Single Sided Wet Etching for Texturing, Thinning, and Packaging Applications

Ricardo I. Fuentes, Ph.D.
Materials and Technologies Corp., (MATECH)
Wappingers Falls, NY 12590

To Be Presented at IWLPC Conference, Oct. 2012

ABSTRACT

The advancement of wafer thinning and surface treatment technologies has been somewhat limited by the methods commonly employed; namely immersion, spin, or spray etching. All these technologies suffer from inherent transport characteristics that result in non-uniformity, limitations in the minimum thickness attainable, and lack of process flexibility.

We will report on results produced by a new technology that has been gaining momentum over the last few years: Linear Scanning. It is inherently single-sided and more uniform as well as cost effective and flexible.

LinearScan etching technology exposes only the process side of the substrate to a thin line of flowing chemicals and scans in a continuous, repeating sequence as many times as necessary to achieve the desired results. The process time is similar to that required by the same chemistry with a conventional method.

The non-process side and edges of the wafer are protected from the etchant by a shaped gas flow making it a truly singled process. Without the dynamics involved in spinning, spraying or immersion techniques, this technology is suitable for very thin wafers, fragile materials, or delicate structures such as those used in 3D packaging and solar applications. The non-process side can be bumped, taped, patterned or otherwise structured and is not affected by the process. Common Linear Scan applications include texturing, thinning, stress relief, among others.

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

INTRODUCTION

Even though, in its essence, wet etching is a simple process; i.e. the removal of material during the interaction between a liquid and a solid substrate, it can involve a series of complicated steps which combined effect lead to the resulting structure or surface. It remains popular in the semiconductor, solar, packaging, optoelectronic, as well as in many other industries because it is often the fastest and most cost-effective way to remove material[1] selectively or across an entire surface.

Thinner packages, higher power densities, and the ever increasing functionality of 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 all these technologies have their shortcomings, such as radial and transport-induced non-uniformities[3.] Also, conventional technologies often result in undesirable exposure of the non-process side to residual liquid or vapors.

Thus it is the need to alleviate the shortcomings of conventional etching technologies, as well as the increased power and flexibility that the control of some of the kinetic variables during etching brings to wet processing, that make LinearScan a very exciting and powerful new technology. Surface texturing is an excellent case in which the LinearScan added control yields engineered surfaces in a faster, cost effective manner.

