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Paper

ASJ SINGULATING MICRO SD CARDS

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ABSTRACT

The full automatic ASJ singulation systems have singulated the Micro SD cards for 3years in 24 hour continuous operation. Its process is based on complete singulating with 0.25mm ASJ. This paper focuses on 0.25mm ASJ singulating Micro SD cards.

The ASJ Singulation includes in three units: ASJ engine, manipulator and handler. The ASJ engine contains discharging abrasive subsystem, recharging abrasive subsystem, sieving abrasive subsystem and recycling abrasive subsystem. The manipulator contains XY robot, vision fiducial alignment system and complete cutting fixture. The handler contains multiple cassette onloader, Jedec tray offloader, cleaning chamber and vision inspection system.

The ASJs singulate the Micro SD cards at speeds of 300 mm/s and at acceleration 3000mm/ss. The unit-per-hour yield is up to 3500UPH. Both process and machine performance was critical to meeting a process capability index (CPK) greater than 1.66. The ASJ singulation is much better than the AWJ singulation.

1. INTRODUCTION

There are continuous and emerging needs in the microelectronics industry. One of the critical processes in fabricating microelectronic components is singulation of strips as Micro SD cards for cell phones, digital cameras and other mobile products. The shape of Micro SD card is intricate geometry, not rectangle. The most common singulation method is using a diamond saws to cut through strips, but diamond saws only can cut straight line, can not cut curvilinear line. This new shape requires a new way of singulation that has the flexibility to cut curvilinear features into the package.

This paper is on using abrasive suspension jets for singulating Micro SD card strips. First, some typical cutting requirements for Micro SD cards will be listed, some background information on cutting methods will be presented. Description of machine features, process parameter, sequence and results of ASJ singulation will then be presented. A comparison between AWJ singulation and ASJ singulation will be presented. Conclusions are given at the end of the paper.

2. MICRO SD CARD AND SINGULATING METHODS

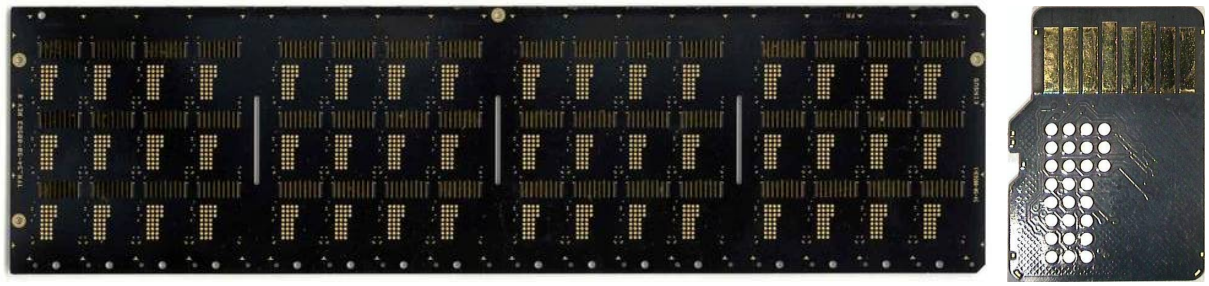

Figure 1. Micro SD Strip and Part

Figure 1 is photo of Micro SD Strip and Part. Each strip contains many pieces of matrix array Micro SD cards; each card involves 10 straight line, 9 radii and 1 corner. The typical requirements for singulating Micro SD card strips are as listed below:

1. Typical strip size: 240 x 74 mm
2. Typical part size: 11 mm x 15 mm
3. Minimum inside corner radius: 0.2 mm
4. Maximum part thickness: 1mm
5. Typical space between components: 1 mm
6. Minimum space between components: 0.4 mm
7. Surface finish of cut edges: ≤ 4 microns
8. Process capability index CPK: 1.66
9. Maximum allowable dimensional tolerance: ± 0.1 mm

10. Productivity: ≥2000 units per hour
11. Machine uptime ≥96%
12. Mean Time Between Failures (MTBF) ≥ 200 hrs
13. Mean Time to Repair (MTTR) ≤ 10 minutes
14. The cut edges should be free from cracks, chip striations, or delamination.

Currently there are 4kinds of singulation process of Micro SD cards in semiconductor manufacturing, but only ASJ singulation can completely singulate the Micro SD cards from strip.

2.1 Hybrid Saw-Grinder Process

The most common singulation method is using a diamond saws to cut through strips, but diamond saws only can cut straight line, can not cut curvilinear line. Some semiconductor manufacturers firstly use the diamond saws to cut the strip into 11mmx15mm rectangles, then use special shape grinder to grind the rectangle into micro SD card shape.

