

Singulation of QFN/MLP Packages

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QFN/MLP substrates behave much differently from most known materials in the microelectronics industry, and therefore present challenges for the dicing process. This paper will cover basic substrate characteristics and various singulation topics including: substrate geometry and material characteristics, substrate design and parameters affecting the cut quality, quality specifications to which the industry aspires, dicing on tape and tape-less mounting, optimizing the dicing process, and the constant demand for increasing units/hr (UPH) while maintaining cut quality. These factors create real challenges, not only in the dicing process, but also with the blade design, which will also be addressed.

Substrate Geometry/Material Characteristics

QFN (quad flat no lead) and MLP (micro lead frame package) substrates consist of two major materials: 1) copper lead frame coated with PPF (Ni/Pd), or with tin (Sn) plating; and 2) polymer molding. These composite materials have different hardness and brittleness characteristics that in a high-volume production mode are challenging. The final die sizes vary from 1x1mm up to 12x12mm. A die size smaller than 3x3mm creates mounting challenges, which will be discussed later. **Figure 1** illustrates the geometry of a common QFN/MLP-type substrate.

The lead frame in most cases is a copper alloy C-194 or Eftac 64T with a hardness of ~135-145 HV ($\frac{1}{2}$ hard). The copper material is relatively soft

and mainly ductile, which during dicing, causes burrs and smearing. The polymer molding compound is reinforced by silica particles (Si_2O_3) in the range of 30-70 μm in size. The molding compound is relatively brittle compared to the copper lead frame, and chipping on the molding part is another problem during dicing. In general, the combination of a ductile material with a brittle material in the same dicing process creates major challenges. The generic plastic deformation graph in **Figure 2** shows the difference between a brittle material and a ductile soft material (copper in this case).

The silica particles in the polymer-molding compound are used as a stabilizer to minimize stresses and to control the flatness of the substrate. The size of the silica particles affects the chipping size; the larger the silica particles, the larger the chipping on the molding. The silica grit pull-out generates small craters that will create edge chipping after the dicing

operation.

Substrate Geometry Design Affects Cut Quality

Both the geometry of the copper lead frame and the outside geometry of the substrate have a major impact on blade loading, which affects cut quality. In general, minimizing the amount of copper the dicing blade faces while dicing through the leads and at the outer rim of the substrate is a key factor to be considered for substrate

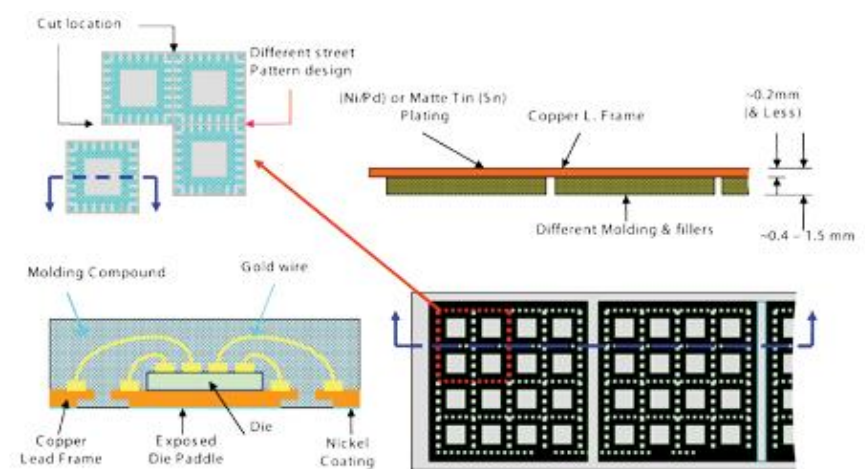


Figure 1: Common QFN/MLP-type substrate

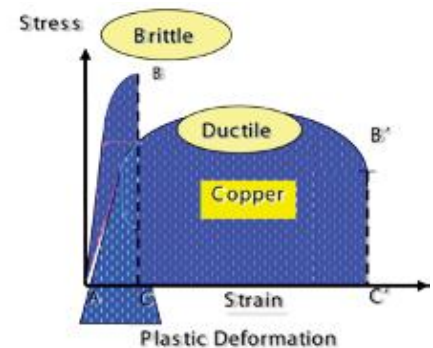


Figure 2: Plastic deformation

design. Minimizing the copper would reduce the load on the dicing blade and subsequently enable a higher feed rate (increased throughputs) and better cut quality (higher yield). The copper amount and geometry is decided by the conductivity and power through the leads, so the design places more consideration on the functional requirements. The production-related difficulties, however, should also be considered. **Figure 3** shows the major elements involved in a QFN-type substrate. The lead cross section at the dicing area needs to be as small as possible. A small square lead cross section is a better design than any other irregular shape. A large lead cross section can cause copper smearing between the leads, and this may cause electrical shorts.