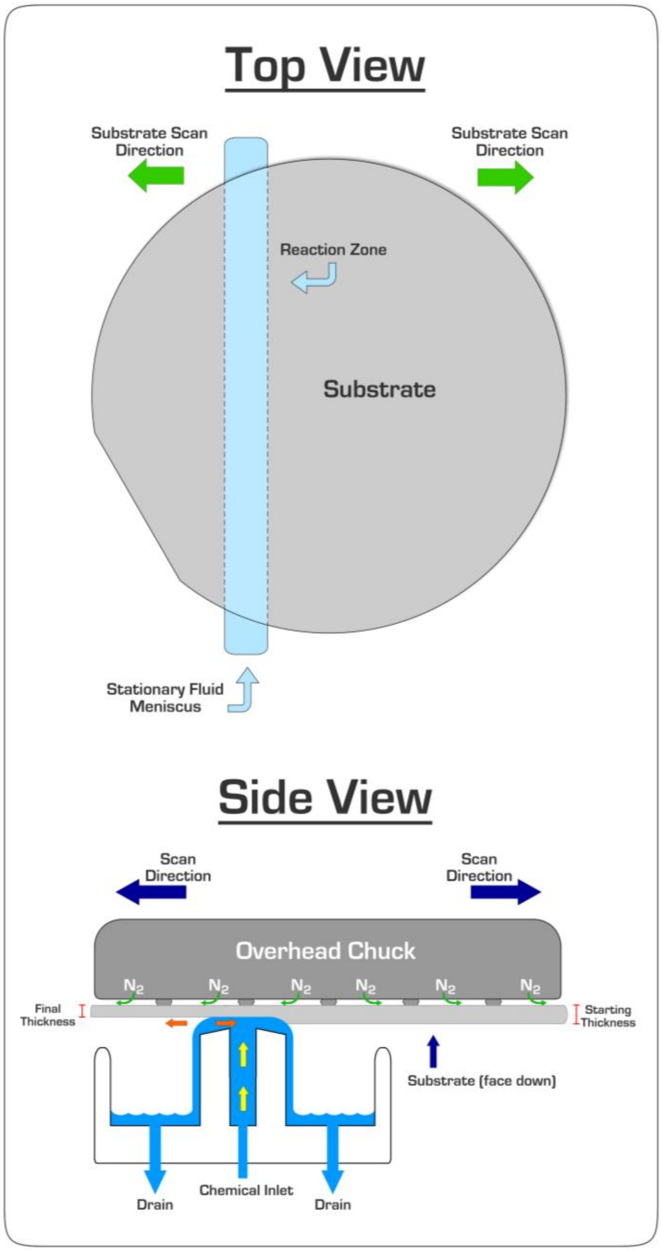

Figure 1. Schematic representation of the LinearScan process depicting the substrate material being removed by the etching process (held process side down), as well as the orthogonal paths of the reactants and the byproducts. The shaped flow of gas (DynamicConfinement), preventing the encroachment of fluid and vapors onto the non-process side (top), is also shown. Note the removal of material (etching) as the wafer is being gently scanned over a narrow pool of chemicals, and the different paths the reaction byproducts take to avoid interference with the supply of fresh reactants to the reaction zone. The top view illustrates the wafer being scanned repeatedly in alternating directions, as necessary, over the fluid meniscus showing the narrow reaction zone where thinning is in progress (wafer is being etched from below).

New device manufacturing techniques have become more demanding, which often requires the use of single-wafer, single-sided processing. In addition, thinner, denser packages, the push for increased functionality and decreased cost are driving this trend[4].

LINEAR SCAN ETCHING

The new technology WaveEtch™ LinearScan™ etching provides high uniformity as well as true single-sidedness on ultra-thin, large substrates[5,6]. 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 byproducts, such as gases and vapors. Exposure of every surface element to the same chemical and transport environment makes the process intrinsically uniform (Figure 1). 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. Reactants enter the reaction zone through the bottom of the pool, while the byproducts exit in a plane parallel to the substrate surface; this delays solution 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.

Most chemistries used with these processes do not require surfactants and are used in smaller volumes at lower flow rates, allowing for more efficient chemical usage[7].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

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. These systems naturally accommodate odd, noncircular, thick shapes, and structures larger than 300mm.

TEXTURING

LinearScan technology allows increased control over events that influence surface development which is crucial in the formation of textured or engineered surfaces. The separate paths that reactants and by-products (including gaseous byproducts) take during linear scan etching as well as the control over the time chemicals are in contact with the surface between scans, allow for a variety of surfaces to be engineered. Textured surfaces are required in applications such as solar cells and backside metallization to achieve lower reflectivity and improved adhesion, respectively.

Gas evolution during etching plays an important role in surface development, as well as "bubble" nucleation and detachment. LinearScan allows for control of some of the parameters that determine such bubble formation and the

