Dual Wheel Miniature Gang for Silicon Wafer Dicing

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Abstract

Shrinking line width geometries in IC-devices translate into a substantial increase in the number of chips per wafer. However, as a consequence, it also results in a greatly extended cut length during wafer dicing. Since the cutting speed is already quite high, no substantial increase of it may be expected. As a solution, the use of a dual gang wheel is suggested in this paper. Whereas conventional gang wheel dicing requires specially designed machines to support the gang wheel arbor, this new approach allows mounting of a dual dicing wheel on the same pair of flanges designed for single hubless dicing wheel use. Dicing tests showed that the dual gang wheel dicing approach is suitable for achieving the same feed rate as single wheel dicing, as well as obtaining a comparable kerf quality.

Introduction

Shrinking line width geometries in IC-devices translate into a greatly reduced die size. As a for instance, for a particular application, today's line width results in an IC real estate of 64.5 mm^2, allowing to place 385 chips on a 200 mm wafer. A reduction of line width as predicted for the foreseeable future will reduce the area per die to 6.5 mm^2, resulting in an increase to 4,285 chips per 200 mm wafer. Obviously, for dicing such a wafer, the total length of cut increases and the time such a wafer has to spend on a dicing saw is extended significantly. If no means for increasing the wafer throughput were found, additional (and in most cases quite costly) dicing machines will have to be added.

Is it possible to achieve higher throughput by simply raising the cutting speed? Most likely not, since the cutting speed is already quite high (around 75 mm/s). Even if we may be able to further increase the cutting speed, if at all, at best we may increase the cutting speed to 90 mm/s, a mere 20 percent gain. However, minimal requirements call for doubling the productivity [1].

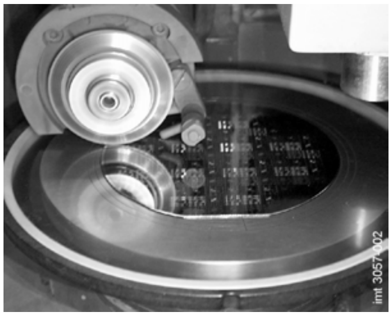

Fig. 1: Dicing of a silicon wafer

Dicing Basics

Dicing, an outside diameter grinding process, is the state of the art approach to separate IC devices manufactured in a batch process on a silicon wafer. Figure 1 depicts dicing of a silicon wafer. The wafer is glued to a flexible tape attached to a film frame mounted on the vacuum chuck of a high-precision dicing saw. The wafer is mounted on a flexible tape due to the pick and place process happening after dicing: by extending the tape, the separated chips are spread, allowing to pick up each one by a robotic system for further packaging.

The grinding wheel is mounted on the dicing saw's high-speed air-bearing spindle with a rotational velocity of up to 40,000 RPM. For executing the cut, the spindle is positioned in z direction (height) for establishing the depth of cut, while the chuck with the wafer mounted on it is positioned in x (feed) and y (indexing) direction. While executing a cut, chuck and wafer are moving parallel to the wheel's rotational plane, resulting in executing a straight cut. To establish the cut location, the chuck is positioned relative to the spindle by a fix distance, the index. For the separation of IC-devices the indexing accuracy of the dicing machine must match the devices' positioning accuracy as determined by the photolithography process. To meet these requirements, the indexing accuracy of state of the art dicing saws is smaller than 0.5 µm.

Dual Gang Wheel

A classic approach to substantially increase productivity is using a gang wheel: multiple wheels are jointly mounted on an arbor, spaced appropriately to allow separation of multiple parts. Typically, gang wheels are difficult to assemble and maintain; they furthermore require a special machine design allowing the support of the arbor on both sides. However, if a dual wheel miniature gang is used, it may be applied to dicing machines designed for single wheel use [2].

The basic approach for the dual wheel miniature gang was to use the same type of flanges as used for single hubless dicing wheels. This type of flanges typically is available for a wheel thickness of up to 1 mm. Instead of mounting one thick wheel, two thin wheels plus a spacer are assembled on the flange's hub. Figure 2 depicts the schematic view of such a dual wheel set-up. It consists of the two flanges (A and B) which ensure a coaxial clamping of the dicing wheels, the two wheels (1 and 2), spacer, and a fastening nut. The spacer maintains both distance and parallelism between the two wheels. Due to the high rotational velocity, tight tolerances in regard to parallelism and axial run-out of both, the dicing wheels and the spacer, were required. As a spacer for the dual gang wheel prototype, a stack of thick dicing wheels with an appropriate total width was chosen. Its outside spacer diameter was ground down to the same outer dimension the flange featured.

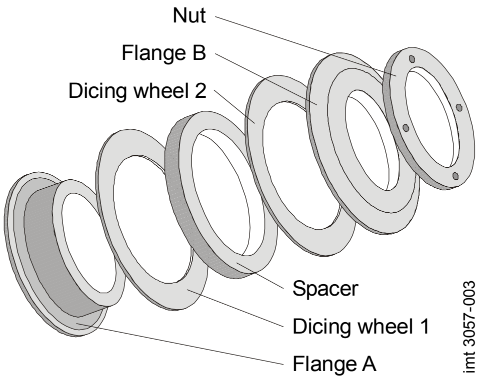

Fig. 2: Schematic sketch of dual gang wheel set-up

A dual wheel miniature gang prototype was built by mounting a pair of 30 µm wheels on a flange, separated by a stack of three 250 µm spacers, resulting in a 0.75 mm distance between the wheels. The thickness tolerance of the spacers was 1 µm. This value matched the IC production requirements.

