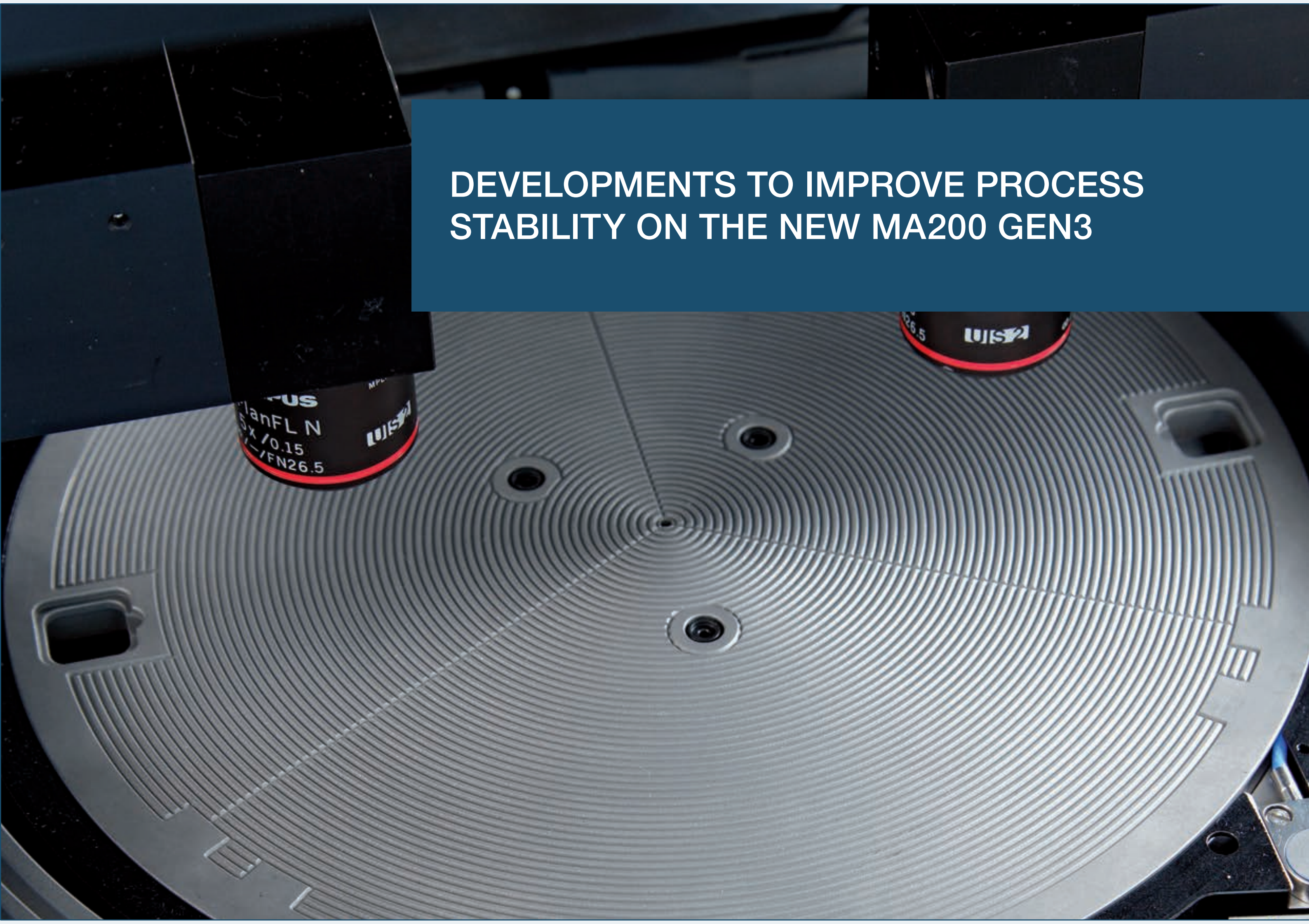
SUSS report+

ISSUE 01/2014

THE CUSTOMER MAGAZINE OF SUSS MICROTEC



DEVELOPMENTS TO IMPROVE PROCESS STABILITY ON THE NEW MA200 GEN3

In the Spotlight

Optimizing Spray Coater Process Parameters

Excimer Laser Via-Drilling - Options to Further Capabilities of Next Generation Wafer Level Processing Devices

SÜSS MicroTec

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+EDITORIAL

Dear Customer & Partner,

The WORLDWIDE DEMAND FOR ELECTRONIC PRODUCTS IS RISING STEADILY. The rapid advancement of communication tools leads not only to significantly expanded and focused social networks, but also it fosters economic globalization and the worldwide dissemination of ideas.
Access to information and communication technologies has increased in recent years in all regions of the world. This rapid development becomes obvious when you consider growth figures over a relatively long period of time. The number of mobile communication connections rose from 34 million in 1993 to approximately 6.8 billion in 2013. (Source: Statista 2014)
This has shaped a new way of life, being connected at any time, being online at any time.

Routinely we buy new "gadgets" with new and exciting features and functions. Did we exploit the entire bandwidth of capabilities that the current and of course now outdated piece had to offer? This question can clearly be answered with "no".
No matter how fast and versatile the devices get. Soon there is another new feature, better functionality or an increase in speed, which excels the last generation tablet, phone, GPS or personal computer. What seemed to be top-notch and hard to beat in performance and capacity just yesterday, is now outdated. It is impressive how fast we get accustomed to the higher speed and complexity.

DYNAMIC MARKETS AND INNOVATIVE PRODUCTS

… and the electronics boom is still underway, with no end in sight. The industry will continue to develop products with ever-improved capacity and capability. The assembly and packaging sector plays a big role in increasing complexity while retaining a tiny footprint. With innovative solutions SUSS MicroTec supports these very important trends in the electronics sector. Our products and solutions for advanced packaging and MEMS fabrication are playing a significant role in the further development of communication and computing devices. In all our divisions, we strive to improve existing products by applying new technologies. This opens up new growth opportunities, such as 3D integration or laser ablation. It is all about the continuous increase of complexity and functionality of electronic circuits without the cost-intensive miniaturization of feature sizes.
Our philosophy: always a step ahead.
We are proud, to be part of that technological evolution and revolution – an enabler behind the scene.

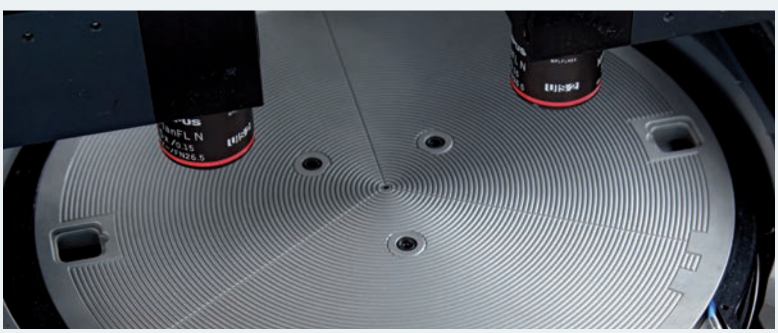
In this issue we will provide insight in latest applications, new techniques and processes from different areas of technology.
Enjoy the read.

Frank P. Averdung
President & CEO
SÜSS MicroTec AG

DEVELOPMENTS TO IMPROVE PROCESS STABILITY ON THE NEW MA200 GEN3

Dr. Marc Hennemeyer SUSS MicroTec Lithography GmbH, Schleissheimer Str. 90, 85748 Garching, Germany

Scrap rate, rework rate and consequentially yield are decisive parameters for the cost of production processes. To achieve the constant reduction of production cost which is needed to stay competitive in semiconductor manufacturing, yield improvements are an important factor. Besides the improvements of the production processes themselves, ongoing development of the production tools support the efforts to bring down the cost of goods sold. Especially in the back end of line yield loss is painful, since source material is very costly. Improving the process stability and avoiding any wafer scrap are therefore desirable goals of any machine development.



With the advancement of 2.5- and 3D integration and the emerging of new bumping processes lithography in the back end saw a continuous shrink of feature sizes. This feature shrink also dictates an ever tightening requirement on the stability of the respective lithography processes. Especially when looking at feature size uniformity, line edge roughness and resist side wall angle, the specifications tightened significantly in the back end market.

Mask aligner lithography is typically thought of to be a mature production technology and to be lacking the capability for game changing development regarding its resolution capabilities. However, when looking at the process stability of the exposure the mask aligner still offers possibilities to improve. The stability of a mask aligner exposure process is defined by the accuracy and stability of the overlay and exposure. SUSS MicroTec has been putting significant effort in identifying those parameters that still are most promising to further improve the stability of mask aligner processes. From the results a long term improvement project is driven, which shall be outlined in this article and already partly found its realization in recent feature and product releases on the SUSS aligner platform.

OVERLAY ACCURACY

Overlay accuracy and its stability is a topic of high concern for all high volume manufacturers. The general functionalities to maintain good overlay accuracy in the mask aligner – high quality pattern recognition system, mechanical stability of the alignment stages and compensation of thermal effects – are already present in SUSS mask aligners. However, the complexity to train reliable alignment pattern, especially in production environments with heavily varying pattern quality demanded an improvement of the training system available on our mask aligners.

Therefore, starting with the MA200 Gen3 SUSS started to roll out the new VisionPro alignment editor software. The new software contains several new possibilities to train targets and has a clearer structure of the user interface. It offers two editors with different levels of com-

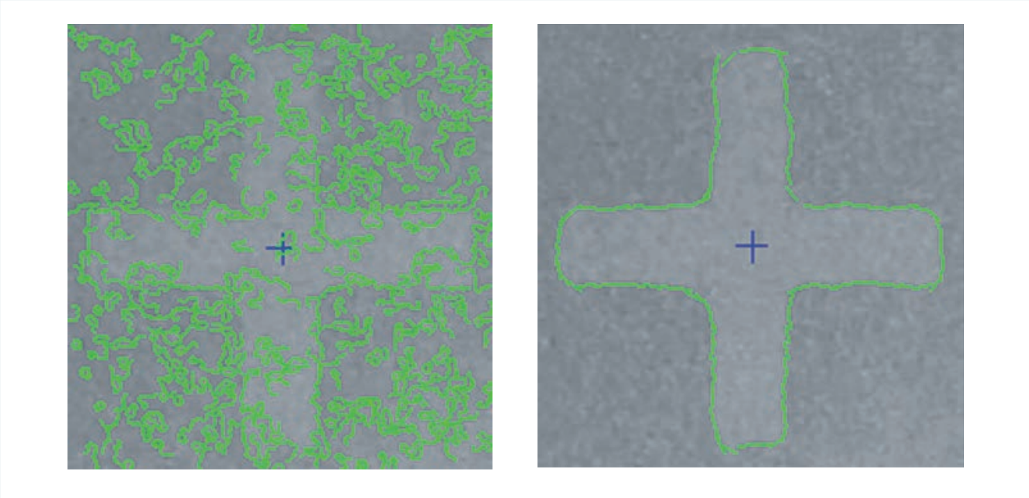


Figure 1: Model trained from real target. Proper usage of grain limits and contrast thresholds can improve the model quality from unusable (left) to stable (right). Direct visual feedback facilitates the understanding of the training results.

plexity allowing the process engineer to select the training tool of choice depending on the difficulty of the pattern training. The base editor gives quick access to the most important training tools and parameters like automated edge recognition and threshold adjustment. It will be sufficient for most training cases. For those cases, where the quality of the targets or the images require a more detailed access to the model creation the advanced training window comes with more powerful, but also more complex tools and parameters as synthetic target creation, model manipulation, masking or grain limit definition. These tools allow addressing even complex tasks where relevant feature information is disguised by e.g. excessive noise in the pattern images (for an example refer to Figure 1).