2.2 Hybrid Laser-Saw Process

The newest laser can cut strip with both straight line and curvilinear line, but its roughness is more than 6um, is bigger than the requirement of Micro SD card. Some semiconductor manufacturers firstly use the laser to cut the radii and notches on the strip; then use diamond saw to singulate the strip by cutting a number of straight lines.

2.3 Hybrid AWJ-Saw Process

Abrasive waterjets are versatile tools for cutting a wide range of electronic components without introducing heat or mechanical distortion. The process uses entrained abrasives in a high velocity waterjet pumped at pressures of 400MPa. The mixing of the waterjet (75 micron) and the abrasives (mesh 220 and finer) occurs in a mixing tube of about 0.38 mm. This represents a limitation of the current AWJ process.

In this method, the AWJ is used to cut the shaped patterns around the parts in the strip without completely singulating it. Diamond saws are then used to singulate the strip by cutting a number of straight lines across the AWJ-made cuts[1][2].

2.4 Complete ASJ Process

The most efficient method of generating abrasive waterjets is to directly pump a premixed abrasive suspension under high pressure through a nozzle, known as the abrasive suspension jet (ASJ) method. Accordingly, ASJs of about 250 microns and down to 50micros could be produced. ASJs have 5 times the cutting energy density of AWJs at the same water pressure. ASJs can, therefore, operate at much lower water pressures than AWJs and still cut at economically viable rates. 700bar is probably the optimum operating pressure for ASJs. ASJ is more precise and more powerful than AWJ[3].

In this method, the ASJ is used to completely singulate the parts in the strip by cutting curvilinear line and straight line around the parts. This process has performed all cutting operations and eliminated the diamond saw, so can be equipped with a handling system such that the strip are loaded on the cutting fixture and singulated parts are loaded on JEDEC trays at the output side of the machine.

3. JS800 ASJ SINGULATION

The ASJ Singulation consists of three units: ASJ engine, manipulator and handler. Figure 2 is the picture of JS800 ASJ Singulation.

Figure 2. JS800 ASJ Singulation

3.1 ASJ Engine

The ASJ system usually includes 4 subsystems:

1. Discharging abrasive subsystem
2. Recharging abrasive subsystem
3. Sieving abrasive subsystem
4. Recycling abrasive subsystem

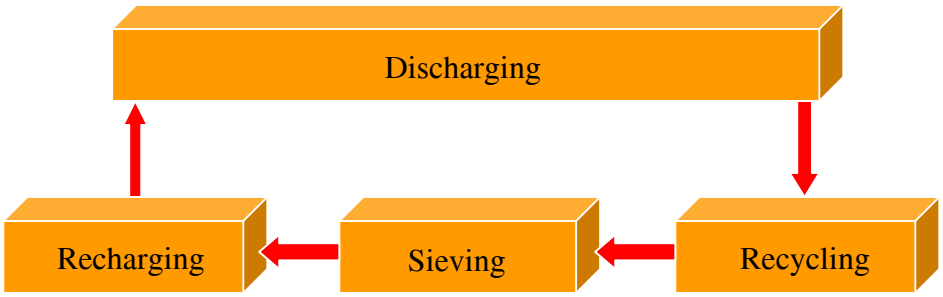

Figure 3. ASJ system usually includes 4 subsystems

3.1.1 Discharging Abrasive Subsystem [3]

The basic flow circuit for ASJ systems is shown in Figure 4. Filtered water is pressurised by a pump and fed to a control unit. The control unit either directs all the water to the nozzle, or it diverts a fluidizing water to an abrasive storage vessel to displace abrasive and carry out of the vessel to mix with the main water; then high pressure pushes out the premixed abrasive suspension through the nozzle to form an abrasive suspension jet.

