Dicing MEMS

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Introduction

Micro-Electro-Mechanical Systems (MEMS) include a large variety of miniaturized intelligent mechanical systems such as accelerometers, flow sensors, motion mirrors and radio-frequency devices. MEMS are manufactured by the combination of well-established methods for the fabrication of integrated circuits (ICs) together with various micromachining processes to selectively etch away desired portions of the silicon wafer upon which the device is based or to create additional layers of material, thus forming a three-dimensional functional structure. The final component may contain minute and extremely delicate structures such as cantilevers, bridges, hinges, gears, membranes and other sensitive features that necessitate special handling and care.

Several basic differences make the dicing of MEMS significantly more challenging than that of typical ICs or other microelectronic components. MEMS may contain membranes, high aspect-ratio topography and other pressure-sensitive components that cannot withstand the impact of water encountered during dicing and the subsequent cleaning cycle, and raise the need for a protective mechanism to shield them from the constant flow of liquid. In addition, MEMS often have moving parts that are super-sensitive to contamination, and in which the presence of tiny debris particles may hinder or even halt movement altogether. Specific types of MEMS (e.g. electrostatic actuators) are especially sensitive to ESD phenomena and may fail upon spontaneous electrostatic discharges.

Current Dicing Approaches

There are several approaches for dicing MEMS that may be employed in order to overcome the challenges created by their fragility and sensitivity to contamination and ESD. One approach is to permanently cap the MEMS, thus creating a physical barrier between the micromechanical parts and the environment. This method both prevents the contamination of the MEMS device by debris and protects it from the impact of the flow of cooling water during dicing and rinse water in the cleaning step that follows. It also reduces the hazards of ESD by eliminating direct contact of sensitive components with the surroundings. Various materials – such as silicon and glass – are used for capping, and several sealing method may be utilized in order to attach the cap. After dicing, the cap remains as a permanent part of the MEMS. A variation of the capping method is the use of a temporary protective sacrificial layer that covers the MEMS device during the actual dicing step, and is later removed or washed away. In most cases, this protective layer is a polymeric film that may be removed by either dry or wet techniques.

The methods outlined above necessitate additional manufacturing steps and processes in order to place the permanent cap or to form and remove the temporary protective film, and add to the overall cost of manufacturing the device.

Innovative Approaches by ADT

Advanced Dicing Technologies (ADT) has developed an array of innovative methods and specialized equipment to overcome the difficulties and obstacles presented by the unique sensitivities of MEMS to the traditional dicing and subsequent cleaning processes. The approach taken by ADT is one in which the dicing equipment and process – and not the MEMS device itself - are modified in order to solve these problems.

One of the main factors that govern the impact of cooling water on the substrate during dicing is the geometry of the cooling block used. ADT has developed cooling blocks specifically for use with MEMS devices, including custom-made cooling blocks tailored to meet the needs of specific customer applications. An example of such a cooling block is shown in Figure 1 which exhibits a cooling block including a rear-end nozzle.

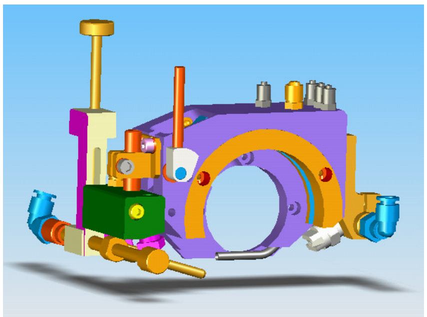

Figure 1*: A non-standard cooling block developed by Advanced Dicing Technologies specifically for dicing MEMS.*

An additional modification to the cooling system geared towards reducing physical damage to sensitive and delicate features is dicing in a cooling bath in which the substrate is completely submerged in the cooling medium during the dicing process. This method essentially reduces the impact of the coolant to zero.

In addition to the negative impact of the streams and sprays of cooling water during dicing, sensitive MEMS devices may also undergo physical damage during the subsequent cleaning cycle, which is most often performed on a cleaning system integrated into the dicing saw itself. The 7200 family of fully automatic dicing saws recently developed by ADT, can be equipped with a unique 'atomizing' nozzle configuration, in which the cleaning/rinsing water is delivered in the form of minute droplets rather than in the form of a continuous stream. The atomized flow of water has improved cleaning properties, thus reducing the probability of MEMS failure due to contamination and debris particles.

