APPLICATION OF THE SUSS ANGULAR EXPOSURE SYSTEM TO FABRICATE TRUE-CHIP-SIZE PACKAGES FOR SAW DEVICES

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EXAMPLES FOR EXPOSURE OF VERTICAL SIDEWALLS

SAW filters are key components for mobile communication. Size reduction of SAW filters allows for further miniaturisation of mobile phones and an extension of their functionality[1-3]. The miniaturisation of the devices demands also a reduction of the package size. To address the packaging requirements EPCOS has developed the Die Sized SAW Package (DSSP), a true chip-size wafer level package for SAW filters. The key for the realization of this package are the 3D-interconnects.

COATING SOLUTION: SPRAY COATING

For high topography wafers, good resist thickness uniformity is necessary for the subsequent process steps, which cannot be achieved with spin coating. Lamination of dry film resist is also not suitable because the topography of the packages is too high and the trenches between the caps are too narrow to allow a good conformal lamination. Spray coating is developed for high topography coatings[4-6] and this method is applied for the customized lithography step, which is described in this paper. Negative tone resists and lift-off resists have been evaluated, but for these resists the coverage of the upper edges is not sufficient. With positive tone photo resist, the coated film uniformity meets the required coating uniformity.

TECHNICAL SOLUTION WITH MASK ALIGNER

The spray coated resist provides a nearly conformal layer that has to be exposed. As the interconnects are running across the sidewalls

the photo resist needs to be exposed and developed completely in these areas. For the standard perpendicular exposure the effective resist film thickness corresponds to the topography depth (Figure 1), that can be easily 10 times the film thickness on the even planes.
For positive tone resist it is essential to expose the complete film layer from top to the wafer surface to make sure that the exposed areas can be developed completely. Chemically amplified resists seem to solve this problem, but even for

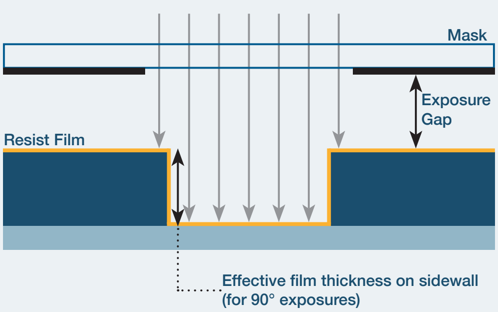

Figure 1: Standard perpendicular exposure of deep trenches and vertical sidewalls

these resists the thickness (corresponding to the sidewall depth) might be too high. If the wafer is exposed with light of an inclination angle of 45° the effective film thickness is nearly uniform across the resist surface. The film thickness on the vertical sidewalls is only 1.4x of the nominal

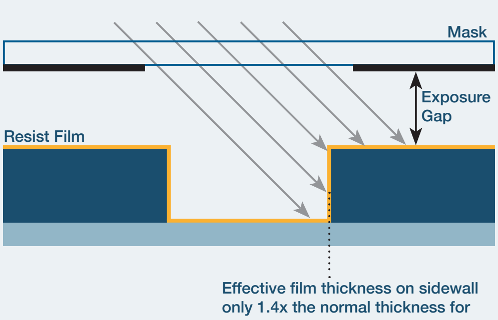

Figure 2: Angular exposure of deep trenches and vertical sidewalls

film thickness (Figure 2).
Due to the inclination angle of the exposure light the shape of the exposed area changes from a circular area for 90° exposure to an ellipsoidal shape for angular exposure. The diameter in y-direction gets larger while the diameter in x-direction decreases. Thus, the angular exposure is possible only for wafers up to 150mm, while the 90° exposure is possible for up to 200mm wafers.
The possibility of angular exposure with inclination angles of 45° and 60°, respectively, is an additional option to the standard perpendicular exposure of wafers. As the optical system itself needed some changes, no upgrade is possible for mask aligners in the field. Additionally, these changes need an increasing of the housing in the front and at the side. Therefore, the footprint of the MA200Compact with angular exposure option is slightly larger then the standard machine.

EXPOSURE EFFECTS: SHADOWS AND REFLECTIONS

As already explained the angular exposure system is used for exposing wafers with high topography structures. The high topography structures are leading to shadow effects due to the inclined light flow and some areas are not exposed. For this reason the wafer needs to be turned by 180° to expose the other side, or 4 times by 90° to expose all sidewalls. Up to 4 exposures will be necessary to structure the interconnects at all sidewalls. For proper exposure of all interconnects accurate alignment is essential.
Reflections from the pattern of the opposite side increases the exposure dose in areas close by the sidewalls of the structures. This has a severe influence on the CD control. The design rules for the mask layout therefore have to compensate this effect.

CHANGES IN ALIGNMENT PROCESS

The alignment process is slightly different from standard proximity printing. With standard perpendicular exposure the position of the exposed structures does not change compared to the mask positions.

For angular exposure, the printed image in the resist is shifted compared to the original position. The shift depends on the exposure gap (Figure 3). It could reliably be predicted by geometrical considerations from the exposure gap and the inclination angle. This has to be noted and can be corrected either by adjusting the mask layout or by using the off-set function in the alignment software.