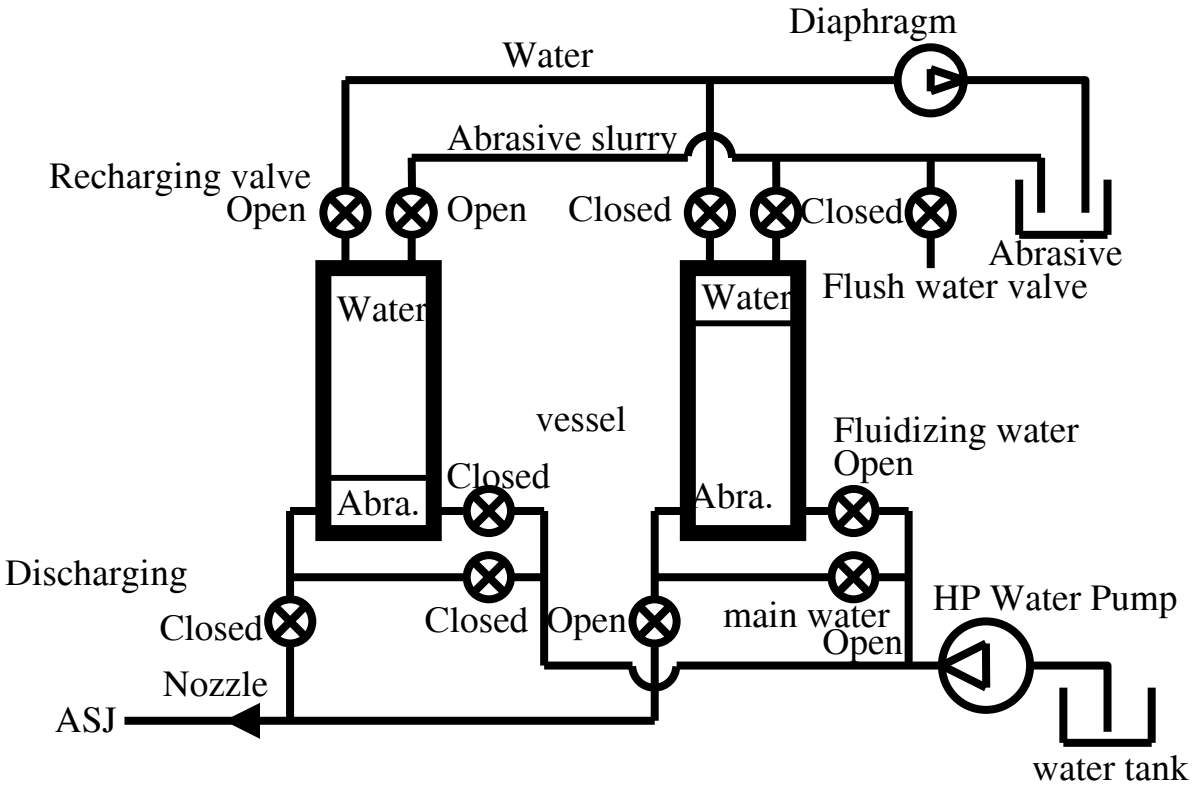

Figure 4. Abrasive Suspension Jet System

A continuous cutting mode contains two high pressure discharging abrasive subsystems and two recharging abrasive subsystems. Two vessels will be in the status of discharging abrasive and recharging abrasive respectively, and will exchange functions automatically when the abrasive in the discharging vessel has been discharged out fully.

3.1.1.1 High Pressure Pump

The spec of high pressure pump is:

Power: 3.5KW
Pressure: 700 bar
Water flow rate: 2 L/min

3.1.1.2 Abrasive Storage Vessel

The abrasive storage vessel is designed to accommodate abrasive, its capacity: 15L. One vessel of abrasive can be discharged about 1 hour.

3.1.1.3 ASJ Nozzles

ASJ nozzles are showed in Figure 5. By designing the nozzle length to match the abrasive size and the desired beam diameter, the pressurized suspension is "collimated" and must proceed through the nozzle in an orderly and predictable manner.

The ASJ nozzle life is depended on the nozzle shape and material.

The preferable nozzle shape is the conical convergent nozzle with three sections: 40° convergent section, 13 ° convergent section and 15 times longer than the diameter of focus section.

The practical nozzle material is polycrystalline diamond. The diameter of the diamond nozzle only increases about 0.001mm after used for 1 hour, the life is about 100 times longer than carbide nozzle. The range of diamond nozzle diameter in the ASJ singulation can be 0.15 mm to 0.35 mm.

Figure 5. Special ASJ Nozzles for Singulation Applications

3.1.1.4 Abrasives

The average abrasive size depends on the ASJ nozzle diameter. The cutting performance increases with abrasive particle size, as does the risk of nozzle blockages. The ASJ Singulation should operate with a maximum particle size of 50% of the nozzle diameter.

Since all the abrasive must be able to pass through the cutting nozzle, the ASJ Singulation can only utilize fully screened abrasive of the appropriate maximum particle size. It is not adequate to rely on abrasive manufacturer's screening. Most industrial abrasives are available as a range of particle sizes, rather than as a single sized material. The ASJ Singulation requires 220# (65um) or 240# (63um) abrasive.

The ASJ Singulation will operate with a range of industrial abrasive including:

1. Garnet Abrasive
2. Aluminium Oxide Abrasive
3. Silicon Carbide Abrasive

Generally the least expensive abrasive performs adequately on many target materials. Improved cutting rates can be achieved with selected abrasives. The abrasive should have sharp angular grains, for best cutting results. Usually Garnet Abrasive performs on soft material, for example, BGA.

An abrasive feed rate of 20% to 40% by mass of the water flow, is recommended for efficient operation. A higher abrasive feed rate will increase cutting performance, although not in proportion to the extra amount of abrasive used. It is not advisable to increase conceration above 70% of water flow, because of increasing risk of nozzle blockages.