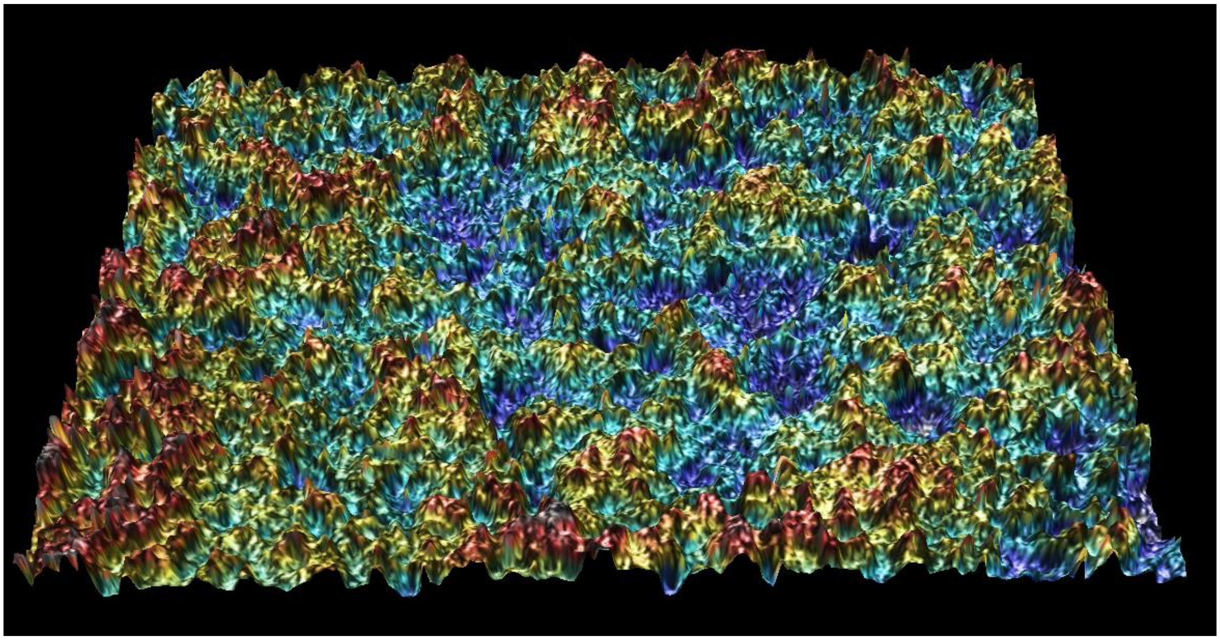

Figure 2. Confocal microscope image of a LinearScan textured surface with an acidic solution viewed at 50X magnification. Note the complex and convoluted nature of the surface, and the absence of smooth flat facets. Sa=0.65 µm , Sq=0.81 µm , Sz=7.52 µm (average, RMS, and maximum roughness depth areal parameters respectively, as per ISO 25178). Such surfaces offer an increased surface area for mechanical interlocking of deposited films, as often required in backside metallization.

impact that the size and spatial distribution of their gas-solid interfaces has on the formation of the surface during etching. Parameters such as scan speed and surface fluid velocity determine the thickness of the boundary layer and the consequent transport characteristics of the process.

Acidic textures are oftentimes desirable because they are faster to achieve and produce complex non-faceted surfaces. LinearScan produces acidic textures of a wide range of scales and on different materials. Figure 2 shows the image of a silicon textured surface for a backside metallization application. The peak-to-valley scale is approximately 7 µm although the attainable range by the LinearScan acidic texturing processes is from sub-micron to tens of microns.

These surfaces are produced in a few seconds to a couple of minutes depending on the amount of material to be removed and the desired final roughness. It is important to notice the complex and non-faceted nature of the surfaces which is a desirable morphology for applications such as backside metallization. The convoluted nature of the surface allows for a very large interfacial area between the metal film and the substrate material resulting in considerable "interlocking" and consequentially increased adhesion strength. The technology is equally capable of producing faceted surfaces by alkaline processes [7].