The also newly introduced direct visual feedback during model training and alignment together with the new image log provides a better understanding of the training results and of issues that might arise with the trained target model in a pilot production. The combination of the new features will support the process engineers to train more reliable target models at shorter times hence improving process accuracy, stability and throughput.

FEATURE SIZE UNIFORMITY

For almost all lithography layers feature size uniformity is the critical quality feature. The feature size uniformity directly influences functional parameters of the finished device as the conductivity of metallization layers in the packaging of ICs or mechanical properties of MEMS structures.

In a mask aligner the feature size is mainly influenced by two different process parameters, exposure dose and gap.

As commonly known, depending on the used material, changing doses have a substantial influence on the feature size. Especially absorbent, chemically non-amplified materials as standard DNQ resists are rather sensitive to dose changes due to their relatively flat resist profile.

Additionally the exposure gap has an important influence on the feature creation through its definition of the contrast in the created aerial image. A recent study performed by SUSS in cooperation with the FhG IZM showed as a side result, that the effect of gap and dose on the process result are

SUSS MA200 Gen3

quite different. While dose variation became mainly visible in the bottom feature size the variations of the gap resulted mainly in changes of the top feature size and, as a result, the side wall angle. The study also quantified the depen-

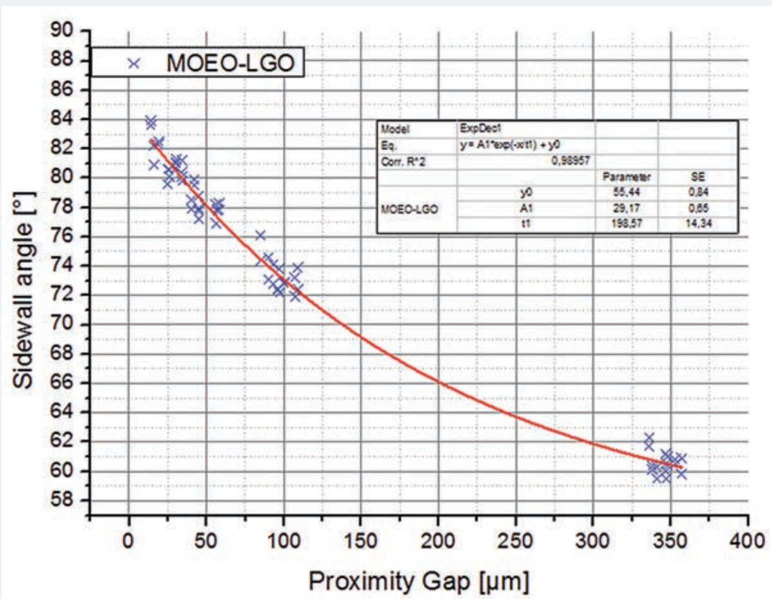


Figure 2: Dependence of the resist profile angle on the proximity gap. The experimental results can be fitted by an exponential curve. Especially for small gaps the dependence of the profile angle on the gap is substantial.

From: F. Windrich, FhG IZM-ASSID, internal project report: Determination of the Resist Sidewall Profile in Dependence on the Proximity Gap for 4 Optical Settings

dence between the exposure gap and the side wall angle for the tested processes. As can be seen from figure 2 the side wall angle decreases exponentially with increasing gap. Due to the exponential behavior, especially at small gaps any gap variation will result in significant variations of the process result.

The results of internal studies as the one quickly presented before, together with the observed development of the process requirements underline the need to further optimize the known good stability of the SUSS mask aligners in both, illumination and gap setting. The first steps of the improvement program focused on enhancing the optical performance of the SUSS mask aligners. At this end, the introduction and ongoing improvement of the constant dose functionality helps to improve the wafer to wafer stability of the processes. The electro-mechanical shutter that is introduced to the aligner platform with the MA200 Gen3 optimizes the accuracy of the dose control further.

To also improve the within wafer uniformity SUSS introduced the MO Exposure Optics®. The benefits of this optics on the process stability are manifold: through the high amount of lenses used to homogenize the light, the MO Exposure Optics® reaches superior illumination uniformity of better than ±2.5 %. Furthermore, the MO Exposure Optics® is capable to uncouple the illumination characteristics at the mask level from the light source. This means that no matter how the electrodes of the Hg-lamp and hence the shape of the short arc is changing, the intensity distribution on the mask and therefore also the intensity uniformity will stay the same during the life time of a bulb and even over a bulb exchange. These features are obviously reducing the portion the illumination is taking from the error budget in the lithographic process.

However, as discussed above, to translate the full effect of these improvements into the process stability it is needed to also reduce the exposure gap variation to a minimum.

A well-adjusted and well-maintained SUSS mask aligner already today offers a very high level of gap setting accuracy and gap uniformity. However, during large scale production machines are always prone to wear. With the traditional passive gap setting system the level to which this wear can be monitored and between maintenance cycles is limited. Silent malfunctions of heavily used motors as e.g. loss of single steps or damages on the proximity system as well as process related disturbances as sporadic presence of particles on wafers and masks can go unnoticed through the exposure process until they got recognized in the quality assurance later in the process chain. Through this, process variation can be increased and in the worst case even yield or scrap and rework rate can be affected. Consequentially this leads to lower

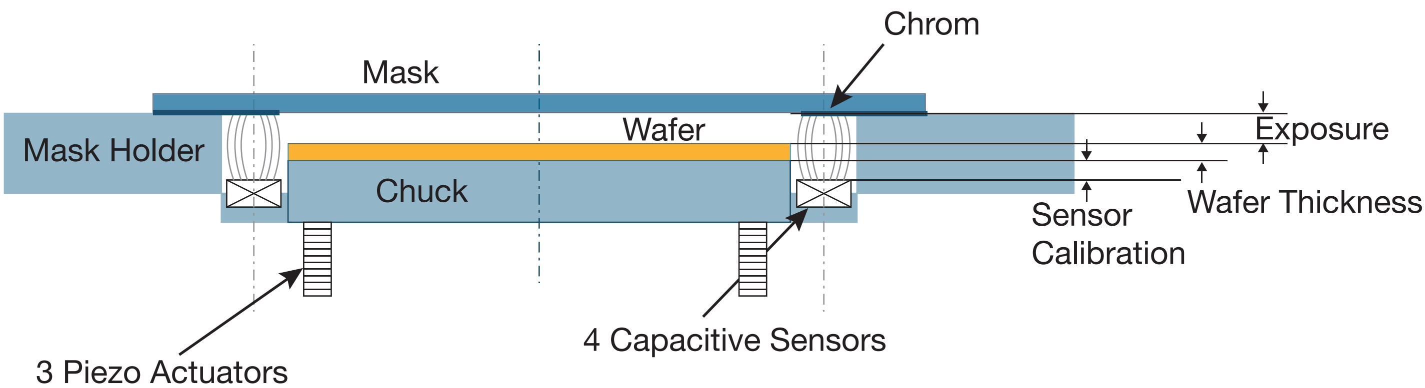


Figure 3: Schematics of the active gap setting. The system measures and controls the real time gap between chuck and mask. Due to the measurement principle the system combines the flexibility to process a wide range of different substrates, surfaces and coatings with a high sensitivity of any misplacements of toolings or materials.

effective throughput and higher cost. To mitigate these risks the next step of the improvement program is the development of a closed loop gap setting and control system for the MA200 Gen3. This system, which is currently in development, will comprise a tool for thickness measurement of the processed substrates as well as a real time measurement of the gap between the chuck and the mask based on capacitive measurement (see Figure 3). Through the direct measurement between chuck and mask the system is even sensitive to variations of the average mask thickness and placement accuracy of the chuck in its holder. Other systems that rely on the distance measurement between chuck holder and mask holder tooling are blind to these errors. The idea to use optical distance measurement between mask and substrate itself was deliberately discarded to maintain the flexibility of the machine regarding processed substrates and surfaces as well as regarding resist materials. Additionally, optical measurement would require clear fields for the measurement which would reduce the usable area on the wafer and would limit the design flexibility of the litho layer.
Through the real time measurement the new system is capable to set the gap with repeatability in the submicrometer range. Since the feedback circuit also recognizes if fatal errors in the gap setting occur, the system warns and interrupts the process before corrupt exposures are performed.
The resulting cd uniformity within the wafer is of course also dependent on thickness variation and flatness of the used materials. Future development projects therefore are planned to also address the flatness issues of masks and wafers by enhancement of the tooling.
SUSS MicroTec is optimistic that the ongoing development on the tooling together with the presented improvements on alignment, illumination and gap setting will push the process stability on the SUSS mask aligner platforms even beyond the already known good performance.

THE AUTHORS

Dr. Marc Hennemeyer is Product Manager at SUSS MicroTec Lithography. He is responsible for the automatic mask aligner product group. After his graduation in Physics at University of Munich where he also received his PhD working on micro fluidic systems for biological applications he joined SUSS MicroTec in the Application Department before he proceeded to his current job. He authored and coauthored several papers on various topics, including micro imprinting and lithography.

OPTIMIZING SPRAY COATER PROCESS PARAMETERS

Dr. Eleonora Storace, Florian Palitschka, Dr. Dietrich Tönnies SUSS MicroTec Lithography GmbH, Schleissheimer Str. 90, 85748 Garching, Germany

Spray coating technology is known for being affected by many different process parameters that, combined together in an ensemble, would lead to a variety of different coating outcomes. In the present article, a systematic analysis on how to optimize spray coating processes, based on the chemical and physical origin of the behaviour of the resist over high topography structures will be discussed.

From the set of measurements shown, it will become clear that two stronger players would be the **resist surface tension** and the **complex dynamics of the resist particles inside the spray cone.** In the following, the effect of those parameters and the ways to control them within the SUSS Altaspray technology will be clarified.

NEW SUSS TEST WAFERS FOR EVALUATING CONFORMAL COATING PROCESSES

Since such an important effect on the coating results is given by the topography of the substrates, an ad-hoc design for the test wafers was optimized, in order to allow a systematic study of the spray coating properties. Figure 1a depicts the layout of the 9-inch test wafer masks. It contains a total of 36 test dice, each having a size of 28 mm x 22.5 mm. The dark lines in the image indicate deep etched areas. Figure 1b shows more details of the die layout of the test dice. The test dice offers a variety of square cavities and trenches of different sizes for evaluating and optimizing conformal coating processes. The data discussed in the present article refers to KOH etched wafers (typical etch angle of 54.7°), with an etching depth of 100 µm.