3.1.2 Recharging Abrasive Subsystem

The Figure 4 also shows the recharging abrasive subsystem. There are recharging pump, recharging valve, vessel and abrasive tank. The air operated diaphragm pump is used to draw water out of the vessel and pump to the abrasive tank during recharging sequence, make the vessel vacuum and suck the abrasive slurry from the abrasive tank into the vessel. This recharging abrasive method has two advantages: the diaphragm pump has long life because most abrasive does not go through the pump; recharging abrasive is fast because the abrasive slurry concentration is high.

3.1.3 Sieving Abrasive Subsystem

With the use of small nozzles, the abrasive particles size control becomes very greater. On average the nozzle is passing 1,000,000 particles per second, only one oversized particle can cause nozzle blockage and subsequent downtime.

The dry sieving method has been tested successfully for particle sizes of over 0.1mm. But when the abrasive particle is less than 0.1mm, the dry sieving is very slow, because fine particles will stick together under moisture.

The submerged sieve has been special designed for fine abrasive below 0.1mm, it has been tested that the submerged sieving is up to 4 times faster than dry sieving for particle sizes of below 0.1mm. The submerged sieving method has another advantage, which facilitates abrasive recycling.

3.1.4 Recycling Abrasive Subsystem

The used abrasive contains most reusable abrasive, fine broken abrasive and kurf material debris. The recycling subsystem is designed to recycle reusable abrasive and dispose fine material and oversized particle so as to reduce ASJ operating costs significantly and to minimize the amount of waste material.

The reusable abrasive in catch tank is extracted by pump into submerged sieve; the fine broken abrasive and debris are carried into the drain by used water.

The recycling abrasive subsystem has obvious advantage, it make the abrasive can be completely used and can be used many times until the abrasive becomes useless abrasive about 5micrometer; the useless abrasive can be carried to drain by used water, do not need any removing work.

3.2 Manipulator

The manipulator contains XY table, vision fiducial alignment system and full cutting fixture.

3.2.1 X-Y Table

There is great flexibility in how linear motors are configured to form an X-Y table. Proprietary linear motion actuators with the required positional accuracy and repeatability are readily available for moving ASJ nozzle, or strip fixture. This means there is considerable flexibility in deciding how X-Y motion systems are configured for a particular machining duty. During the development program the following configurations have been used successfully:

1. Moving an ASJ nozzle in the X-Y direction over a fixed strip fixture.
2. Moving an ASJ nozzle in the X direction and a strip fixture in the Y direction.
3. Moving a strip fixture in the X-Y directions under a fixed ASJ nozzle.

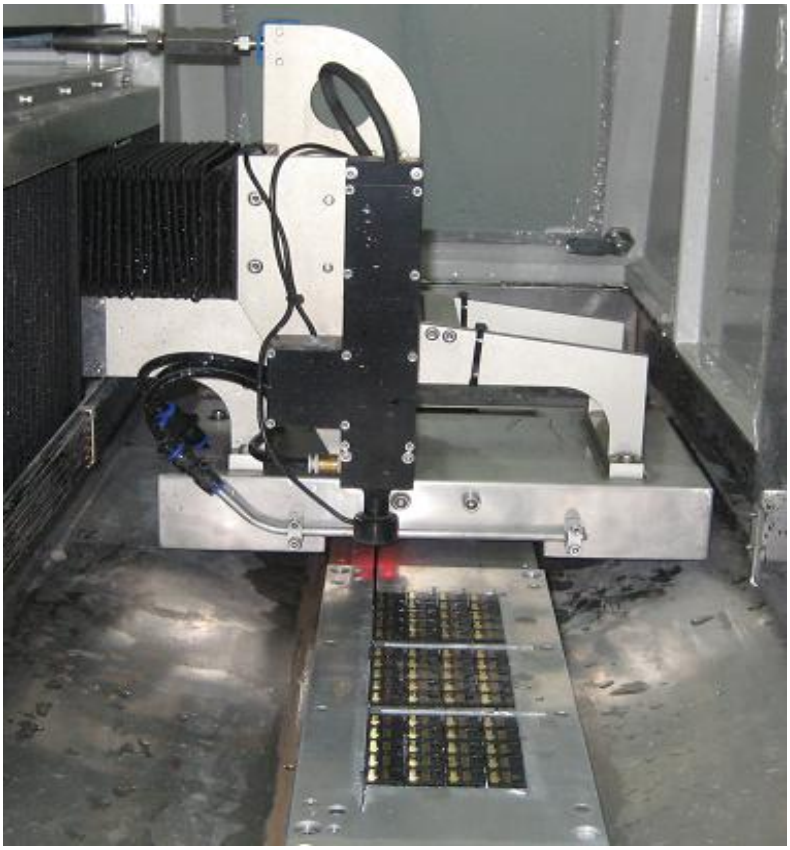

Figure 6. X-Y Table

Because strip fixture is heavier than ASJ nozzle and cutting area is very massy, in order to reduce the load of X-Y table and well protect the X-Y table, moving an ASJ nozzle in the X-Y direction over a fixed strip fixture is being used for singulating strip, Figure 6.