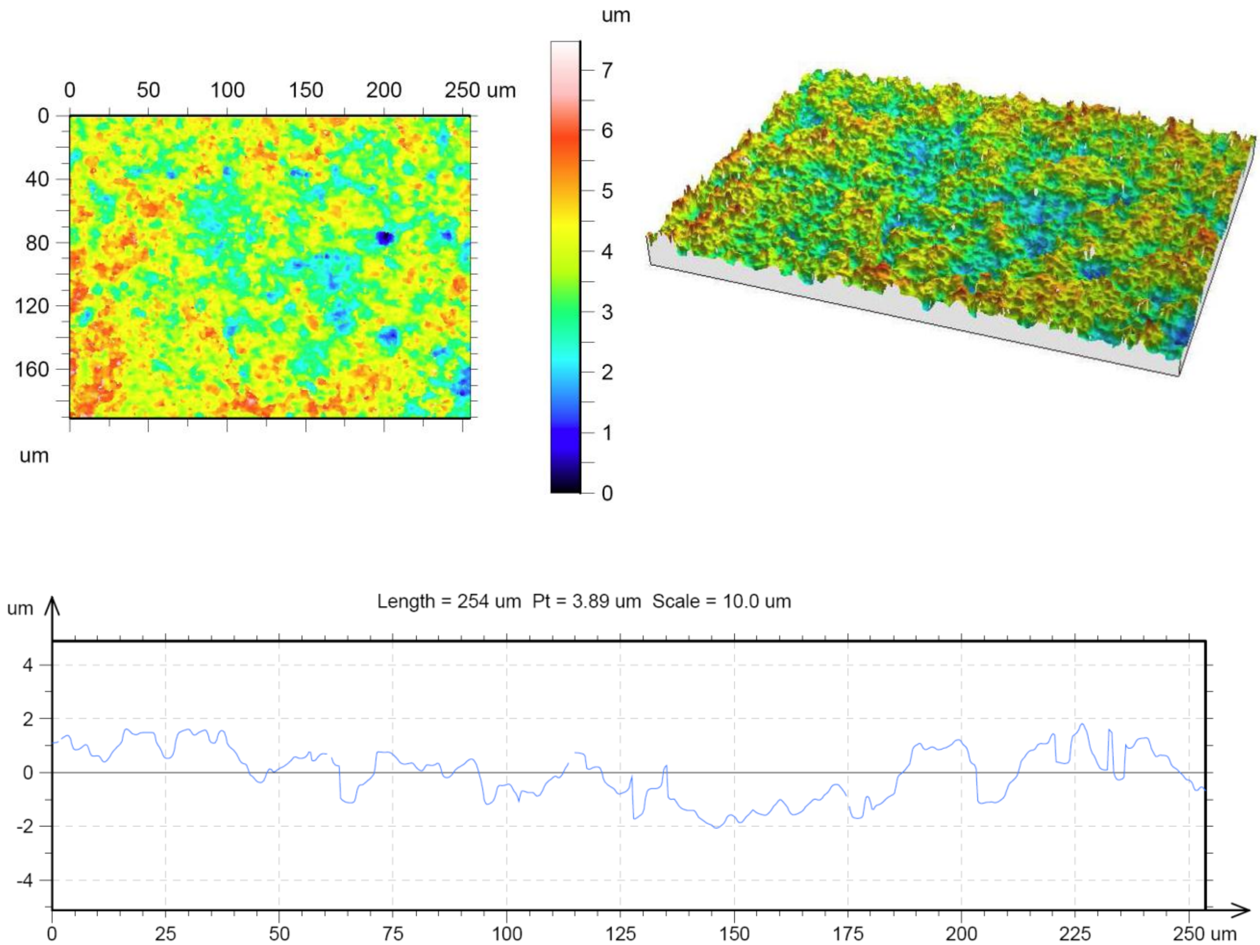

Figure 3a, b, c. Top-left to right clockwise. Confocal microscope images, map, and profile of the same surface depicted in Figure 2. Ra=0.62 µm, Rq=0.74 µm, Rt=3.23 µm (average, RMS, and maximum roughness depth line parameters respectively, as per ISO 4287). The additional control that the LinearScan process exerts over the solid-liquid interface allows the production of surfaces like this in fast and cost effective manner.

THINNING AND PACKAGING

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 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.

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 absence of hydrodynamic edge effects, the edges of the wafers are free of edge sharpness and the formation of other features common in spin/spray etch systems that significantly weaken the substrates[8].

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.