Minimizing unsupported copper around the QFN/MLP substrate is fairly crucial as it can easily break the blades and consequently affect the productivity. The best solution is to

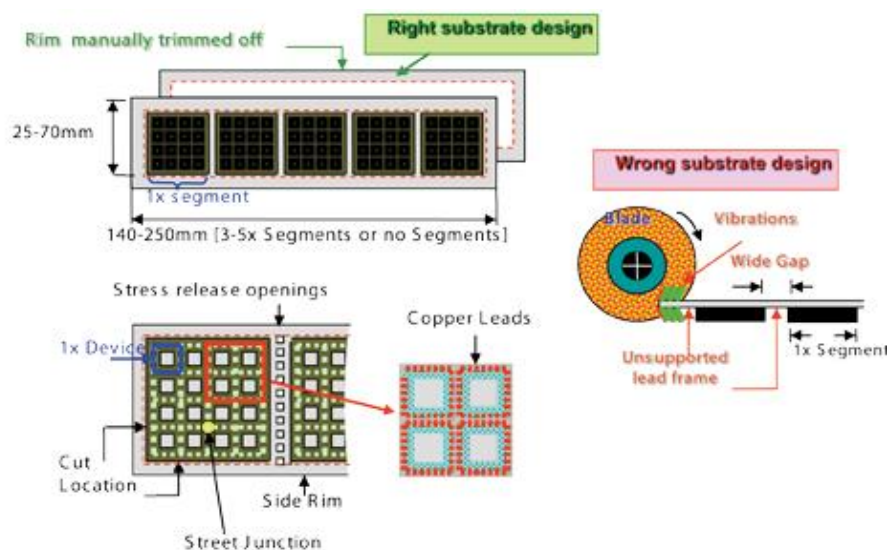


Figure 3: QFN/MLP glossary

design the outer lead frame rim in a "snap off" form that can be manually removed before dicing. If a segment design is applied (**Figure 3**), the area between the segments should be minimized and it should include large stress release openings. It is also

desirable that the molding be as close as possible to the lead frame edge. Half-etched lead frame design has become common in the industry. Such a design is more favorable to dicing and contributes to an improvement in the cut quality, as well as blade life. The

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idea is to reduce the amount of copper that the blade needs to remove from the substrate. In general, the larger the etched area, the smaller the load exerted on the blade during the dicing process. Half-etched substrates can be diced with harder blades resulting in longer blade life while maintaining good cut quality.

Effect of Lead Coating/Plating on Cut Quality

The microelectronic industry is driven towards implementing environment friendly "green" products and processes. Conventional QFN leads are lead/tin (Pb/Sn) or nickel/palladium (Ni/Pd) plated. To reduce costs and comply with environmental standards, these materials are now being gradually replaced by matte tin (Sn) plating. Visually, substrates with matte tin plating appear dull compared to the shiny finish of the conventional plated substrates. These types of substrates are also subject to potential damage during conventional dicing due to the possibility of leads melting as the matte tin melting temperature is lower at 232°C compared to the materials used in conventional substrates (**Figure 4**). To overcome this problem, the blade and the process should be optimized for minimum load. This minimization could be realized by a softer blade, using lower spindle speeds within the range of 15k-20krpm (for 2" O.D. blades), and in some cases, chilling the water to about 12°C. The above parameters should be optimized according to the application.