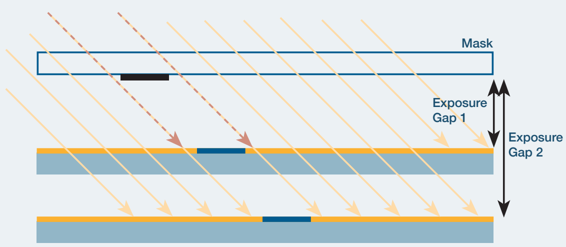

Figure 3: Schematic illustration of pattern printing shift caused by angular exposure

The dependence of the alignment accuracy on the exposure gap requires a precise control of the exposure gap. Due to the strong gap dependency the alignment accuracy is approx. +/-5µm for the angular exposure while it is +/-0.5µm (direct alignment) and +/-1µm (standard alignment), respectively, for perpendicular exposure. Any unevenness or particles between chuck and wafer changes the exposure gap and thus influences the alignment accuracy.

PERFORMANCE OF THE ANGULAR EXPOSURE SYSTEM

The light intensity and the light uniformity across the exposure area are comparable to the standard exposure system. For measurement of the light intensity a special probe holder is used that tilts the probe surface towards the inclination angle to keep the measurement error small.

The resolution results are in the same range for the angular exposure system as for the standard

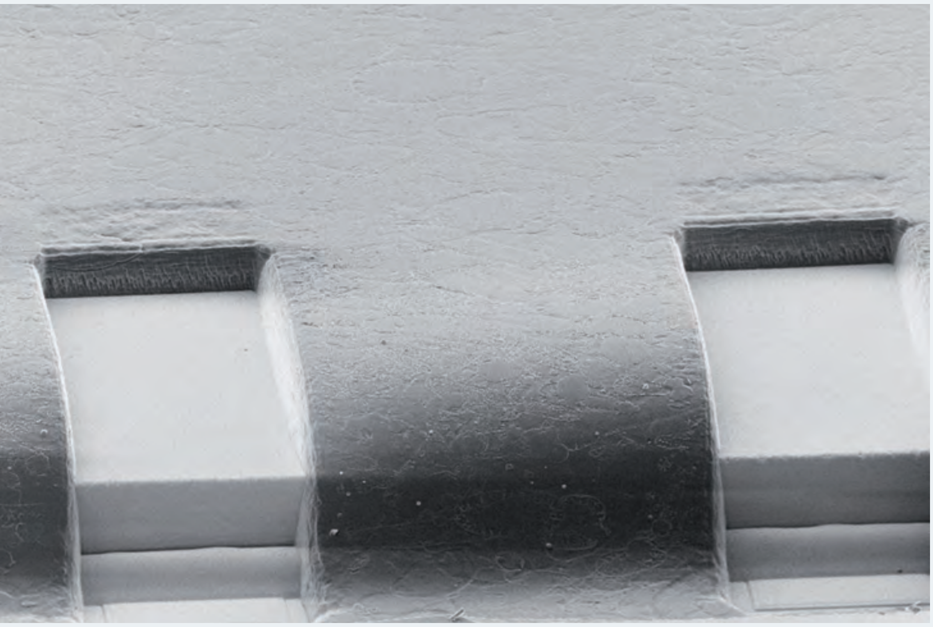

Figure 4: SEM image of spray coated, exposed and developed resist pattern for the metal interconnect

Figure 5: Successfully processed metal connects

perpendicular exposure. The Figures 4 and 5 demonstrate successfully processed interconnects after lithography and after metal patterning for the DSSP package, respectively.

SUMMARY

SAW components require low cost, small size, high reliability and good electrical performance. These requirements do not only relate to the SAW component itself but also to its packaging. True chip size packaging as DSSP meets these reqirements but poses a challenge to the photo-lithographical process due to its packaging caused topography.

For high topography structures like true-chip-size packaged SAW devices 3D-lithography is required. Conformal coating of such high topography wafers is solved by spray coating of positive tone resist.

For the exposure of the interconnect structures on the vertical sidewalls of the package, SUSS MicroTec and EPCOS developed a solution for this challenge with the angular exposure system.

The inclination angle gap exposure causes a shift in the print that can be corrected by the mask layout or by the offset parameters of the alignment software to achieve accurate alignment. As the shift depends on the exposure gap, the correction factor needs to be calculated by geometrical considerations. For exposure of all sidewalls of the structures, up to 4 exposures are necessary.

Realization of the metal connects for high topography structures on the wafers is done successfully with SUSS lithography equipment. Simulations and experimental resuslts proofed the fulfillment of the requirements of the DSSP and the processing technology successfully.

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Barbara L'huillier joined SUSS MicroTec as application engineer for mask aligners in October 2006. In 2009 her field of activity was extended by spin coaters. She received her diploma in electrical engineering from Ulm University, Germany, in 2002 and her PhD degree from Ulm University in 2008, working with GaN light-emitting diode structures on semi-polar crystal planes

Michael Jacobs joined SUSS MicroTec Lithography GmbH as an applications engineer for coaters and spray coaters in December 2003. In 2008 he changed his activity to bonder applications, from 2010 he was focusing on fusion bonding and temporary bonding working at SUSS MicroTec Inc., USA. Since September 2010 he has been working for SUSS MicroTec Sternenfels. In Sternenfels his field of activity is working for permanent and temporary bonding. He obtained his degree as an engineer for physical/medical technology in 2003 from the University of Applied Sciences in Aachen, Germany, working on manufacturing and characterization of microelectrodes for the integration in microanalysis systems.