To meet the Micro SD Cards' requirements, the following needs to be considered:

1. A machine with 0.010 mm accuracy is needed. Because the strip size is relatively small, less than 250mm x 80mm, the machine working area will also be 250mm x 80mm. This helps obtaining the required accuracy. For relatively high speed shape cutting, the motion system must be capable of the proper acceleration and deceleration values while keeping smooth motion. A cantilever arm was used to move the cutting head over the cutting area in two dimensions.
2. For accurately locating the jet relative to the cut paths, vision fiducial alignment system must be needed. In case of vision, fiducials on the strip will be used. The vision camera mounted in housing is mounted near the cutting head.
3. Also, the strip must be held accurately and rigidly to prevent any motion during cutting. So the vacuum fixture must be needed.
4. The cutting process and the motion system should be stable and robust to meet the reliability and performance requirements. For the ASJ process, this implies using robust pumping and high pressure components, robust abrasive flow condition for no plugging, and relatively long lifetime components.

5. Software: PC-based software was used to develop tool paths program out of strips CAD information. The software is integrated with the vision system so that coordinate locations of fiducials are transmitted to the cutting program.

3.2.2 Strip Fixture

A strip contains 28 to 80pcs parts, the size of Micro SD card is 11mm x 15mm. To singulate the strip, each small part must be supported and held by a vacuum fixture. Also, the water jet should not cut the vacuum passages in the fixture although the water jet almost can cut any material.

There are 2 methods in how the water jets do not cut the vacuum passages in the fixture:

1. Water jet only runs beside the vacuum passages in the fixture, does not run across the vacuum passage. According this concept, the dual half cutting fixtures have been invented.
2. Water jet not only runs beside the vacuum passages in the fixture, but also runs across the vacuum passages. Some wear-resistant material must be used to protect the vacuum passages. According this concept, the single full cutting fixture has been invented.

The complete water jet singulation system must perform all cutting operations, its process can be accomplished in two ways depending on strip fixturing methods.

3.2.2.1 Dual Half Cutting Fixtures

In this case, the strip is chucked twice in two separate fixtures. The first fixture is used for cutting selected patterns, but leaving tabs or certain lines or contours uncut. The other fixture is used for singulating the strip by cutting the tabs, or the uncut contours or lines. Figure 7 shows a picture of dual half cutting fixtures. The dual half fixtures are connected to a vacuum system via 2 vacuum ports. Figure 8 shows strip configuration after first half cutting.

To cut a strip with dual half cutting fixture, twice loading, twice vision, twice cut and twice unloading are needed. It makes transition and handling very complex, it needs double operating time and lost cutting quality.

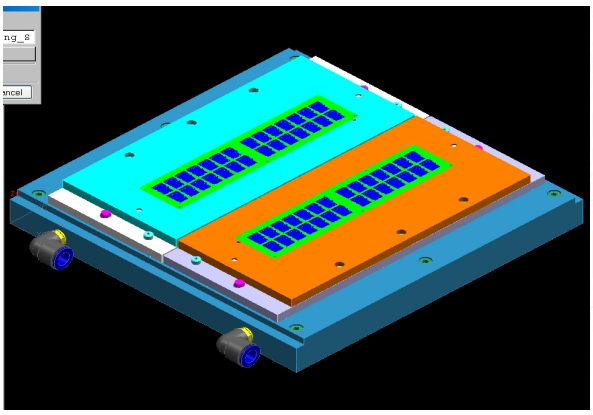

Figure 7. Dual Half Cutting Fixtures

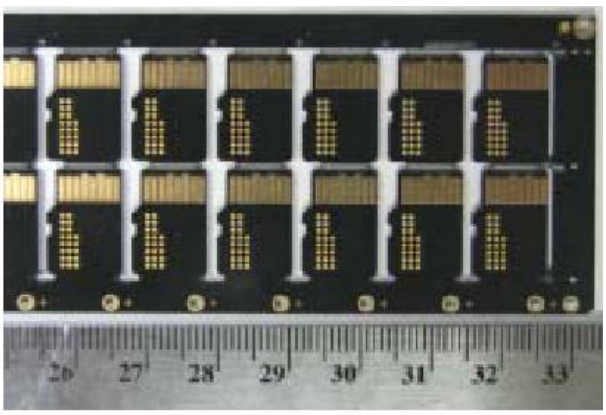

Figure 8. Strip Configuration after first half cutting

3.2.2.2 Single Full Cutting Fixture

In this case, the strip is chucked once in a single fixture for complete singulation. The parts are completely singulated without moving. The fixture must be designed such that its integrity is not affected by the closed path cuts made around the parts. Also, the jet should not directly cut the vacuum passages in the fixture. The vacuum passages must be protected by some wear-resistant material.