In each die there are:

1. 5 large cavities (1 mm x 1 mm, 2 mm x 2 mm, 3 mm x 3 mm, 4 mm x 4 mm, 5 mm x 5 mm)
2. 8 trenches, each of them 5 mm long (width: 25 µm, 50 µm, 100 µm, 200 µm, 400 µm, 600 µm, 800 µm, 1000 µm), and
3. 8 sets of smaller square vias (25 µm, 50 µm, 100 µm, 200 µm, 400 µm, 600 µm, 800 µm, 1000 µm)

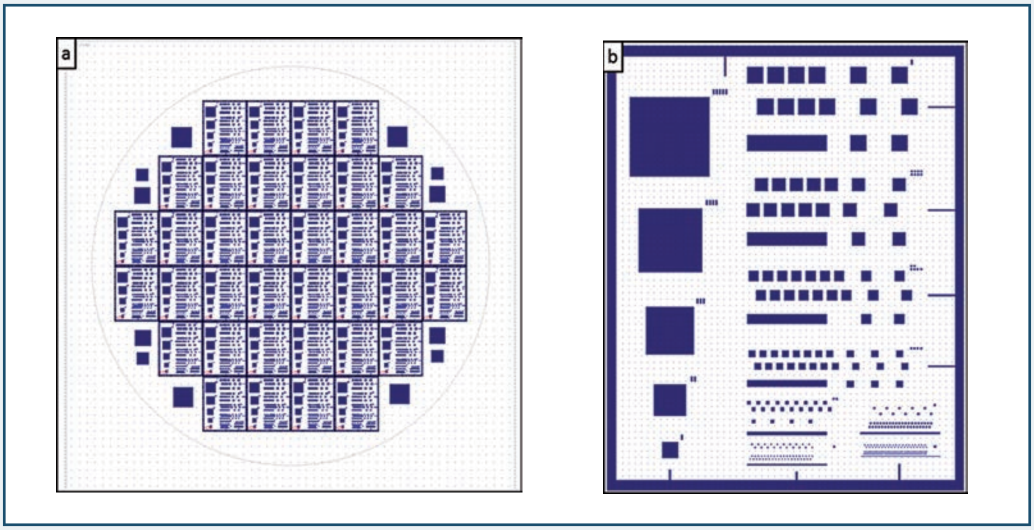


Figure 1.
a) Layout of test wafer with 36 dices per 200 mm wafer
b) Design of individual test dice. Dark lines indicate the KOH etched areas.

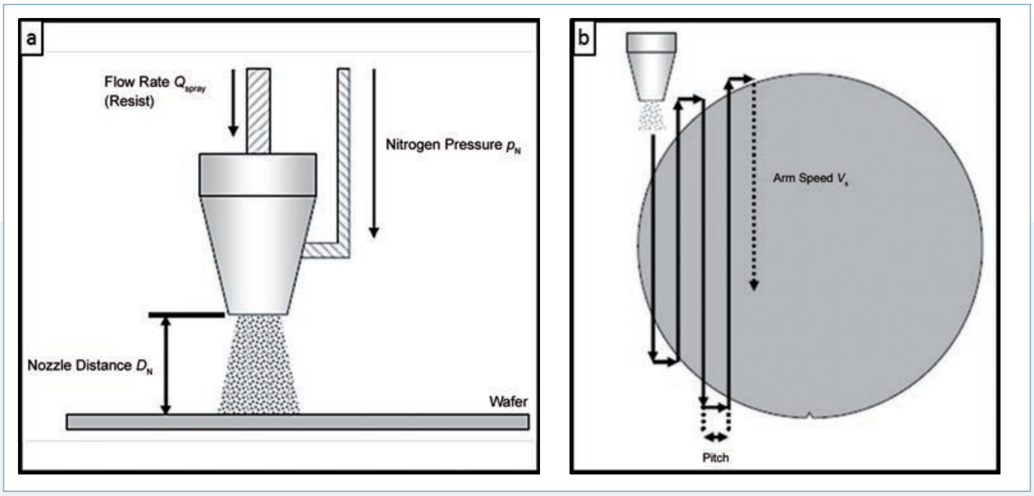


Figure 2: a) The nozzle setup parameters, defining the shape and the intensity of the resist spray cone.
b) The meander setup, defining the movement of the nozzle relative to the substrate.

GENERAL PROCESS SETUP

SUSS MicroTec's spray coating technology uses binary spray nozzles that atomize the photoresist by pressurized nitrogen. Figure 2a depicts the parameters that control the operation of the spray nozzle. The spray nozzle scans across the wafer area, as shown in Figure 2b. The spray arm scans the wafer by a succession of linear scans with constant pitch. During this scan the wafer chuck remains stationary.

There are seven important process parameters that can be adjusted for best performance of the spray coater: The **flow rate Q_{spray}** controls the total amount of resist that is sprayed onto the wafer within a certain period of time. The **nitrogen pressure p_N**: The nitrogen atomizes the resist to form the spray cone. The **nozzle distance D_N** gives additional means to tune the air flow inside topographic structures. The **pitch D** defines the distance of adjacent scanning lines. The **speed v_s** of the spray arm, together with the flow rate Q_{spray}, defines the amount of resist deposited locally during one scan. The number N of full wafer scans defines how often the full wafer scan is repeated and thus how many resist layers are deposited. By setting **temperature T_c of the wafer chuck** the user has means to stabilize the resist film immediately after droplet deposition.

For all the data shown in the following, a positive-tone DNQ/Novolak based resist has been sprayed, the AZ4999, developed by AZ Electronic Materials specifically for the SUSS spray coating technology.

Even though each specific process might have different coverage requirements, depending on the whole lithographic process, for the sake of simplicity here we will focus mostly on the resist conformality, defined as the ratio between the minimum and the maximum resist thickness across the substrate topography. The resist coverage across each pattern will be measured by optical microscopy of its cross-section, typically at five distinct locations: The top plateau (*T1*), the top corner (*T2*), the side wall (*T3*, eventually split in $T3_{min}$ and $T3_{max}$), the bottom corner (*T4*) and the bottom plateau (*T5*).

OPTIMIZATION OF THE COATING PARAMETERS SET

Starting from the SUSS standard baseline coating recipe, several parameters can be singularly tuned, in order to extract which physical and chemical resist properties have the stronger effect on the coating results and how to control them. Two aspects would arise as particularly significant: The **resist surface tension** and the **complex dynamics of the resist particles inside the spray cone**.

By increasing the temperature, the resist mixture becomes more liquid and the resist film is allowed to minimize its surface energy by pulling the resist away from the top corners. Simultaneously, the solvent component of the resist mixture evaporates and the coated layer hardens in the shape, defined by the minimized surface energy.

An example of this behaviour is shown in Figure 3: (a) is a cross section of a sample coated at a chuck temperature of 60°C; one can notice that the resist easily covers the whole profile, giving a

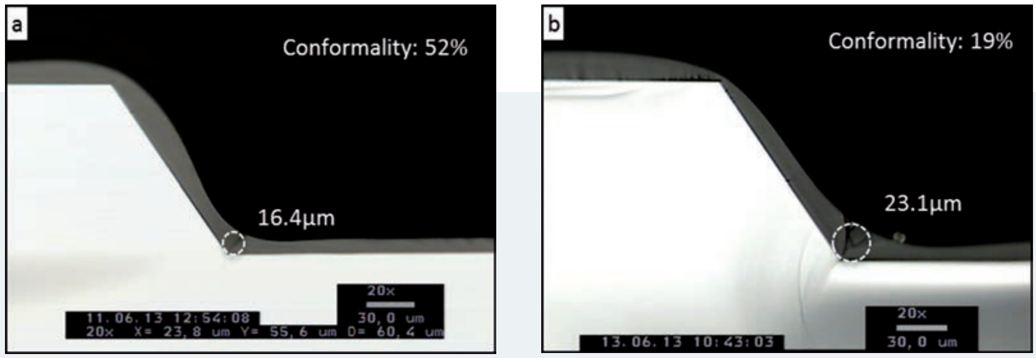


Figure 3. Cross sectional views of spray coated samples (Tc: 60°C) before (a) and after (b) the soft bake step at 90°C for 90s

conformality as high as 52 %.

When a sample coated with the same recipe as (a) undergoes the soft bake step (90 seconds at 90°C), the resist starts flowing again and the result is shown in (b): The conformality is now down to 19 %.

Spraying a *drier resist mixture*, i.e. a less liquid material, significantly minimizes the surface tension effect.

The high tuneability of process parameters offered by the SUSS Altaspray technology allows for several different methods to achieve a dry resist coating; most effective have been proven to be:

1. using a chuck temperature, during the coating, as close as possible to the soft bake temperature, as shown in the left side of Figure 4, where conformality is plotted as a function of the chuck temperature for different cavity sizes, and
2. decreasing the volume of the dispensed resist, while increasing the number of full wafer scans (right side of Figure 4, where the points corresponding to the 16-scans recipe lie at a higher position as the ones from the 8-scans recipe, that, in their turn, are higher than the ones from the 4-scans recipe).

The first method accelerates thermally the solvent evaporation, while the second one achieves its aim by slowing down the overall process and therefore leaving more time to the solvent to evaporate between consecutively coated layers. Depending on the specific process requirements (soft bake temperature, overall throughput, resist chemistry,…) either one, the other, or both methods could be selected.

A second important player in the spray coating technology is the dynamic of the resist particle inside the spray cone: The turbulent motion of those particles would in fact define where the resist will accumulate over the substrate topography. Process parameters that can be

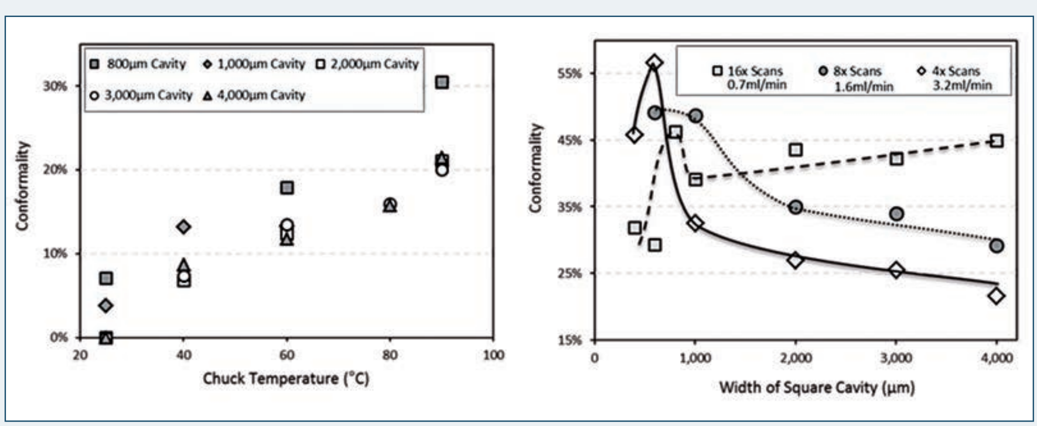


Figure 4. Left: Conformality of spray coated AZ4999 resist film for various 100 µm deep etched square cavities as a function of chuck temperature. After spray deposition the wafers were softbaked for 90 s at 90°C.
Right: Conformality of resist film versus cavity size (100 µm deep KOH etched) for three different resist flow rates: 0.7 ml/min (16 x scan), 1.6 ml/min (8 x scan) and 3.2 ml/min (4 x scan).

utilized to tune the aerodynamic of the spray cone are:

1. The nitrogen flow, that atomizes the resist into a spray, gives higher kinetic force to the particles and affects the solvent content of the resist - acetone mixture, and
2. The nozzle height that regulates the area of the cone cross section and the strength of the spray.