Thin dicing wheels

A precondition for developing the dual wheel mini gang was the availability of thin dicing wheels. Considering that, due to flange clamping restrictions, the thickness of the wheel/spacer combination had to be below 1 mm, it is obvious that only very thin wheels may be used. As a for instance, mounting two 30 µm thick wheels allows a maximum spacing of approx. 940 µm. The smallest available dicing wheels are 15 µm thick. The limiting factor for the use of these wheels is the wheel exposure: if the exposure ratio, i.e. the ratio between exposure dimension and wheel thickness, is too great, the axial wheel stiffness may be insufficient for achieving a stable grinding process. Exposure ratios for conventional dicing processes typically do not exceed 30:1; maximum ratios of up to 46:1 were obtained, allowing a 0.92 mm exposure for a 20 µm wheel [3]. What wheel exposures are required in today's semiconductor processes? For dicing wafers, the depth of cut varies between 0.8 mm for standard 12" wafers and 0.2 mm for wafers reduced in thickness by backgrinding. Furthermore, 20 µm and 30 µm wheels are capable of operating at cut speeds up to 70 mm/s [4].

Dicing with a dual gang wheel

In order to prove the feasibility of using a standard flange for gang wheel dicing, the set-up, as described above, was used in cutting tests. For the tests, 4" silicon wafers with a thickness of 525 µm, mounted on a tape carrier, were used (compare Fig. 1). The cut depth was 0.55 mm. Table 1 summarizes the test parameters.

Table 1

Test parameters

Work piece	Wheel Binder	Diamond grain size	Wheel diameter	Wheel width	Feed rate	Depth of cut	Cut speed
Silicon, 100 mm round	Metal	3-6 µm	56 mm	30 µm	1, 3, 10, 20, 40, 70 mm/s	0.55 mm	58 m/s

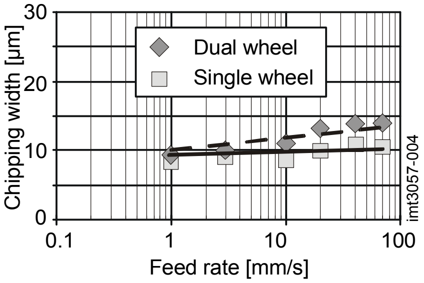

Fig. 3: Feed rate vs. chipping for dual wheel and single wheel set-up

The investigations allow the comparison of the performance of the gang wheel with a single wheel process. Figure 3 shows the chipping width rate for gang wheel and single wheel dicing as a function of feed rate. In both cases, the maximum feed rate was 70 mm/s. While for lower feed rates the chipping of both tests was equal, the gang wheel caused bigger chipping at higher cut speeds. A reason might be found in the coolant supply: the test machine

was equipped with a single coolant nozzle with appr. 2 mm diameter. For a gang wheel, the coolant jet might not be wide enough to ensure adequate chip removal, leading to increased chipping.
Figure 4 (left) shows a SEM micrograph of the dual wheel mini-gang, Fig. 4 (right) depicts a pair of kerfs ground by it. The distance between the two kerfs is 0.75 mm.

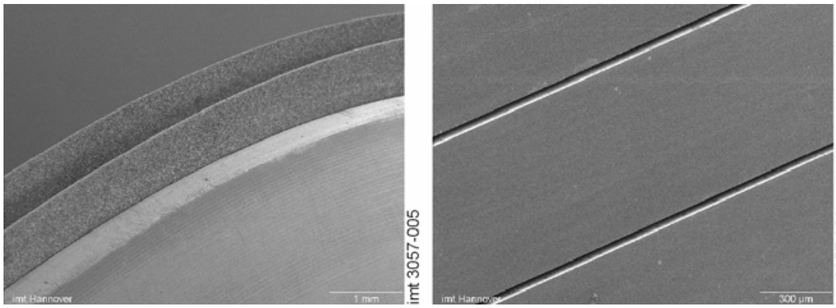

Fig. 4: SEM images of a flange with dual dicing wheel set-up (left) and of a dual kerf ground at a feed rate of 20 mm/s (right)

Conclusion

A potential solution for increasing the cutting performance of existing dicing saws is the use of a dual miniature gang. Using thin dicing wheels and a spacer of appropriate thickness ultimately dictated by the width of the chip, a dual gang wheel was facilitated on a pair of flanges originally intended for single wheel dicing. Since the flanges for single wheel dicing were offering only limited clamping space, only very thin wheels can be used for this set-up. It was shown that hubless wheels of a width of 30 µm were well suited for standard silicon wafer dicing applications. Tests with the gang wheel set-up demonstrated the capabilities of a standard dicing saw with standard equipment. The dual mini-gang is capable of dicing wafers with chips in the 1 mm range, achieving the same cutting speed (70 mm/s) as single dicing wheels.

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