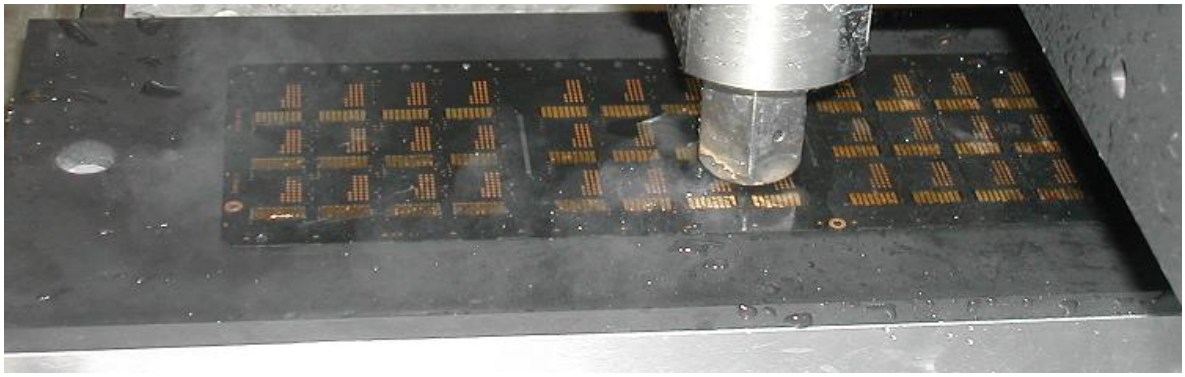

Figure 9. ASJ Is Singulating Micro SD Strip on Single Full Cutting Fixture

Figure 9 shows a picture of the cutting head on a single full cutting fixture. To cut a strip with single full cutting fixture, the ASJ singulation only need once loading, once vision, once cut and once unloading . Its operating is very simple and fast, and its cutting quality of Micro SD cards is the best of all kind cuttings.

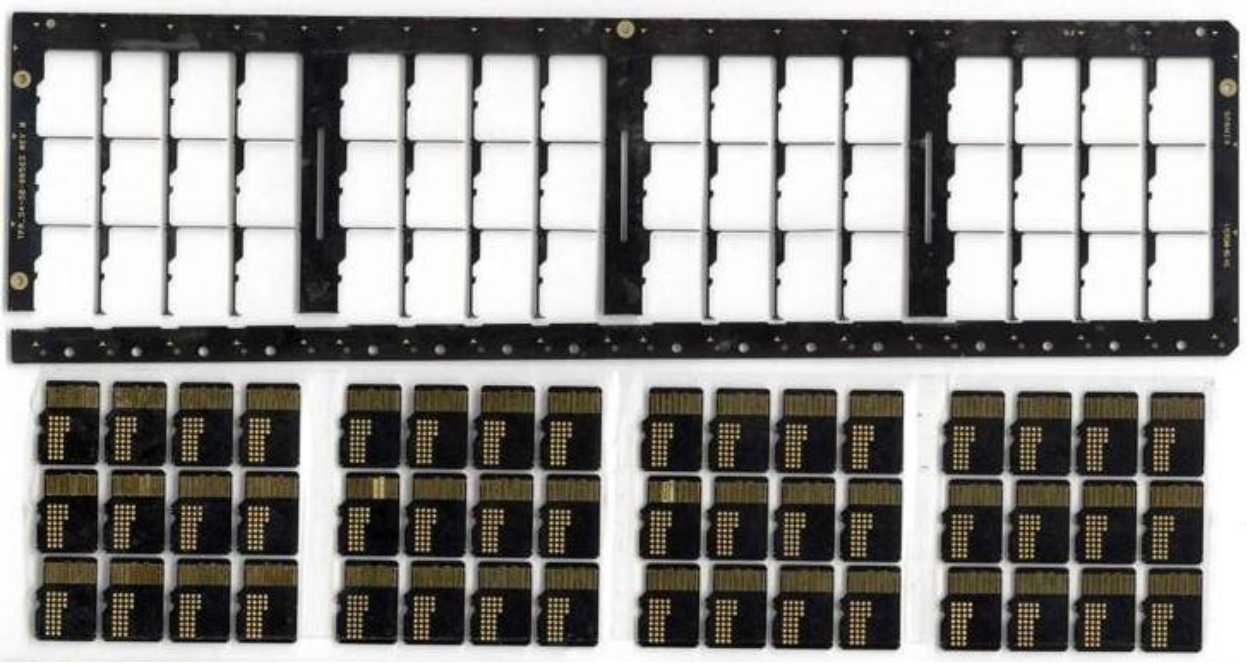

Figure 10. Scrap and Micro SD Cards cut on full cutting Fixture with ASJ Singulation