A typical case is reported in Figure 5, where the resist conformality is plotted as a function of the trenches width for different nitrogen flows: higher nitrogen pressure, by adding kinetic energy to the resist particles, increases the turbulence within the spray cone. The resist, therefore, is scattered around within the topography cavity and, instead of depositing on the bottom, accumulates on the upper part, namely the top corner and the upper portion of the side wall. Since the conformality is, in most cases, a ratio between the resist thickness at the top corner and the one at the bottom of the cavity, the overall conformality is then increased.

The aerodynamics of the resist particles is also affected by *topological effects*, i.e. the shape, the size and the depth of the substrate structures will contribute to the achievable conformality. When the spray cone, for example, moves across a narrow and deep cavity, a large amount of the resist will not succeed in reaching the very bottom of the topography, because there it will find an air cushion that will make it scatter back upwards. On the contrary, shallower and wider features will accumulate a large amount of the resist on the bottom corner, since the spray cone can fill the whole area and push the resist particles towards the (lower regions of the) side walls.

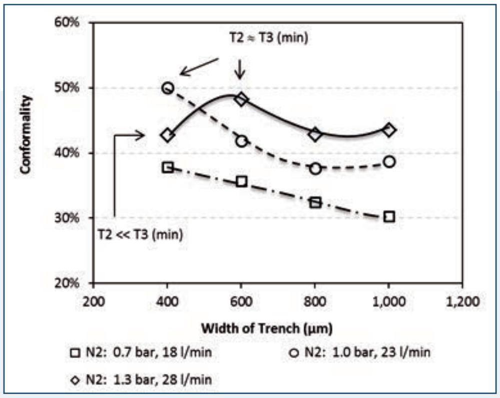


Figure 5. Conformality of resist films spray coated across 100µm deep KOH trenches as a function of structure size and nitrogen pressure. For large structures best conformality is achieved with high nitrogen pressure settings.

CONCLUSIONS

In spray coating many different aspects will affect the resist coverage and a process recipe has to take all of them into account by tuning the set of parameters as in an ensemble. For this reason it is then crucial to understand the chemical and physical reasons underlying the general coating results, to be able to constructively combine the several recipe parameters into an effective set.

From results as the ones shown in the present article, we can clearly define that particularly important are the resist surface tension and the aerodynamic of the particles in the spray cone and we can systematically outline how those could be controlled via the SUSS Altaspray technology.

THE AUTHORS

Dr Eleonora Storace is Lead Technologist for Imprint and Spray Coat at SUSS MicroTec Lithography in Garching, Germany. After her graduation in Solid State Physics at the Università degli Studi dell'Insubria (Como, Italy), she completed her PhD at the Max Planck Institute for Solid State Research (Stuttgart, Germany) with an experimental work on magneto-transport through low-dimensional systems. In October 2010, she joined the Application Department of SMTL and she is based in Garching, Germany.

Florian Palitschka graduated in Physics at the Ludwigs- Maximilians-Universität München in 2008. Afterwards he has worked as a Research Assistant at the Physics Department of the Universität der Bundeswehr in the field of advanced and novel semiconductor devices. Since 2013 he works as Application Engineer for SUSS MicroTec in Garching, focused on Spray Coating technology.

Dr. Dietrich Tönnies is head of the Applications Department and Demo Lab at SUSS MicroTec's headquarter in Garching, Germany. He joined SUSS in 1997 as Product Manager for Mask Aligners and for many years, was responsible for developing the company's Advanced Packaging market.

OPTIMIZING SPRAY COATING YIELD AND THROUGHPUT

Dr. Thomas Grund, Katrin Fischer SUSS MicroTec Lithography GmbH, Ferdinand-von-Steinbeis-Ring 10, 75447 Sternenfels, Germany

A well-structured approach to optimize the many process parameters during spray coating is described in the article „Optimizing Spray Coater Process Parameters“ within this issue of the SUSS report. To complete the picture and significantly increase yield and throughput especially but not limited to production tools, also technical improvements have been recently developed for the SUSS AltaSpray technology.

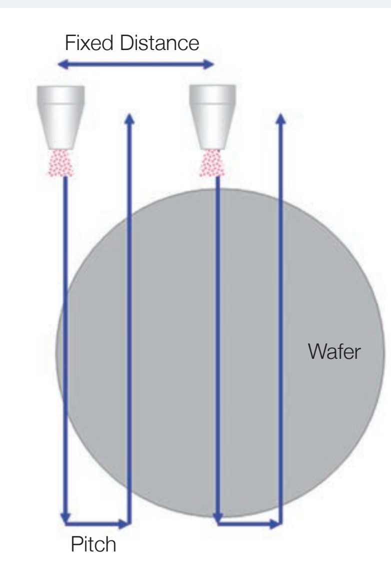


Figure 1. Two spray nozzles are moved in parallel over the substrate surface.

IMPROVED YIELD AND COST OF OWNERSHIP BY STABILIZING RESIST FLOW RATES

To reach the well renown high coating conformality of the SUSS AltaSpray technology, a specialized nozzle, which represents the core technology of the system, was developed for the technology introduction in 2004. But not only the nozzle design - rather all parts of the dispense line are designed and optimized to match the requirements and prerequisites of the coating method. A dedicated pump system is used to generate a steady and stable resist flow rate with adequate pressure and flow rate. Feedback from a high number of installed tools at research institutions as well as production sites, confirm the reliable functionality of the setup. However, especially in a production environment, a calibration of the systems resist flow rate is needed on a regular basis to keep the requested process stability and is part of the maintenance procedure. With the now available closed loop control system for the resist flow, two major advantages are achieved:

- The frequency of calibrating the system is lowered significantly and in most cases reduced to monitoring the system performance without the need to adjust parameters. This reduces maintenance time, thus, improving the Cost of Ownership.
- The mean resist thickness variation from wafer to wafer is also improved. As an example, for a dedicated process evaluation, the cpk value without the closed loop system is < 1.35 (about 4 Sigma). By introducing the closed loop control system, this changes to a stellar cpk value of > 3.5 (cpk of 2.00 represents about 6 Sigma).

A further advantage of the developed closed loop control system is, that it is field upgradable on all AltaSpray tools without influencing the spray coating results.

IMPROVED THROUGHPUT BY A DOUBLE SPRAY NOZZLE SYSTEM

The conventional SUSS AltaSpray coating technology is represented by a single spray nozzle, that is moved over a stationary substrate surface in a raster path. The process parameters of this raster (meander) are the travel speed of the nozzle and the pitch between the single paths, so called pitch width, (see Figure 2 of the article „Optimizing Spray Coater Process Parameters“, within this issue of the SUSS report). After finishing the first resist layer, the substrate orientation is turned by 90° and the next resist layer is coated. This procedure can be repeated several times, until the desired resist thickness is achieved. A major advantage of the repetitive turning and coating of the substrates are excellent homogenous coating results. Without any doubts, spray coating offers its own very unique advantages and in specific cases is the only option. However, one of the major disadvantages, especially when it comes to larger substrate sizes, is the rather long process time. To encounter this challenge, a double spray nozzle system was developed. The technical solution contains two identical spray nozzles, that are moved over the substrate surface with a fixed distance to each other. This distance is usually half the substrate diameter (see Figure 1). This means, only half of the meanders are necessary to coat the full substrate area. After the first layer is achieved, the substrates orientation is turned 90° and the second resist layer can be applied as described for the single nozzle process.

The critical parameters for this case are the combination of the distance of the nozzles to each other and the pitch width. Are the nozzles located too close to each other, areas of the substrate are coated more than once per layer as can be seen in Figure 2. An elevated cross can clearly be distinguished in the topography map of a resist coated silicon wafer. The cross

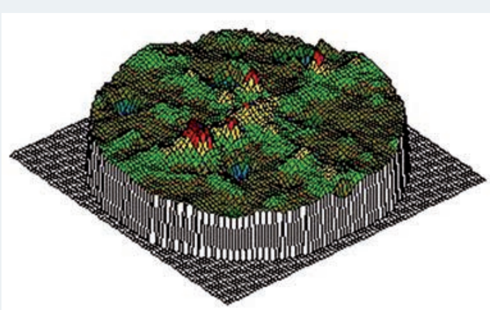


Figure 2: Qualitative topography map of a spray coated silicon wafer with a double nozzle system. The spray nozzles are mounted too close to each other.

type geometry stems from the repetitive 90° turning of the wafer after applying each resist layer. Without the turning, only a line type geometry would be visible. In the shown example case the resist AZ 4999 was used with a final layer thickness of some ten micrometers.

If the nozzle to nozzle distance is too high, some of the substrate areas are not coated with enough resist, resulting in a cross type valley topography as can be seen in Figure 3.

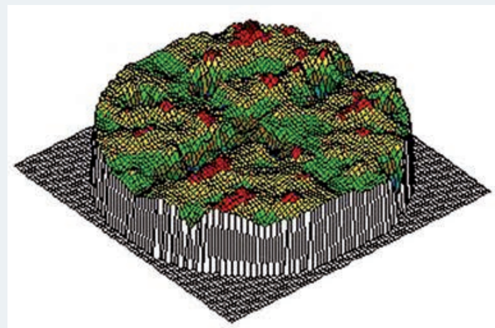


Figure 3: Qualitative topography map of a spray coated silicon wafer with a double nozzle system. The spray nozzles are mounted too far away from each other.

When the distance is adjusted correctly as shown in Figure 4, no topography artifacts can be identified and thus no negative influence of the double nozzle system can be distinguished. For the shown sample process, the needed time to spray coat a 150 mm silicon wafer is reduced by >40% compared to the single nozzle process, thus, significantly rising the overall throughput of the coating tool.

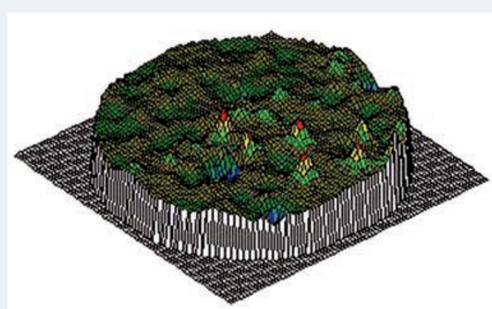
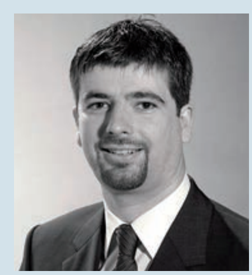


Figure 4: Qualitative topography map of a spray coated silicon wafer with a double nozzle system. The spray nozzles are mounted in a correct distance to each other.

CONCLUSION

By introducing the shown technical developments to the SUSS AltaSpray technology, especially high volume manufactures can benefit from the resulting yield and throughput improvements. The reduced process times might even open up new fields of application where spray coating was up to now not cost effective due to the often long process times.

Katrin Fischer studied chemistry at the NTA Isny. She worked in the R&D department at the Fraunhofer Institute IISB in Erlangen, before joining SUSS MicroTec in 2001 as a Production and R&D Manager. Katrin Fischer became part of the core team for developing the SUSS AltaSpray technology. Since 2005 she has the position of an International Product Manager Coater Systems and graduated with an MBA at the University of Ingolstadt in 2007.



Thomas Grund studied mechanical engineering with a specialization in microsystems technology at the Technical University of Karlsruhe. For his work on batch integration technologies for hybrid microsystems he earned a PhD degree from the Karlsruhe Institute of Technology (KIT) in 2010. Afterwards, Thomas Grund became project manager for an application of deep X-ray lithography at the KIT. He joined SUSS MicroTec at the beginning of 2012 as International Product Manager Coater Systems.