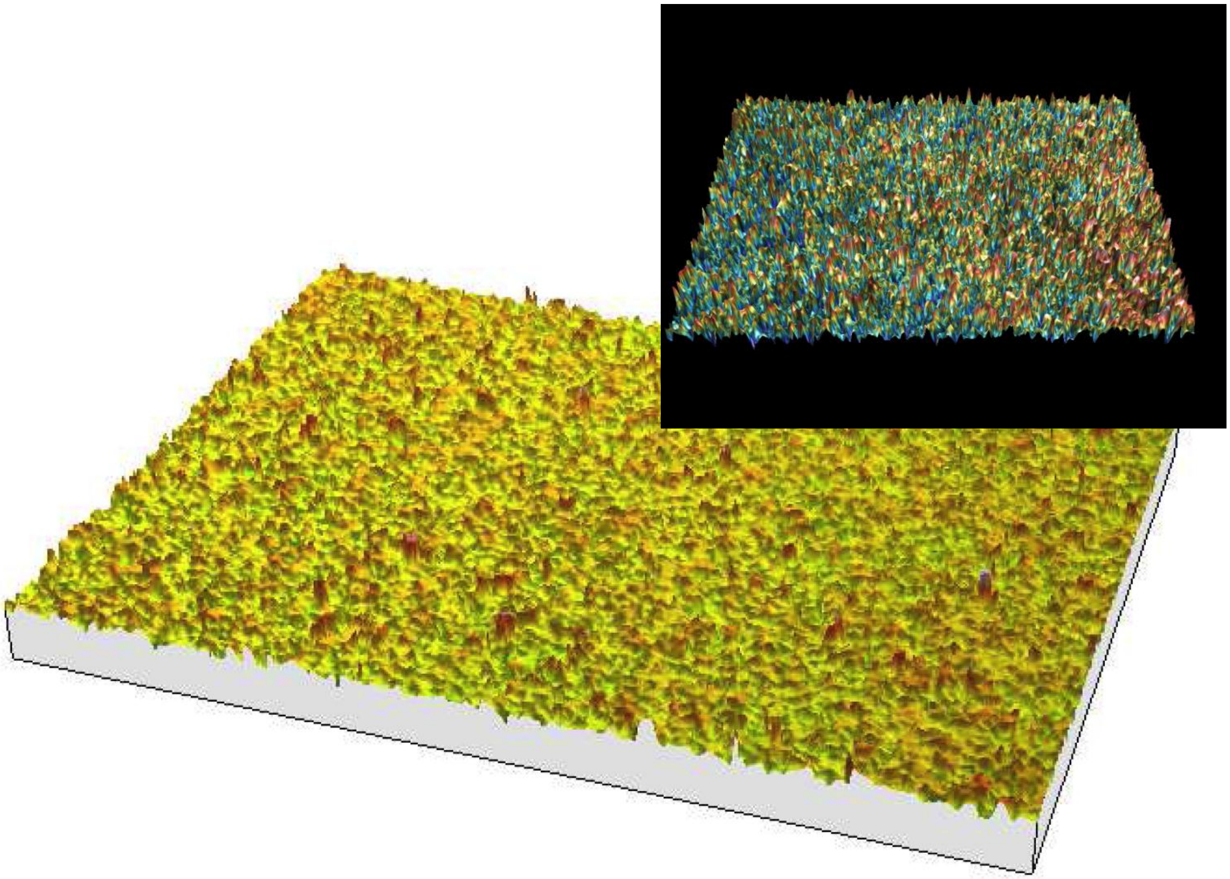

Figure 4. Acidic textures, shown in this figure at lower magnification (20X) can be easily achieved with the LinearScan etching technology. Ra=1.82 µm, Rq=2.25 µm, Rt=13.4 µm, Sa=2.03 µm, Sq=2.62 µm, Sz=51.9 µm (average, RMS, and maximum roughness depth, line and areal parameters, respectively, as per ISO 4287 and 25178). Roughness levels achievable with this technology can range from the above to sub-micron levels.

ACKNOWLEDGEMENTS

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

Ricardo Fuentes is the founder and president of Materials and Technologies, Corp., (MATECH), 22 Bill Horton Way, Wappingers Falls, NY 12590, United States; phone (845) 463-2799, e-mail info@matech.com.

REFERENCES

[1] Marc J. Madou, "Fundamentals of microfabrication: the science of miniaturization" 2002 CRC Press, LLC, p. 110.

[2] Robert Castellano, "Wafer & Device Packaging and Interconnect" September/October 2010 p.10.

[3] Ricardo I. Fuentes, "Intrinsically Uniform Single-sided Wafer Thinning", Levitronix User Conference, 2011.

[4] IWLPC, 6th Annual International Wafer-Level Packaging Conference proceedings, October 27-30, 2009, Santa Clara, CA.

[5] Ricardo I. Fuentes, "Extending Process Flexibility for Single-wafer Etch," Solid State Technology, July 2007.

[6] Ricardo I. Fuentes, “Single-sided Wafer Thinning and Handling,” Chip Scale Review, Jan/Feb 2011.

[7] Ricardo I. Fuentes, “Single-sided Wafer Thinning for 3D Integration,” Annual International Wafer-Level Packaging Conference proceedings, 2010, Santa Clara, CA.

[8] G. Coletti, C.J.J. Tool and L. J. Geerligs, “**MECHANICAL** STRENGTH OF SILICON WAFERS AND ITS MODELLING,” 15th Workshop on Crystalline Silicon Solar Cells & Modules: Materials and Processes, Vail Colorado, USA, 7-10 August, 2005.