Figure 10 is Scrap and Micro SD Cards cut on single full cutting fixture with ASJ Singulation. There are 48 pieces of Micro SD cards in the strip. Cutting speeds varied from up to 300mm/s; Cutting acceleration varied from up to 3000mm/ss. Cutting one Micro SD Card only needs 0.84s. Figure 11 shows the cutting quality.

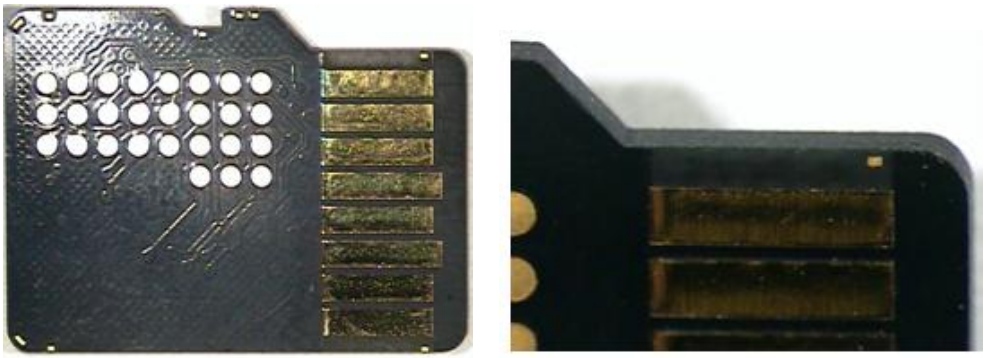

Figure 11. Micro SD Card Singulated with ASJ Singulation

3.3 Handler

The full automatic ASJ singulation system must be equipped with a handling system such that the strips can be automatic loaded on the cutting fixture from strip magazine and the singulated parts can be automatic unloaded from the cutting fixture and loaded on JEDEC trays at the output side of the machine.