Quality Criteria and Specifications

Most end users have rather similar quality criteria. The quality specification is a function of the QFN substrate design and the end product requirements. Many parameters affect the quality of the singulation process. The main parameters are: 1) substrate geometry (total thickness, copper thickness, device size, i.e., smaller devices may shift during dicing due to relieved mounting force); 2) outside substrate rim design, unsupported or

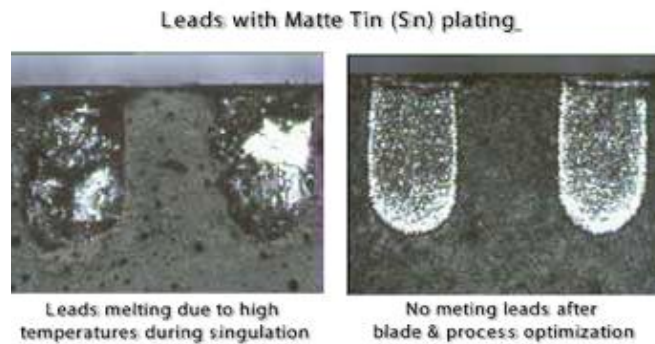


Figure 4: Lead melting

trim design (**Figure 3**); 3) number of leads; 4) lead coating type; 5) lead cross section geometry; 6) type of mounting; 7) UPH requirements/feed rates, and 8) blade type.

Figure 5 illustrates the different quality criteria. Typical quality specifications are: 1) Y burrs: 0.050mm, 2) Z burrs: 0.050mm, 3) X burrs: 0.050mm, 4) lead smearing: max 25% of the lead pitch (may vary among users); 5) no delamination of leads; and 6) no melting of lead coating. Additionally, many users require 0.020-0.030mm on the X, Y and Z burr dimensions.

The above quality specification is mainly used for QFN products ranging from 0.9mm to 1.2mm in thickness. Thin QFN (typically 0.4mm–0.6mm thick) requires tighter quality specifications. Other QFN products, such as "POWER QFN" are

much thicker - up to 4.0mm. Thick QFN substrates made with much thicker copper lead frames of >0.500mm introduce singulation difficulties; they require different quality requirements per application. However, the POWER QFN niche

is smaller compared to the standard QFN market.

Dicing on Tape and Tape-less Mounting

There are two different mounting methods used in QFN singulation: tape mounting and tape-less mounting. In general, QFN/MLP substrates are not as flat as other microelectronic substrates. In many cases, this nonuniform flatness complicates the singulation process. In today's singulation lines, end users typically want relatively high feed rates of up to 100mm/sec, which adds to the difficulties associated with consistent mounting.

Tape Mounting

Most end users need UV tapes of various thicknesses and adhesion force. Typical thickness may vary from 0.100mm to 0.200mm depending on the

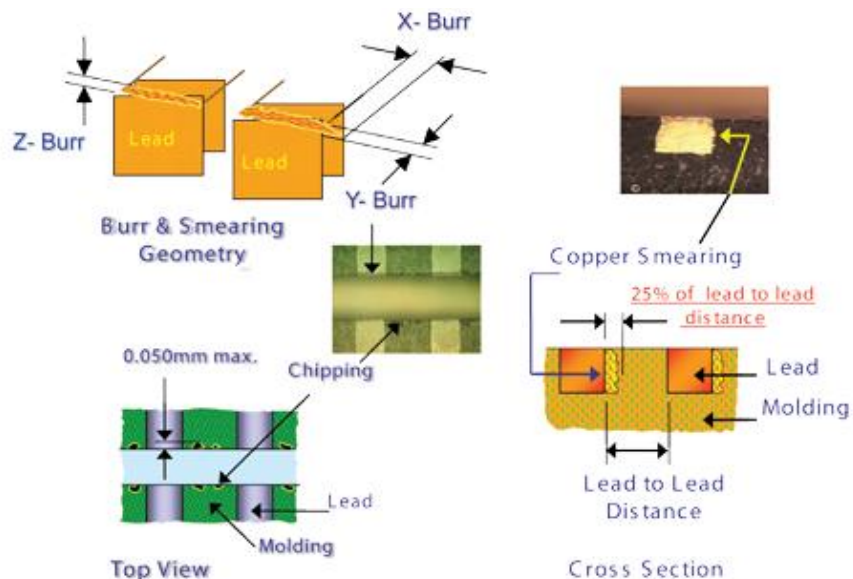


Figure 5: QFN quality criteria

application. The UV tape has strong adhesive, which helps to dice problematic, small devices - those smaller than 3x3mm - without losing devices that are more prone to shift during dicing, or even fly off. Releasing the diced units off the tape requires exposing the tape to UV light for a certain time to accumulate sufficient energy density to alleviate the adhesion force. The mounting method is relatively known and simple, and so is the dismounting; both methods are widely used in the industry for a variety of applications.

