Non-Traditional Dicing of MEMS Devices

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ABSTRACT

Many of the processes that are used in the manufacture of MEMS are taken directly from IC fabrication. Singulating the wafer into individual MEMS is such a process. Most MEMS are singulated using diamond blade dicing barrowed from the IC process. MEMS are many times more sensitive to contamination, vibration, thermal, and electrical shock than ICs. This sensitivity requires modifications to the dicing process. These modifications are often improvements instead of solutions. SD laser dicing is a non traditional singulation process. A laser is focused below the surface of the substrate creating a modified layer. Optical and physical characteristics of the substrate dictate the type of laser used for the SD process. This paper will compare blade dicing to the SD laser process.

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Keywords: MEMS, dicing, particles, stealth dicing

1 STEALTH DICING ENABLAING VOLUME PRODUCTION OF MEMS

Stealth Dicing (SD) is being accepted in the volume production of MEMS. As MEMS increasingly becoming a part of everyday life, manufacturing of the MEMS goes from low volume production, in wafer starts/month, to medium volume production.

Through quality improvements and lower cost of ownership SD aids in MEMS moving from R&D and low volume into full volume production. When production ramps up, yields must improve to allow for automated manufacturing. Along with improving yields is the push for lower costs.

According to the well respected Yole Developpement group the predicted CAGR of MEMS devices is 13%. That would give a $10.8 billion market in 2011. [1]

By being a dry and non-contact process SD eliminates or reduces the traditional yield issues of damage and particles associated with traditional blade dicing.

2 THE SD PROCESS

Laser light with a wavelength allowing for a balance between transmission and absorption is focused below the surface of the silicon wafer. At the point of focus the energy converts the single crystal silicon to a microcrystalline structure. This modification of the silicon creates a vertical separation between the two MEMS devices. The modified layer is termed the SD layer. Silicon thickness and a number of other factors such as edge quality determine if one or multiple SD layers will be created.

2.1 Structure of the SD Layer

Figure 1 below shows a single SD layer on a 50μm thick silicon sample. The SD layer is some distance below the surface. 15 micrometers of silicon has been modified vertically.

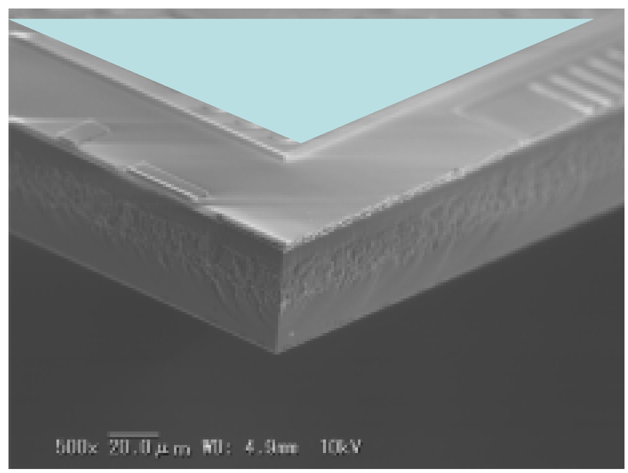

Figure 1: Edge view of a single SD layer.

Figure 2 below shows a thicker silicon sample. At 300µm thick a number of SD layers are necessary. In this case 7 are used.

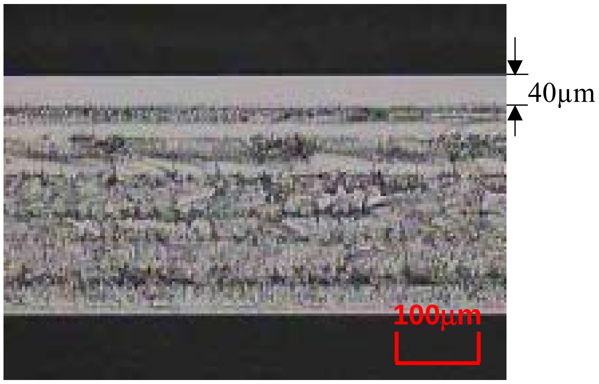

Figure 2: Edge view showing multiple SD layers.

In order to create a clean separation between the MEMS die, vertical height of the SD layer is many times larger than the horizontal component. Figure 3 shows the horizontal component or width of the SD layer.

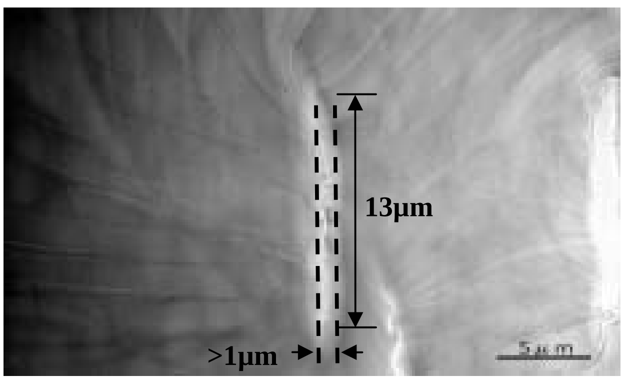

Figure 3: Cross section showing the width of the SD layer.