EFFICIENT OZONE, SULFATE AND AMMONIUM FREE RESIST STRIPPING PROCESS

Davide Dattilo SUSS MicroTec Photomask Equipment, Ferdinand-von-Steinbeis-Ring 10, 75447 Sternenfels, Germany
Uwe Dietze SUSS MicroTec Inc., 430 Indio Way, Sunnyvale, CA 94085, USA

1. INTRODUCTION

Conventional resist strip processes employ a variety of steps geared towards highly effective removal of organic and inorganic contamination from the mask surface.

Figure 1 summarizes the process steps in mask cleaning and the mostly used chemistries employed in 193i mask cleaning.

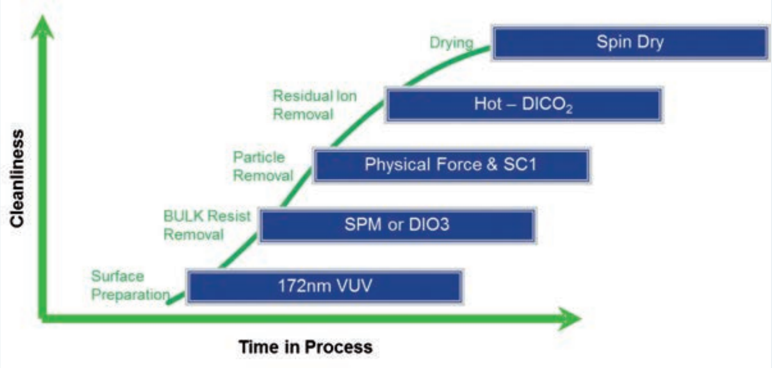


Figure 1. Principle sequence of a photomask cleaning process illustrating the increasing cleanliness of the photomask with progressing process time.

For proper wetting of the photomask surface with cleaning chemicals, higher surface energy is desired. A photomask surface is needed to be in hydrophilic state prior to the application of wet chemistries. Hydrophilic surfaces promote better liquid distribution and uniform chemical effects across the surface; as part of the POR cleaning process flow a 172nm excimer VUV step was used to achieve a low water contact-angle on the surface. The UV radiations under the oxygen atmosphere create oxygen radicals leading to surface organic bond cleavage as well as direct surface activation for better wetting[8,9]. However, the high energy radiations exposure of the photomask surface may also cause interface stress or material diffusion, which eventually transforms into unpredictable mask registration shifts. Ozone water (DIO_3) or conventional SPM ($H_2SO_4 + H_2O_2$) was used for resist stripping and organic removal, however haze formation[10,11] or oxidative degradation of photomask materials[12,13] has been observed as a result of the very high oxidation potential of Ozone and Sulfate ions getting trapped on the surface and reacted with ammonium ions used in the following process steps. Such material damage can affect optical properties of the materials and can also cause CD shift.

APM (dilute $NH_4OH + H_2O_2$) chemistry is typically used with MegaSonic agitation for particle removal. For the advanced technology nodes the problem of damaged sub resolution assist features (SRAF) is highly common in 193i optical masks. The acoustic energy transfer in MegaSonic systems can result into acoustic cavitation[14, 15]. Acoustic cavitation occurs due to the sinusoidal pressure variations that travel through the liquid along with the acoustic wave. During the low pressure component of the acoustic wave, small cavities form in the liquid, which can implode in the high pressure part of the propagating wave[16]. This implosion phenomenon is called transient cavitation. Implosion of cavitating bubbles leads to localized high pressure and temperature values which create shock waves in the liquid resulting not just in particle removal but also in feature damage, hence transient cavitation must be avoided. Instead stable cavities must be promoted, which can undergo large amplitude pulsations without implosion, resulting into micro-streaming and such micro-streaming can lead to intense shear stresses along the boundary[17]. These shear stresses lead to drag forces and rolling moments which subsequently overcome the adhesion force between particle and surface[18]. Since there are no shock waves generated, the chances for Ru pitting reduce significantly.

The cavitation bubble behavior is dependent on physical properties of the cleaning media. The gas or vapours filled in the cavitation bubbles define the bubble wall movement or the pulsation of the bubble under propagating acoustic wave. This bubble wall movement defines the nature of the cavity, i.e. whether it would stay a stable pulsating bubble or it will collapse under acoustic pressure. The gas or vapour inside the bubble constitutes gaseous or vaporous state of the cleaning chemistry used during cleaning. If an appropriate cleaning media with optimized physical properties is chosen, it is feasible to generate predominantly stable cavitation.

A hot water rinse with DI-water at temperatures around 80°C is used as a standard approach to reduce the residual ion level on the photomask surface. This process has limitations pertaining to intrinsic cleanliness of the DI-water at elevated temperatures above 70°C (particle adders from heating systems)[19]. Moreover there is temperature drop during Hot-DI transfer from heater system to point of use (photomask surface), which significantly reduces the temperature below 80°C and diminishes the ion removal capability.

In this paper sulfate and ammonium free new chemistries and techniques are presented to overcome the described drawbacks arising from:

1) UV exposure during surface preparation;
2) Oxidizing agents exposure during bulk resist removal;
3) Transient cavitation exposure of sub-nano meter features during particle removal;

The presented alternative approaches are shown in Figure 2.

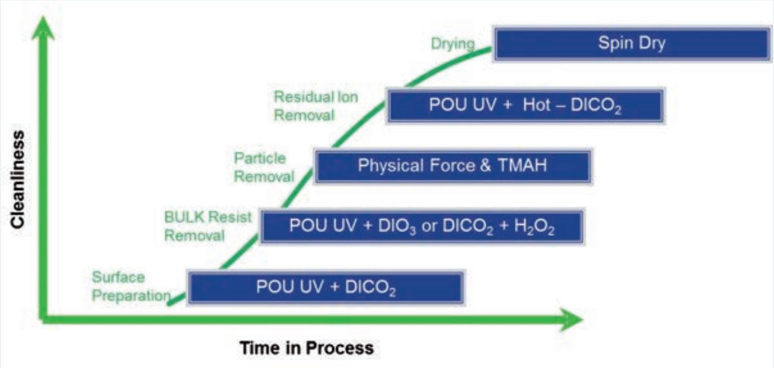


Figure 2. Modified sequence of a photomask cleaning process: direct UV absorption or UV mediated photo-chemical products are used for surface conditioning and bulk resist removal. Physical force cleaning has been modified with TMAH as alkaline chemical.

172 nm UV photochemistry has been replaced by 185 nm or 254 nm UV chemistry for surface conditioning; experimental results show that the contact angle can be efficiently tuned to hydrophilic by direct exposure of the surface to longer wavelength UV-light.

Photolized ozone or hydrogen peroxide is here presented as a valid alternative to SPM or DI-O3 to accomplish bulk resist removal.

Finally, TMAH chemistry is presented as alternative to ammonium hydroxide chemistry to induce more stable cavitation thus allowing to SRAF preservation and pattern durability.

Figure 3 illustrates the two different possible approaches to run photo-chemically driven cleaning processes;

254 nm UV-light is directly absorbed by organic

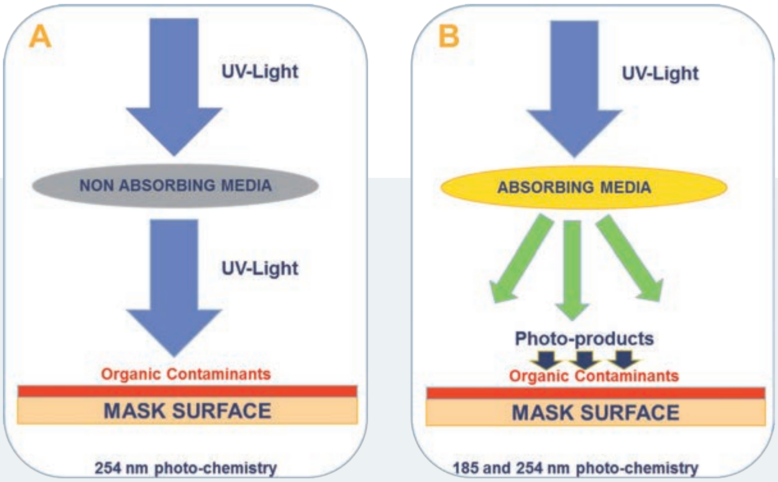


Figure 3. Direct 254 nm UV light absorption in presence of non-absorbing media (A); photolysis of absorbing media leading to photo-products which in turn attach organic molecules and degrade them (B).

contaminants in presence of non-absorbing media leading to crust resist removal or surface conditioning (Figure 3A). At 254 nm organic molecules have a maximum absorption which is bringing the Carbon atoms in their excited state (C*); an electron transfer to molecular Oxygen leads to radical Oxygen anion that attacks the organic molecule radicals R to lead to Peroxyl radicals ($RO_2^{\cdot -}$), that undergoes to consecutive oxidation reactions to CO_2 and water. This reaction scheme can be summarized as follows[6]:

$C = = = = C^*$

$C^* + O_2 = C^{\cdot +} + O_2^{\cdot -}$

$R + O_2^{\cdot -} = RO_2^{\cdot -}$

$RO_2^{\cdot -} = = = CO_2 + H_2O$

Each of these radical reactions competes with recombination; however the intensity of the supplied light ensures enough radical concentration to get to organic oxidation to carbon dioxide and water.

Absorption can also take place on metal or silica (SiO_2, glass or quartz) surfaces often leading to thin oxide layers resulting in a more polar, i.e. hydrophilic surface.

In the presence of absorbing media, such as Ozone (O_3), Oxygen (O_2) or Hydrogen Peroxide, the absorption of UV light leads to photo-products which in turn attach the organic (resist) molecules on the surface (Figure 3B). 254 nm or 185 nm emissions from medium and low pressure Mercury lamps can be selectively used to photolise these chemicals. At these wavelengths such media (Oxygen, Water, Ozone, Hydrogen Peroxide) lead to photolysis, with generation of highly reactive singlet Oxygen (O (1D)) and Hydroxyl radicals[20]:

Oxygen (185 nm)	$O_2 = O^{\cdot}(1D) + O^{\cdot}(1D)$
	$O^{\cdot}(1D) + H_2O = HO^{\cdot} + HO^{\cdot}$
Water (185 nm)	$H_2O = H^{\cdot} + HO^{\cdot}$
Hydrogen Peroxide (254 nm)	$H_2O_2 = HO^{\cdot} + HO^{\cdot}$
Ozone (254 nm)	$O_3 = O_2 + O^{\cdot}(1D)$
	$O^{\cdot}(1D) + H_2O = HO^{\cdot} + HO^{\cdot}$

Hydroxyl radicals are usually responsible for organic removal from the surface; the reaction mechanism is known as hydrogen abstraction and produces organic radicals R. which in turn attach molecular oxygen to lead to Peroxyl radicals that undergo consecutive oxidation reactions to water and carbon dioxide:

$OH^{\cdot} + RH = R^{\cdot} + H_2O$

$R^{\cdot} + O_2 = RO_2^{\cdot} = = CO_2 + H_2O$

Megasonic clean is here presented with the modification of the alkaline chemistry, which typically employed ammonium hydroxide for this purpose; TMAH is a valid alternative to this chemistry for several reasons:

1) Respect to ammonium hydroxide is a strong base, thus totally dissociated in ions when put in water, leading to favorable pH and Zeta Potential with much smaller used amounts, thus leading to higher PRE;
2) Ammonium Hydroxide exist in equilibrium with dissolved gaseous ammonia (NH3) leading to transient cavitation as previously reported[7]

Scheme 1 summarizes the involved equilibria in solution.

a) $NH_4^+ + OH^- \rightleftharpoons NH_4OH \rightleftharpoons NH_{3(g)} + H_2O$

b) $N(CH_3)_4OH \longrightarrow N(CH_3)_4^+ + OH^-$

Scheme 1. Dissociation and decomposition behavior of Ammonium Hydroxide and TMAH; a) Partial dissociation of NH_4OH as weak base ($pK_b = 4.75$) and its equilibrium with ammonia (NH_3) and water; b) complete dissociation of TMAH as strong base into tetramethyl ammonium cation and hydroxiles.