Advantages of tape mounting include: 1) proven dicing and handling processes, 2) any die size can be diced, 3) enables dicing of multiple panels, and 4) flexible, i.e., applicable for other applications on the same saw. The disadvantages of tape mounting are: 1) requires a wafer mouter and UV station, 2) UV tape is expensive, 3) UV shelf life is limited and necessitates monitoring, 4) tape is not friendly to the blade, 5) it cannot be integrated with a pick and place machine (i.e., fully automated system).

Tape-less Mounting

Tape-less mounting has become a prevalent solution for mass production. In integrated systems, the QFN substrates are loaded automatically from an input magazine onto a rubber (nest) covered metal jig replacing the conventional dicing chuck. The jig is perforated with holes through which vacuum is supplied to hold the substrate before dicing, and each individual part after dicing. This singulation method is the most common technology used today. The main idea of this system is to use a unique vacuum chuck design that can provide vacuum clamp down for single devices after the singulation process. The singulated devices are then inspected for visual quality criteria after which an automatic handler pick and place arm places the good parts into waffle trays. The blade on the dicing system is dicing about 0.020" (0.5mm) below the substrate into a trench in the rubber nest that holds down the diced devices by vacuum (Figure 6).

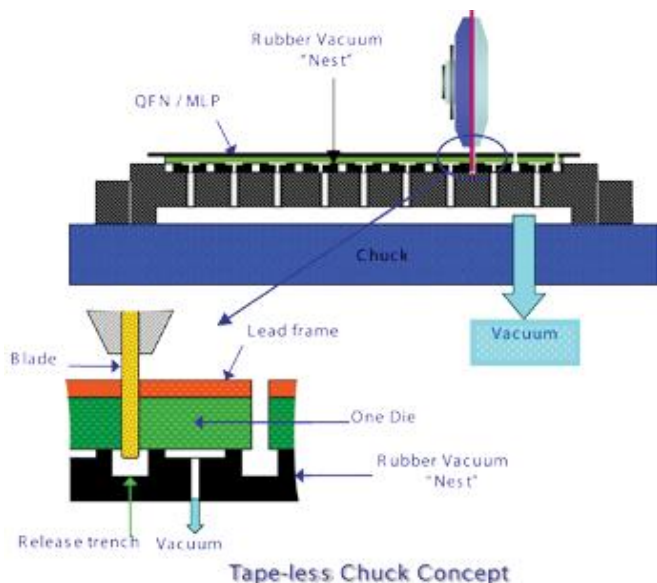


Figure 6: Tape-less chuck concept

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The main limitation of the tape-less jig is its ability to hold devices smaller than 3x3mm. The reason for this limitation is the insufficient surface of each device to be held up to the jig solely by force of the vacuum. In those cases, a tape mounting is the only practical alternative. Still, there are advantages of a tape-less mounting system: 1) shorter handling time, 2) cost savings - no need for expensive UV tape, 3) cut depth is less critical as opposed to tape mounting, 4) a tape mounter and UV station are not needed, 5) a mechanical support for the side/rim copper edges can be designed, 6) can be used in a fully automated production line, and 7) much higher throughput.

Disadvantages of a tape-less system include 1) less flexibility - a special jig for each device size is required, 2) it can only handle devices down to 3x3mm, 3) less durable with respect to vacuum-related failures such as die fly off, and 4) it requires expensive and complicated equipment compared to stand alone dicing systems.

Optimizing the Dicing Process

Any dicing process optimization requires a close look at the dicing saw process parameters and in parallel, optimizing the dicing blade. QFN/MLP applications differ from user to user. Most users have a variety of QFN substrates with different geometries, layout thicknesses, device sizes, number of copper leads, lead designs, etc. The vast majority of these attributes derive from the product's functionality. The main dicing parameters to be optimized, aside from the blade selection, which will be discussed later, are listed below.

Mounting. For tape: tape thickness, hardness, UV adhesion tackiness, adhesion force, adhesion relief, and cost. For tape-less: jig design to fit the device size, proper vacuum condition to handle the device.