3 CONVENTIONAL BLADE DICING

Blade dicing is currently the most common way to separate a semiconductor wafer into devices. As with other processes that have been adapted from IC fabrication for the manufacture of MEMS fabrication some changes are necessary.

The typical IC wafer has a passivation layer protecting it from the environment. Additionally ICs are for the most part unaffected by moderate vibration, heating, and electrostatic discharge (ESD). This is not the case for most MEMS. For many MEMS being effected by the environment is their function, they need to have the active mechanical components exposed to the atmosphere. Cantilevers, gears, hinges, bridges, and membranes of the MEMS devices are often extremely fragile and have extremely fine movements. For example a resonator can have a peak-to-peak displacement of 10nm. During dicing, contamination, vibration, heating, and ESD can reduce the performance or cause the device to catastrophically fail.

3.1 Blade Dicing Contamination

Contamination can affect a device in two ways. A fine film of sub micrometer particles can disrupt the function or reduce the reliability of a device. Larger particles can hinder or impede movable parts rendering devices useless.

As the dicing blade cuts through the wafer particles are created. Most of these particles are suspended in water and then carried away by the water being showered on the wafer. For IC's the relatively smooth surface allows the particles to be carried away and in some cases surfactants are added to aid the sheeting action. The particles that remain on the wafer are easily washed away in a spin rinser dryer. Structures of the MEMS often trap the particles and surfactants that would normally rinse off of the wafer. In order to dice with the traditional blade the design of the MEMS may be limited.

To allow the use of standard dicing saws prior to dicing the surface of the MEMS wafer can be covered with a temporary protective film or permanent cap. Another similar alternative is to coat the surface of the MEMS wafer with an oxide or polymer layer that covers the devices and holds the structures in place. After dicing, the film or coating is removed, releasing the MEMS.

3.2 Physical Damage

Due to the fragile nature of MEMS, limiting the amount of stress applied to the wafer is a primary consideration. This is in opposition to eliminating contamination with standard processing. Increasing water flow and pressure is a common way to reduce contamination. With MEMS there is a high likelihood of damage from the water.

Figure 4: Water spray during blade dicing.

Figure 4 shows the amount and force of the water that is applied to IC wafers. Water is supplied to the blade throughout the dicing process using a high-pressure nozzle as shown. Water serves both to remove the heat of dicing and to slough off the material being cut.

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As with protecting the MEMS from particles applying a temporary film or capping the wafer will protect the devices from the damaging water. Removing the film from individual die is usually a time consuming and costly manual process. Cap wafers are usually silicon or glass. The cap is an integral part of the device and remains after dicing. Both methods protect the devices from contamination and physical damage done by water spray but not from vibration.

Vibration during dicing and cleaning can damage the fragile and pressure sensitive components of the MEMS. During dicing the blade rotates brining abrasive particles in contact with the wafer. Rotating at roughly 30,000 rpm the blade creates a vibration. Added vibration to this is a spray of water that is directed at the cut area and the wash cycle.

To dampen the vibration force applied to the MEMS devices the wafer is submerged in water during dicing. This method lowers the impact of the water on the surface of the wafer.

3.3 ESD Damage

A sudden discharge of electrostatic energy can damage the electronic components in MEMS devices. Inside of the dicing saw there are a number of stages where charges are built up. Wafer transfer between stations lead to several locations where an uncontrolled discharge can occur. For MEMS dicing it is essential that the dicing saw be equipped with ionizers. Typically the ionizers are fixed and the wafer moves or passes by the ionizer. SEMI E78-1102 is a standard for electrostatic compatibility. Much of the standard can be applied to MEMS processing.

DI (De-Ionized) water is often used when dicing ICs and MEMS. Ions are removed from the water in order to insure a device free of ionic contamination. Some MEMS and most bonding pads are susceptible to contamination by a number of ionic elements. The electrical isolation of the wafer due to the dicing tape, high resistivity of the water and the high rotation speed of the blade combine to cause charge build up. By re-ionizing the water with CO_2 the resistivity of the water is reduced and the bicarbonate has no negative effects on the MEMS.

4 SD QUALITY

The SD process is non-contact and does not involve water. For these two reasons the issues with blade dicing are not of concern. ESD damage from wafer transfer is still a concern and is addressed in the same manner, with ionizers. This is not to say that the SD process does not have any quality issues. When manufacturing a MEMS device using the SD process the key quality issues to be aware of are particles, impulse vibration, die form factor, and double die.