Molecular symmetry plays also an important role; the bigger positive ions of TMAH molecules prevent etching into Silicon or Molybdenum[21]; Figure 4 shows the different dimensions of NH_4^+ and $N(CH_3)_4^+$ ions.

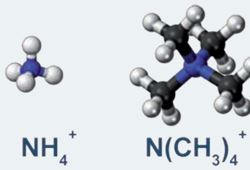


Figure 4. Cation sizes for NH_4^+ (ionic size 1.43 Å) and $N(CH_3)_4^+$ (ionic size 2.51 Å)

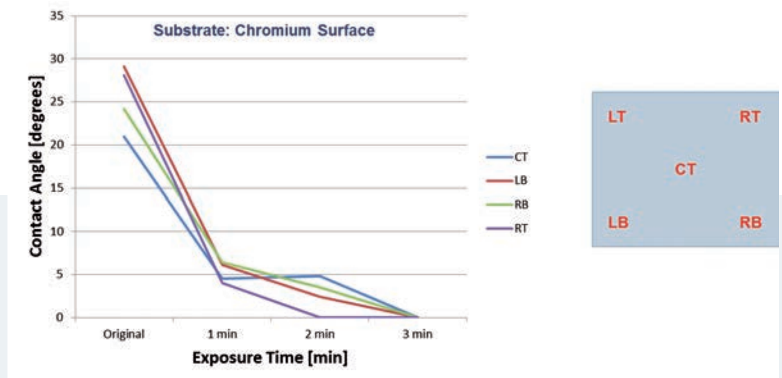


Figure 5. Treatment of Chromium Surface to 1, 2 and 3 minutes of UV-light in combination with DI-CO_2; exposure times longer than 2 minutes bring the contact angle to zero.

2. EXPERIMENTAL

2.1 PROCESS PARAMETERS

All the tests were performed using the SUSS MaskTrack*Pro* (MT*Pro*) mask cleaning tool. The process parameters were automatically monitored and controlled with a standard recipe programmed on the MTPro tool. DI water used for the tests was de-gassed before it was supplied to the cleaning chemical distribution system. Chemicals (TMAH or H_2O_2) and gases (CO_2) were added into the de-gassed water to prepare the respective cleaning media. The cleaning media tested are: SC1, TMAH, Ozone.

2.2 CHARACTERIZATION

Strip rates were measured by measuring photoresist coated before and after the process.

Pattern damage was tested using optical Phase Shift Masks (PSM) with Sub Resolution Assist Feature (SRAF) size suited for advanced technology nodes. For this evaluation, an advanced mechanical feature of the MTPro was utilized, Focused Spot Cleaning (FSC)[10]. Acoustic energy was measured using a handheld acoustic sensor meter. PRE was tested on deposited SiN particles on blank substrates. PSM mask CD is measured using a CD-SEM tool. Phase and Transmission loss based on TMAH POR (Process of Record) is compared with conventional POR.

3. RESULTS & DISCUSSION

3.1 SURFACE CONDITIONING

172 nm UV exposure was replaced with DI-CO_2 water treatment upon 254 nm exposure from Mercury lamp. 1, 2 and 3 minutes of exposure of Chromium surfaces efficiently decrease the contact angle to <5°, thus leading to a very hydrophilic surface. Results are summarized in Figure 5. The milder photochemical conditions (longer wavelength) ensure damage preventing on the metal surface.

3.2 RESIST CRUST REMOVAL

The described direct photochemical approach (Figure 3A) has been used for crust resist removal; to prove that a photoresist spin coated mask blank was exposed to DI-CO_2 in presence of 254 nm UV light; the results are shown in Figure 6. Highly hydrophobic resist surfaces are turned into more hydrophilic thus indicating efficient crust resist removal.

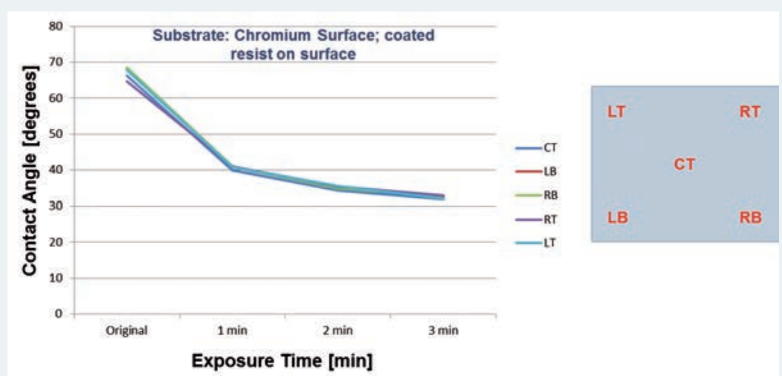


Figure 6. Treatment of resist coated Chromium surface to 1, 2 and 3 minutes of UV-light in combination with DI-CO_2; the decrease in contact angle reaches about 40 degrees.

3.3 BULK RESIST REMOVAL

Efficient Ozone or Hydrogen Peroxide decomposition under UV light (254 nm or 185 nm) is used for bulk resist removal. A resist coated mask was partially scanned under IUV conditions to evaluate strip rates also in the non-scanned areas, i.e. stripping from any un-decomposed Ozone or Hydrogen Peroxide. The process parameters are optimized to have minimum strip rate in the non-scanned area of the mask and maximum rate in the scanned regions. The stripping results are summarized in Figure 7.

Several process parameters have been chan-

	Condition #	1	2	3	4	5	6	7	8	9	10	11	12
Condition	H2O-O3, ppm	low	low	low	low	medium	medium	medium	medium	medium	medium	high	high
	H2O-CO2 Heated	no	yes	yes	no	no	yes	no	yes	no	no	no	no
	UV power, %	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
	Lamp distance	medium	medium	medium	small	large	medium	medium	medium	medium	medium	medium	small
	Scan speed, mm/s	50	50	50	50	50	50	50	50	50	50	50	50
	Process time, s	360	360	360	360	360	360	360	360	360	360	360	360

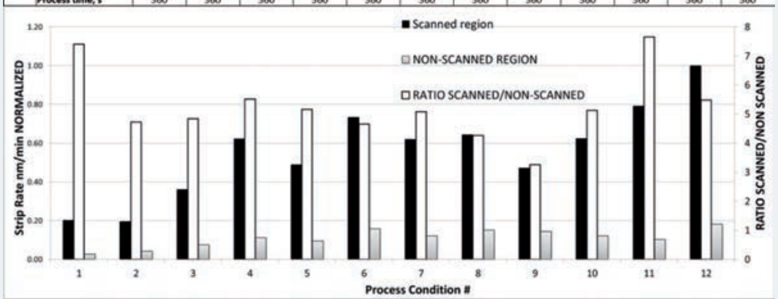


Figure 7. Stripping results obtained by photolysis of absorbing media (such as Ozonated water); stripping in the non-scanned regions of the surface indicate damage risk due to un-decomposed oxidizing agents. Low ratios scanned to non-scanned regions in parallel with good strip rate in the scanned regions indicate good process conditions.

ged to find the best stripping conditions which should coincide with high scanned to non-scanned regions ratios and high absolute strip rate in the scanned regions.

3.4 PARTICLE REMOVAL

The described TMAH chemical benefits have been demonstrated in terms of SRAF preservation, risk of Ruthenium pitting, particle removal efficiency and CD shift. TMAH has been tested alone and in combination with H_2O_2. Typically SC1 and NH_4OH-DI show higher PRE than H_2-DI as well as better CD shift, therefore in this study TMAH and TMAH + H_2O_2 were compared with SC1 in terms of PRE and CD shift. These results are shown in Figure 8. TMAH chemistry gives significantly higher PRE as compared to SC1. This higher removal efficiency is attributed to higher pH and higher zeta potential as discussed in the introduction above. TMAH and its combination with H_2O_2 have also been compared to SC1 in terms of SRAF preservation and risk of Ru pitting; the results are summarized in Figure 9.

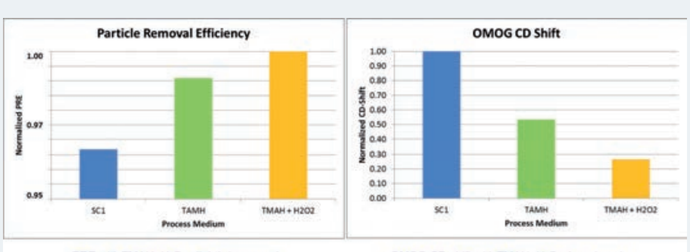


Figure 8. Left: PRE comparison between SC1 and TMAH and TMAH + H_2O_2; the latter chemistry provides the higher PRE. Right: OMOG CD shift comparison between SC1 and TMAH and TMAH + H_2O_2; the latter chemistry provides higher reduction of CD shift.

The shown improved SRAF preservation and lower Ruthenium damage risk is explained by better cavitation control due to the elimination of gaseous ammonia (NH_3) as described above.

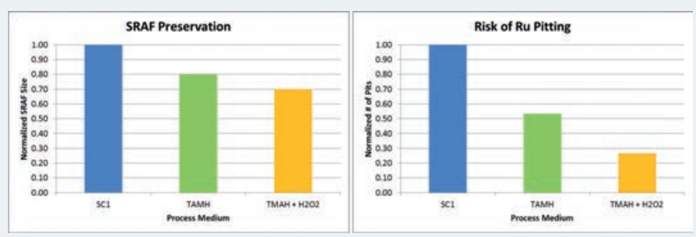


Figure 9. Left: SRAF preservation comparison between SC1 and TMAH and TMAH + H_2O_2; TMAH and TMAH + H_2O_2 preserve SRAF of smaller size. Right: Risk of Ruthenium pitting comparison between SC1 and TMAH and TMAH + H_2O_2; TMAH and TMAH + H_2O_2 also reduce risk of Ru Pitting.

4. SUMMARY

In this paper the cleaning process has been discussed with possible drawbacks arising from highly oxidising agents and not favourable chemistries for cavitation during physical force cleaning. An alternative sulphate and ammonium free process is here proposed and discussed. The results show that surface preservation is possible by replacing SPM by In-situ UV photolized Ozone or Hydrogen Peroxide; moreover, replacement of Ammonium Hydroxide with Tetramethylammonium Hydroxide (TMAH) favourably influences cavitation properties leading to reduced feature damage in FRAS 193i photomasks. The elimination of Sulphate and Ammonium also prevents haze formation typically due to the combination SPM and APM chemistries.