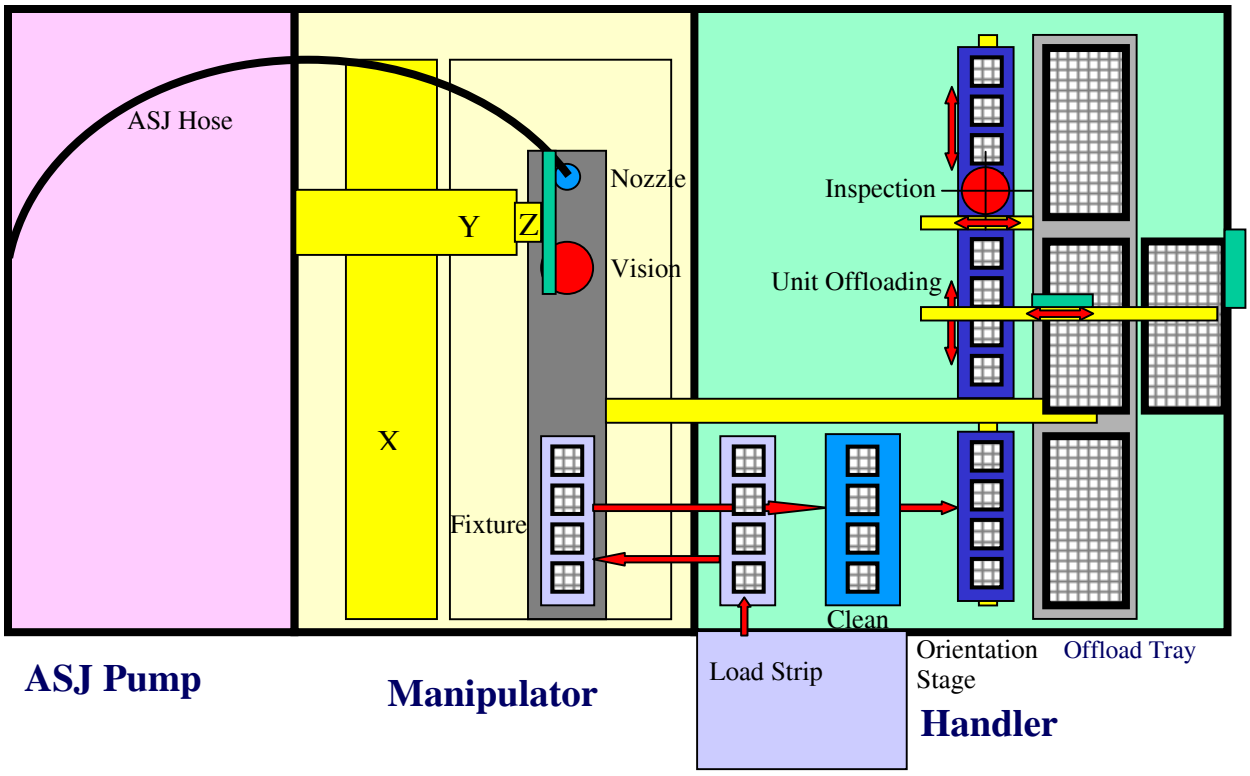

Figure 12. ASJ Singulation Process Flow

The handler contains multiple cassette onloader, Jedec tray offloader, cleaning chamber and vision inspection system. Figure 12 is the process flow of handling. The ASJ Singulation process consisted of the following main steps:

1. Unload a strip out of a standard magazine
2. Pick strip
3. Load the strip on cutting fixture
4. Vision probing: A vision camera locates the center of selected fiducial. The cut patterns are referenced to these fiducial.
5. Cutting: The software used has a feature of slowing down automatically around tight corners to obtain the required geometry.
6. Remove scrap
7. Pick units
8. Load new strip
9. Clean and dry units
10. Load units on inspection fixture
11. Inspecting units
12. Off load units on JEDEC tray.

4. COMPARISON BETWEEN AWJ SINGULATION AND ASJ SINGULATION

Currently there are 2kinds of water jet singulation used for Micro SD cards in semiconductor manufacturing, one is half-automatic AWJ singulation[1][2]; another is full-automatic ASJ singulation. They have different performance characteristics. Table 1 is a comparison between AWJ singulation and ASJ singulation. We could know that the ASJ Singulation is much better than AWJ Singulation.

Table 1. Comparison between AWJ Singulation and ASJ Singulation

Item	Performance	AWJ Singulation	ASJ Singulation
1	Abrasive jet engine	AWJ	ASJ
2	Pressure	379MPa	70MPa
3	Water nozzle diameter	0.1mm	N/A
4	Water flow rate	0.3L/min	1L/min
5	Abrasive jet nozzle diameter	0.38mm	0.25mm
6	Abrasive size	220 Mesh Garnet	220 Mesh Garnet
7	Abrasive flow rate	36g/min	320g/min
8	Garnet usage	55kg/machine/day	10kg/machine/day
9	Recycle garnet system	N/A	YES
10	Remove garnet system	YES	N/A
11	System reliable	Reliable	Reliable
12	Manipulator Type	XY table on Catch tank	XY Table over Catch Tank
13	XY table type	Gantry	Cantilever
14	Cut area	820mm x 480mm	250mm x 80mm
15	Cut model	Half-cut	Full-cut
16	Cut fixture type	Half cut vacuum fixture	Full Cut Vacuum fixture
17	Cutting speed	45mm/s	300mm/s
18	Cutting acceleration	--	3000mm/ss
19	Productivity	400-800UPH	2000-3500UPH
20	Vision locating system	Yes	Yes
21	Nozzle compensation	Yes	Yes

22	Target teaching	Yes	Yes
23	Process capability index CPK	1.6	1.66
24	Cut surface roughness	≤ 4 microns	1.55~2.60um
25	Handler	N/A	Yes
26	Load and unload strip	Manual load/unload	Automatic load/unload

5. CONCLUSIONS

1. Currently there are four kinds of singulation process of Micro SD cards in semiconductor manufacturing, but only ASJ singulation can completely singulate the Micro SD cards from strip.
2. The fully automatic ASJ Singulations consist of three units: ASJ engine, manipulator and handler. They have singulated the Micro SD cards for 3years in 24 hour continuous operation. Its process is based on complete cutting with 0.25mm ASJ.
3. The submerged sieving is up to 4 times faster than dry sieving for particle sizes of below 0.1mm. It facilitates abrasive recycling
4. The ASJ recycling abrasive subsystem has obvious advantage, it make the abrasive can be completely used and can be used many times until the abrasive becomes useless abrasive about 5micrometer; the useless abrasive can be carried to drain by used water without any removing work.
5. To cut a strip with single full cutting fixture, the ASJ singulation only need once loading, once vision, once cut and once unloading . Its operating is very simple and fast, and its cutting quality of Micro SD cards is the best of all kind cutting.
6. The ASJ process has been successfully implemented for cutting Micro SD cards. The ASJ machining systems and process capability index is over 1.66 for critical dimensions. Its productivity is up to 3500UPH. The development of ASJ singulation is successful.
7. The ASJ singulation is much better than the AWJ singulation.

6. REFERENCES

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