4.1 Particles

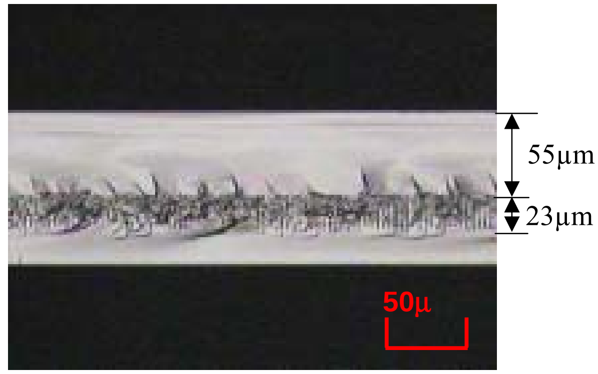

Figure 5: Scalloping.

Figure 5 shows the scalloping on the edge of a die. This occurs when the majority of the silicon in the cut plane is not modified by an SD layer. Quite often a wafer can be diced using a single or a limited number of SD layers. The fewer the number of SD layers the higher the throughput.

Where there is an SD layer the silicon has been mostly if not completely separated. Areas that are not modified are still whole. Where the scalloping appears on the edge of a die is where the silicon between the die was connected. Expanding the tape holding the wafers will break this connecting silicon separating the die. When the silicon breaks often silicon particles are generated. In many cases some of these particles will make it to the surface of the die. For MEMS devices that are sensitive to particles such as silicon microphones it is necessary to increase the number of SD layers in order to reduce the risk of particle contamination.

4.2 Impulse Vibration

As discussed above when die are separated there is an amount of silicon connecting the die. When this connection is severed there is an amount of impulse vibration. The fewer the SD layers the more silicon connects die together. For a device that has had a number of SD layers the amount of silicon connecting it to the neighboring die is minimal leading to the least amount of impulse vibration. As the number of SD layers is reduced the amount of impulse vibration during separation increases.

Only a very few MEMS designs are fragile enough to be affected by impulse vibration. Because there are no standards to measure impulse vibration process specifications do not contain criteria. As of now there has not been any quality issues found due to impulse vibration. With devices becoming more and more sensitive this may change.

4.3 Die Form Factor

Figure 3 above showed how narrow the separation between die can be. This narrow separation allows for a reduction in the dicing street width and an increase in the wafer real estate used for devices. Figure 6 shows die that are expanded following the SD process. There is no silicon lost between the die.

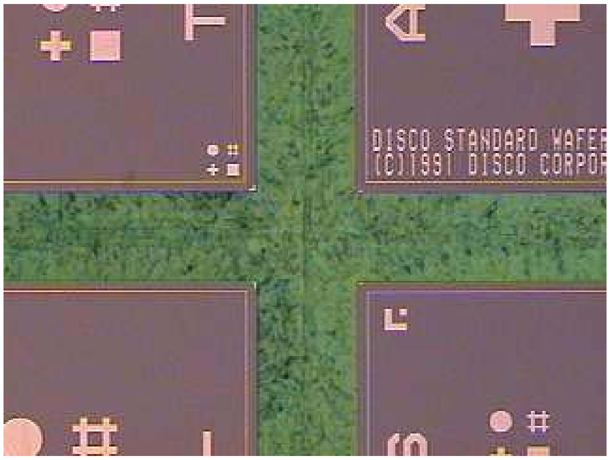

Figure 6: Zero kerf width.

To allow for blade dicing, if the dicing street was 120µm wide, after moving to the SD process the dicing street might be reduced to 20µm wide. Due to the size of many MEMS reducing the street width would dramatically increase the number of die/wafer.

The issue is that because there is no material removed from the dicing process the die have grown. Many processes cannot accept a 100µm variation in die size. When moving to the SD process the wafers have to be designed for the reduced street width.

4.4 Double Die

The force separating the die is simply the force generated by the silicon. Many times there are materials in the dicing street. To separate the materials in the dicing street the separating silicon has to have enough energy to continue the separation through the materials in the dicing street. If there is not enough energy the die do not separate and double die exist.

By removing all materials from the dicing street the problem does not exist. Because this is not always possible the SD process is often modified to create more singulating force. Many times this means adding SD layers at the expense of throughput.

5 CONCLUSION

Up until recently traditional dicing methods were used on MEMS which often limited the design and output of many MEMS devices. In the first years of life a great number of MEMS designs had to be abandoned because they could not be tested or diced. New processes, such as Stealth Dicing is helping bring MEMS into higher volume production and may allow designers even more freedom to create our nano-future.

REFERENCES

[1] Yole Développement, "Global MEMS/Microsystems - Markets and Opportunities, 1, 2007.

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