THE AUTHORS

Davide Dattilo took his master degree in Chemistry in 2000 and his PhD in Molecular Materials in 2004.
He gained experience in Surface Chemistry during his 3 years post-doc at the University of Padova, where he studied the basic reactivity of crystalline substrates such as Silicon and Gold.
He worked for 5 years in the R&D department of Molecular Stamping, a bio tech company where he has been responsible of the development of Surface Chemistry for the immobilization of organic molecules on solid substrates and passivation approaches. Since 2012 he is Process Scientist at SUSS MicroTec Photomask Equipment leading R&D projects for cleaning of optical and EUV photo-masks.

Uwe Dietze has been with SUSS MicroTec Photomask Equipment (formerly HamaTech APE) since 1990 in various functions of customer service, sales and management. He is holding a Bachelor of Science Degree in Mechanical Engineering and has gained 32 years of experience in photomask and semiconductor technology.
As Senior Director Surface Technology Innovations he is today responsible for the development of advanced features and technologies for SUSS wafer and photomask processing equipment.

ACKNOWLEDGEMENT

Authors would like to acknowledge Arun John Kadaksham, SEMATECH, for his support of studies on Ru pitting; SEMATECH , for helping with damage studies on EUV blanks and patterned masks; Rudolf Huber, SUSS MicroTec Lithography Division, for his support on ISUV radiation characterization; Jyh-Wei Hsu, SUSS MicroTec Taiwan, for his support on surface preparation and resist strip optimization; Min Liu, SUSS MicroTec USA, for his support of Megasonic process characterization; Sherjang Singh, former employee of SUSS PE, for his work on Megasonic cavitation control.

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EXCIMER LASER VIA-DRILLING - OPTIONS TO FURTHER CAPABILITIES OF NEXT GENERATION WAFER LEVEL PROCESSING DEVICES

Matthew Gingerella, Matt Souter SUSS MicroTec Photonic Systems Inc., 220 Klug Circle, Corona, California 92880-5409, USA

INTRODUCTION

SUSS MicroTec Photonic Systems (SMTPS) has extended its Excimer laser ablation expertise, and knowledge gained from close relationships with key advanced semiconductor material manufacturers, to Advanced Packaging's top cutting-edge companies and research institutions (Figure 1).

IBM Fraunhofer

Figure 1. SUSS MicroTec Photonic Systems is engaged in valuable JDA's with IBM and Fraunhofer.

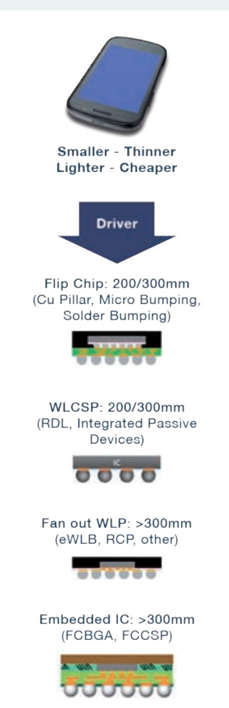


Figure 2. Cell phones and handhelds driving the need for smaller, thinner, lighter Next Gen Advanced Packages

By doing so, SUSS MicroTec has opened new and innovative avenues for industry-leaders to develop more capable and reliable Next Generation Wafer Level Processing (WLP) Devices. This article highlights SUSS's Excimer Laser Via-Drilling technology and its role in shaping Next Generation WLP Devices.

BACKGROUND - AP INDUSTRY CHALLENGES

The explosive demand for increased cell phone capability and ever-shrinking form factor, has forced the hand held electronic device manufacturers into emergency reaction-mode with one mantra: **"Smaller – Thinner – Lighter – Cheaper - Faster."** These are the common drivers for all of the major applications, including WLCSP, FOWLP, and flip-chip products (Figure 2). Since each of these drivers adds increased complexity and challenges to the fabrication process, it is understandable that the top-level demand by the industry is mitigating risks caused by the added complexity, while at the same time managing costs.

The traditional Photo Polymer Dielectrics used today (eg: PI, PBO, BCB, Epoxy) lack the necessary properties (thermal, mechanical, electrical) to mitigate Next GEN chip-failures as well as to drive down costs. Early industry trends indicate that new higher performance dielectric materials, such as Non-photo Polymers and Epoxy Mold Compounds (EMC) are favored as a means to combat the thermal/mechanical limitations of photo-dielectrics to help reduce these chip failures. The extensive benefits and improved reliability to be gained by these non-photoimagable materials are listed in Figure 3, below.

+ Better CTE matching
+ Lower cure temperature
+ Better modulus matching
+ Lower residual stress
+ Reduced out-gassing
+ Longer shelf-life
+ No special storage requirements

Figure 3. Next Generation WLP desired material properties

However, legacy photolithography and wet-etch patterning methods are barriers to material adoption of Non-Photo Polymers due to several technical and cost constraints:

1) More expensive processing
2) Limited resolution
3) Wet-etch limitations at high-pitch and
4) Wet developing difficulties in small vias

Consequently, there is considerable interest in using Excimer laser ablation in lieu of photolithography to form these vias (Figure 4) in dielectrics. Excimer ablation enables processing of reduced via dimensions and a broader range of dielectric materials, including inherently photosensitive and non-photosensitive options.

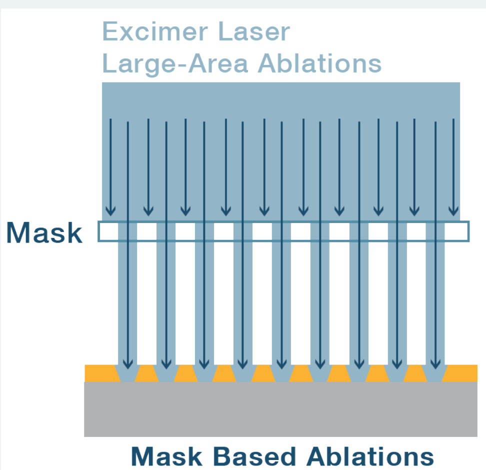


Figure 4. Mask based laser ablation optimizes throughput and pattern placement

The laser ablation process provides improved feature resolution and reduced via opening sizes, resulting in significantly improved interconnect density.

PROCESS COMPARISON

Laser via drilling is a more simplified process compared to traditional photolithography methods. A reduction in process steps decreases overall costs and increases process yields.

The traditional photolithography process consists of the following 6-steps: coat dielectric, soft bake, UV expose, develop, hard bake and plasma clean. In contrast, the Excimer laser drilling process consists of 4-steps: Coat dielectric, Hard bake/blanket expose, laser ablation and plasma descum/clean (Figure 5).

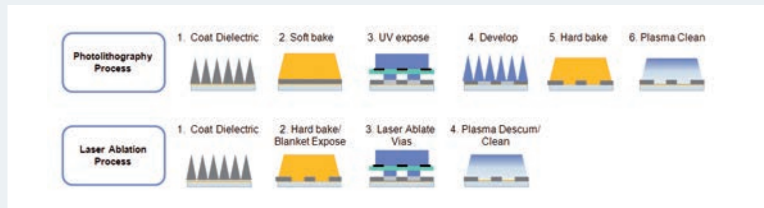


Figure 5. Comparison of the number of process step for photolithography (6) and laser ablation process (4).

The examples in this paper will demonstrate how using laser via drilling can dramatically improve the design rules for next generation Vias and RDL layouts.

LASER VIA DRILLING (ABLATION)

Laser via ablation offers “state of the art” process results with improved feature resolution (~3 µm) and reduced via opening sizes (Typically 1:1 ratio). This laser process allows for designing significantly higher density interconnect layouts for underlying metal redistribution layers and metal pads.

Figures 6-9 present a test matrix of via and line dimensions in a 7 µm thick PBO dielectric. Via dimensions as small as 7.3 µm are demonstrated

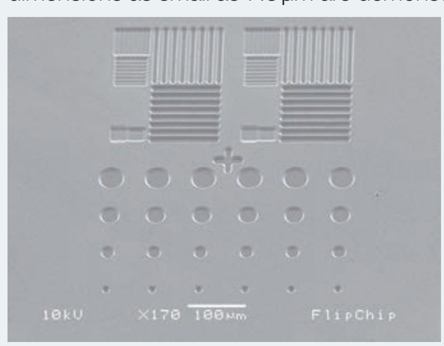


Figure 6. Via & L/S features ablated in 6 µm PBO

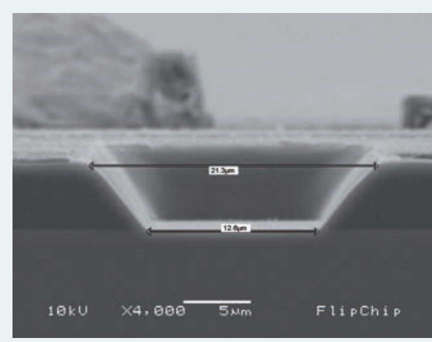
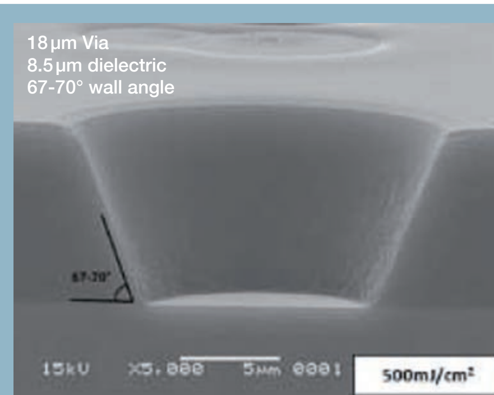


Figure 7. Square Via (~20 µm) ablated in 6 µm PBO

with an application desired sidewall angle of 60 degrees. The Excimer laser process also enables the ability to manipulate the sidewall via angle profile by simply adjusting the laser fluence and other settings. The typical sidewall angle range is generally between 50~82 degrees, depending on material type.

Side-wall Angle Control
+ Wall angle control
+ Higher fluence:
  Steeper wall-angle
+ Lower fluence:
  Shallow wall-angle

Pictures courtesy of FlipChip International



Pictures courtesy of FlipChip International

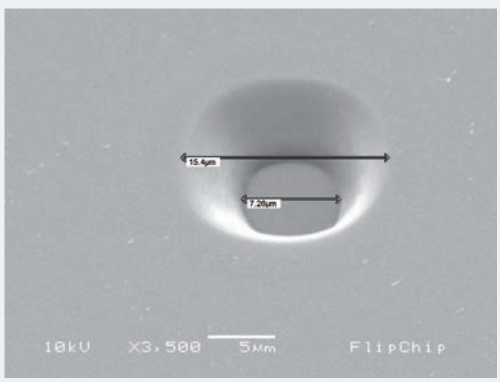


Figure 8. Via (~15 µm) PBO ablated in 6 µm PBO

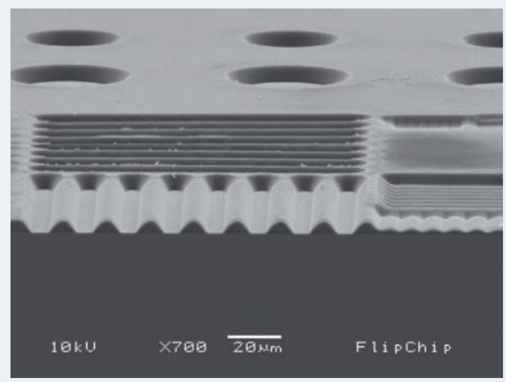


Figure 9. 8 µm L/S features ablated in 6 µm PBO

Excimer laser ablation is ideal for selectively removing materials, such as polymers; while stopping on a different material, such as a metal layer that is (> ~1 µm) thick. A thick metal pad acts as a natural stop layer for Excimer ablation of vias with no damage or metal removal occurring to the metal pad. Figure 10 demonstrates the ability to ablate to a copper surface without damaging or etching the copper layer. The red arrow illustrates the sidewall angle of ~75 degrees through a 14 µm thick dielectric layer. In addition, by controlling the fluence and other settings the Excimer ablation is able to stop at a certain depth in the dielectric without a metal backstop.