The presence of debris may also be controlled by reducing electrostatic discharges that attract minute particles. Electrostatic charges and the resulting electric fields increase particle deposition due to the Coulomb forces (electrostatic attraction = ESA), and particle attraction is directly proportional to the electric field. ADT's 7200 series of automatic dicing saws (basic configuration with integrated handling and cleaning system) has been certified as being in compliance with the SEMI E78-1102 standard regarding electrostatic compatibility (Figure 2).

ESTION
PROFESSIONAL SERVICES
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Certification

Advanced Dicing Technologies Ltd (ADT)
automatic dicing saws for 200 mm, 7200 Series
(basic configuration including handling and cleaning system)

Are compliant to SEMI E78-1102 Standard
with
Level 1 (including 2-4) for ESD sensitivity
Level 1 (including 2-4) for particle attraction sensitivity
Level 4 (including 3-1) for equipment malfunction sensitivity

This certification refers to and is valid with
ESTION Report no.: ADT-ISR-7200-E78-05-09-12

September 13, 2005
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Figure 2*: Certification of compliance of Advanced Dicing Technologies 7200 series of automatic dicing saws with the SEMI E78-1102 standard.*

In addition to particle attraction, the uncontrolled discharge of electrostatic charges can cause both physical damage in the form of localized scorching and lead to malfunction of sensitive electronic components often found in MEMS devices. Several factors can contribute to electrostatic charges build-up both during the dicing process and during the various stages in which the MEMS-bearing frame is transferred between different stations within the machine. Most dicing operations are conducted using deionized (DI) water as the coolant. DI water is used for its purity and lack of dissolved ions. However, this lack of ions results in low conductivity of the water, and its inability to conduct electrostatic charges away from the substrate being diced. One solution to the ESD phenomena related to the high resistance of DI water is to incorporate a reionizing unit, which increases conductivity by the addition of carbon dioxide gas. The carbon dioxide forms bicarbonate ions that are harmless, yet sufficient to increase conductivity to the desired level. As stated, electrostatic charges may originate from the movement of the substrate between the different stations in the saw. ADT's 7200 series of dicing saws are equipped with ionizing elements that accompany all movement within the machine. Figure 3a shows a schematic of the area between the dicer and cleaning station emphasizing a stationary ionizer located between the two. Figure 3b shows a second mobile unit connected to the material handling system (MHS). The combination of both units reduce ESD to acceptable levels in full compliance with SEMI E78-1102 standard.

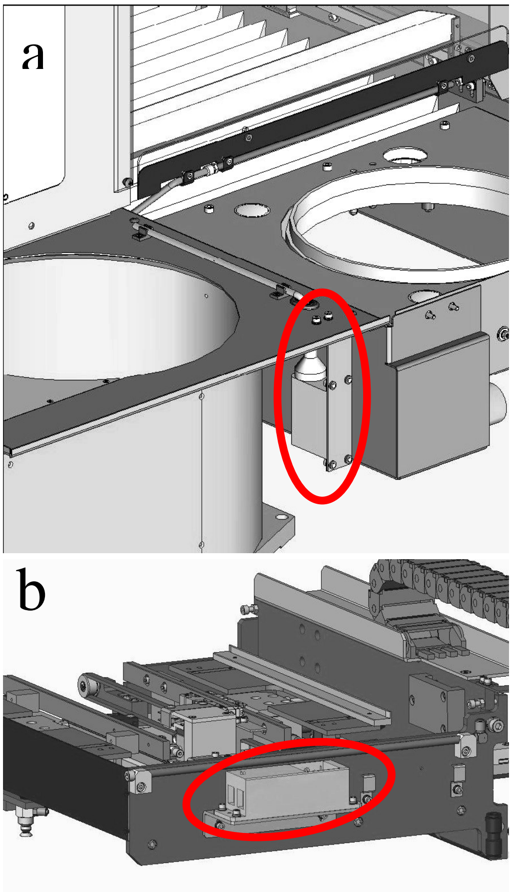
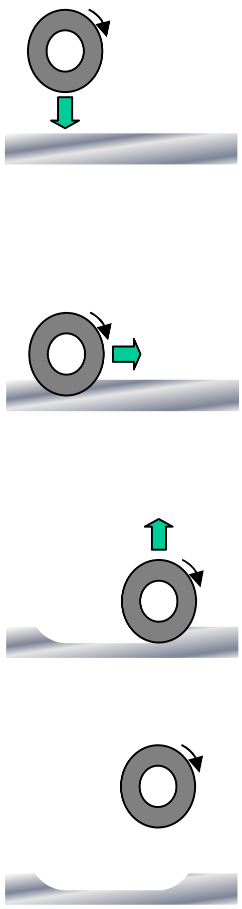


