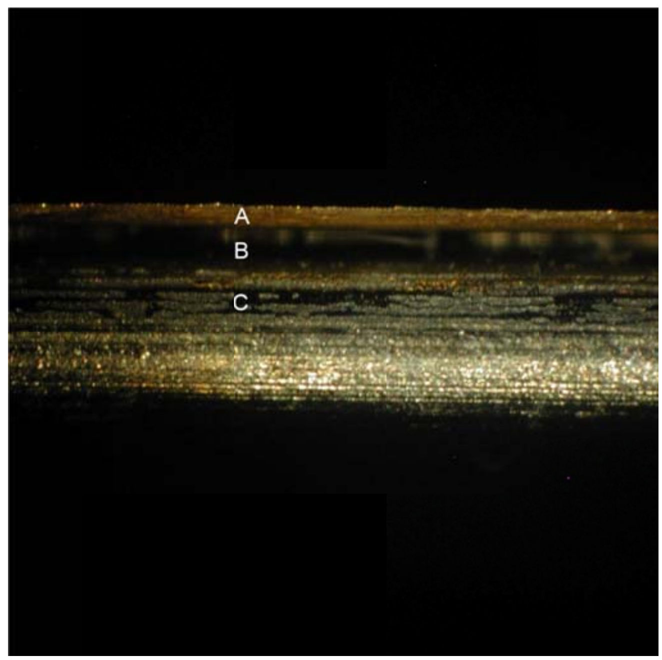


Figure 5. A 50 um wafer (A) is shown after being thinned down from 125 um with a WaveEtch tool. The TTV is 5%. The unaffected bonding layer can be also seen (B) as well as the carrier substrate (C). There is no need to protect the non-process side of the assembly during etching.

The ability to use virtually any chemistry to interact with any substrate material enables the systems to process any material of interest. In addition to packaging applications, the systems are being used to etch or thin InP, Ge, GaAs, Si, polysilicon, glass, and quartz, among others. Substrates of odd shapes and within a large range of size and thickness are being processed. This method provides a new way to do wet thinning for packaging applications in a more precise, efficient, and environmentally friendly manner.

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WaveEtch™, LinearScan™, and DynamicConfinement™ are trademarks of Materials and Technologies Corp. (MATECH)

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