The ability for laser drilling to stop on metal pads without damaging them is a critical requirement for Advanced Packaging applications. A comparison of Excimer and DPSS laser drilling results in polymer, down to a ~1.4 µm thick Al pad, are shown in Figure 11. The results clearly demonstrates that Excimer laser drilling is able to selectively stop on the Al pad without damaging it due to its flat top beam profile. In contrast, the DPSS laser results show significant damage to the Al pads.

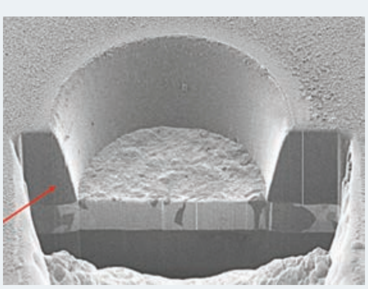


Figure 10. Laser ablated via stopping on a Cu pad (>1 µm thick) without damaging the pad

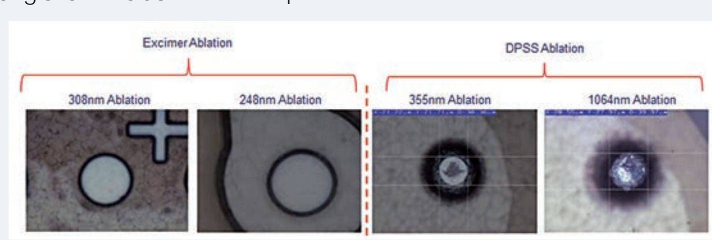


Figure 11. DPSS Laser ablation of vias damaged Al pads; Excimer laser ablation of vias did not.

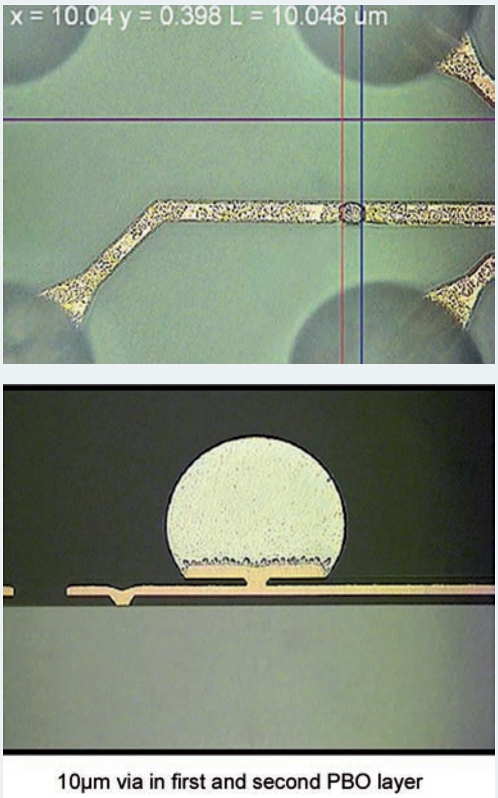


Figure 12. Eximer laser ablated 10 µm vias on 10 µm RDLtrace.
Pictures courtesy of FlipChip International

DESIGN IMPROVEMENT ENABLER

Since Excimer laser via ablation can produce smaller via dimensions compared to standard photolithography methods, using this innovative technology can dramatically improve the design rules for next generation RDL layouts. Excimer laser ablation enables three important advantages for flip-chip and other wafer-level packaging applications:

1) a larger quantity and reduced via dimensions to be placed on the device;
2) ability to utilize better performing polymers; and
3) enable manufacturing cost reductions.

In fact, Excimer laser ablation could possibly reduce some two-layer RDL designs down to just one-layer, further simplifying the manufacturing process.

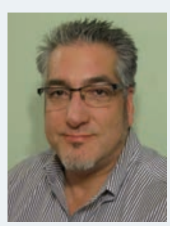
The following example demonstrates the ability to ablate a 10 µm via to a 10 µm RDL and shows successful subsequent plating (Figure 12).

To simplify its industry adoption, the Excimer laser via drilling process has been successfully and seamlessly integrated into a standard photolithography process flow.

Excimer laser via drilling is an enabler for the use of “non-photosensitive” organic dielectrics. In contrast, photolithography with “non-photo” polymers would require additional processing steps and increase manufacturing costs. Excimer laser ablation is attractive because it provides superior patterning capabilities and reduces manufacturing costs.

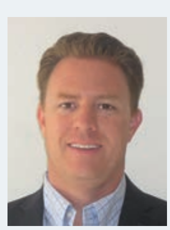
The use of the latest “non-photo” dielectrics will improve mechanical and thermal properties in next generation device packaging – even as the bump diameters and pitches continue to shrink. The expected result is more capable WLP devices with improved product yield for next generation products.

THE AUTHORS



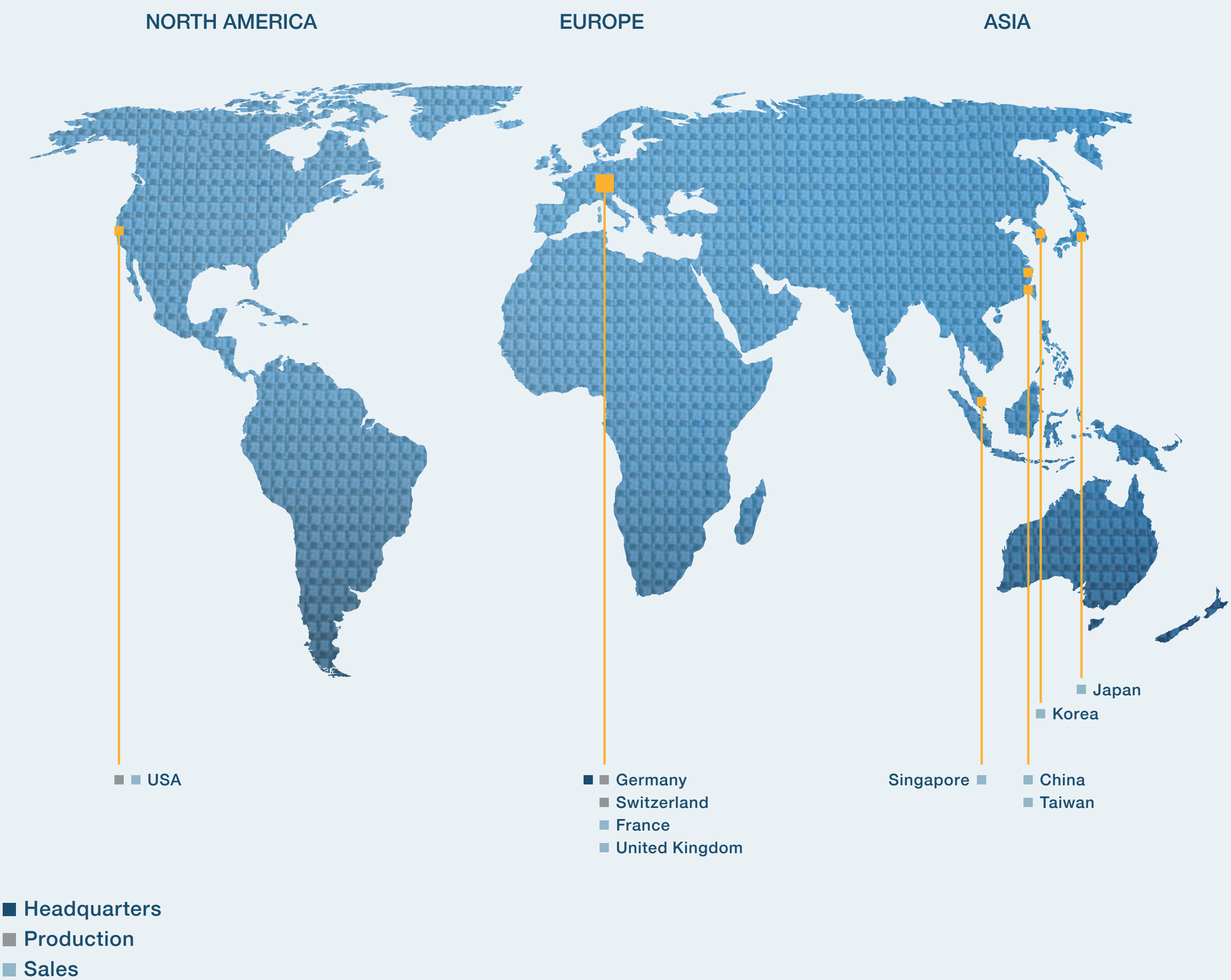
Matthew Gingerella is a seasoned applications engineer and solutions-based capital-equipment sales professional. His education includes a Bachelor’s Degree in Chemistry from CSUF and a two-year degree in Electronics Technology. His background encompasses manufacturing, industrial processes, regulatory compliance, sales, service, marketing and training.

He is presently an International Product Specialist for SUSS MicroTec Photonic Systems located in Corona, CA. He has spent over 7-years working closely with the scientists, researchers, engineers and management of top-tier high-technology companies to help develop and qualify SUSS MicroTec’s laser ablation and projection photolithography patterning solutions for their cutting-edge applications and processes. Gingerella is an application specialist for the following markets: Semiconductor Advanced Packaging, WLP/3D TSV/RDL; Biosensors, Diagnostic Sensors, Rigid & Flexible Displays, E-Paper, Photovoltaics, and Organic Electronics.



Matt Souter graduated in 1992 from CSULB in California with a BS in Mechanical Engineering. He joined Tamarack Scientific in 2001 and has been active in the role of VP of Sales and Marketing for both the Laser Ablation and Photolithography product lines. Much of his focus as of late, has been in the research and development of alternative patterning techniques using Excimer laser ablation as a means to not only meet next generation Advanced Packaging requirements, but also address a means to lower manufacturing costs. Matt has recently authored an exciting new laser process for the removal of metal seed layers in lieu of standard processing approaches, addressing both technical limitations as well as a reduction in manufacturing costs. This process is currently patent pending. With the recent acquisition, he currently works as Global Sales Director and Laser System Product Manager for SUSS MicroTec.

SÜSS MicroTec



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Imprint

Publisher:
SÜSS MicroTec AG
Schleissheimer Str. 90
85748 Garching
Germany
info@suss.com

Chairman:
Dr. Stefan Reineck

Executive Board:
Frank Averdung (CEO)
Michael Knopp (CFO)

Register Court Munich
HRB Nr. 121347

Value added tax identification number:
DE192123619

Editorial:
Hosgör Sarioglu, Corporate Marketing Manager

Print: Mediahaus Biering GmbH, Munich

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