Figure 3: *Ionizing elements in the ADT 7200 series automatic dicing saws. (a) Stationary unit between dicer and cleaner; (b) Mobile unit on MHS.*

The 7200 family of fully automatic dicing saws has several additional features which are utilized in the dicing of MEMS. One such feature is the built-in ability of the saw to accurately measure the height of the substrate being diced. This feature termed "height on part" is especially useful when performing partial cuts (i.e. not all the way through) into substrates of which the height is not precisely know beforehand, for example when part of the height of the substance is composed of an adhesive layer of undetermined thickness. An additional ability of the 7200 dicing saws commonly utilized in dicing MEMS with a beveled blade is the machines capability to determine the correct dicing depth according to the width of the top of the kerf. By measuring the top opening of the kerf the saw continuously calculates the correct dicing depth and compensates for blade wear. Accordingly, this feature is termed "z-compensation.

The 7200 family of dicing saws also has the capability of performing a unique type of dicing action commonly referred to as a "chop cut" or a "plunge cut". In this operation the blade does not cut the substrate from edge to edge, but rather enters it at some point away from the edge and dices a predetermined distance before being raised out of the substrate. The cut may be partial or transcend the full thickness of the substrate. The general concept is schematically demonstrated in Figure 4 for a partial cut. The chop- or plunge-cut may be used, for example, to cut a rectangular section out of a wafer.



(a) (b) (c) (d)

Figure 4*: Chop- or plunge-cut concept.*

While dicing MEMS (especially when performing partial cuts), it if often of great importance to maintain the square-shaped edge of the dicing blade. During dicing, the blade wears down resulting in a curved edge. In extreme cases the shape of the edge is a semi-circle. The 7200 saw may be equipped with an optional on-line dressing station to maintain blade edge shape. The dressing station option is fully integrated into the 7200 saw software package and all dressing process parameters may be pre-defined along with the frequency at which the blade is dressed. The dressing station may be used for dressing of new blades, for periodic cleaning of blades from accumulated buildup which causes blade overload, and for blade reshaping.

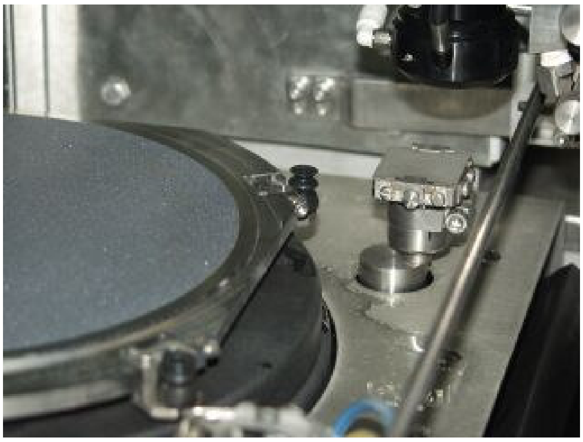


Figure 5*: Optional dressing station.*

Summary and Conclusions

We have seen that dicing MEMS is accompanied by several challenges that stem from the sensitivity of these devices to mechanical pressure, to contamination and to electrostatic discharges. ADT has presented an array of innovative process- and equipment-based solutions to answer these challenges without the need for modifications of the MEMS device itself in the form of hermetic caps and protective layers.