Cooling. Type (regular water, D.I., additives), temperature, cooling nozzle design/coolant pressure and flow.

Blade dressing and override. Use of feed rate built-up profile.

Spindle RPM and feed rate. Cut

depth (relevant for both tape and tapeless); dicing sequence (cut map) – normally the shorter cut length is to be diced first; alignment, kerf check, and kerf position correction.

Blade Optimization

Besides the dicing equipment, the blade is probably the most important part involved in the singulation process. The QFN materials composite requirements challenge the blade to have conflicting capabilities, practically impossible to blend in a single blade type. Such a blade is expected to be suitable for very ductile materials and very brittle materials at the same time. This contradiction can only be addressed by a trade-off analysis that weighs various requirements such as, quality, blade longevity, and cost.

When QFN/MLP was introduced into the industry, the initial feed rate was ~5mm/sec. Today, the majority of the market is using 70-80mm/sec and some users are even running at 100mm/sec. This high feed rate has become possible partially as a result of improved QFN/MLP substrate geometry (using half-etched lead frames), but mostly because of optimizing the dicing blade matrix. The most common blade used today for QFN singulation is a phenolic resin matrix. Metal sintered blades are also used, but to a much lesser extent. Users continue to demand faster feed rates, longer blade life, and cut quality, while maintaining feed rate and blade life. Along with these considerations, users also strive for low cost.

The main goal of any blade used for

singulating QFN substrates is the ability to maintain a long blade life while maintaining its kerf size. This attribute is essential for the tight tolerance to which the final device/package size is subjected. Any side wear on the blade will eventually affect the device size. Users, however, are less keen at compromising on feed rate and/or quality to achieve the blade life. Resin type blades do have a higher radial wear, which helps maintain a good kerf profile, and at the same time, the right device size. Metal sintered blades do have less radial wear, but they are prone to side wear over time. Such wear would eventually be reflected in the device size as shown in **Figure 7**. Metal sintered blades are harder and tend to result in larger burrs.

Optimizing a blade matrix for either quality or throughput would require a sound understanding of the 1) substrate structure, 2) comprehensive knowledge of the dicing process as maintained on site, and 3) blade formulations and manufacturing techniques.

Most blade parameters do change from user to user depending on the substrate geometry structure and the quality requirements. **Tables 1** and **2** list a few general blade parameters used in the QFN market.

Increasing UPH While Maintaining Cut Quality

The QFN application has been in the market for about a decade and a half with a continuous demand to improve both quality, but mainly UPH. The Initial production feed rate was ~5mm/s

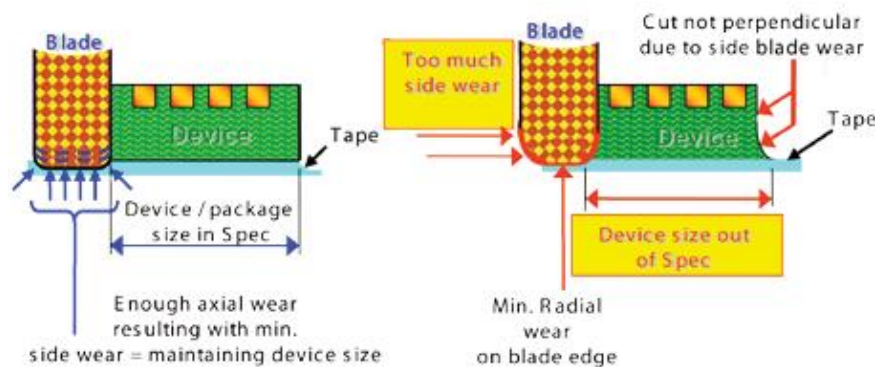


Figure 7: Effect of too much side wear

Substrate thickness (mm)	Device size (mm)	Mounting	Blade Matrix	Blade thickness	Diamond grit size (µm)
0.8 – 1.2	1 x 1 up to 12x12	Tape	Resin	.008"-.020" 0.200-0.508mm	45 - 88
0.8 – 1.2	3 x 3 up to 12x12	Tape-less	Resin & Sintered	.008"-.020" 0.200-0.508mm	45 – 88 - Resin 40 – 53 -Sintered


Table 1: General blade parameters for standard QFN packages

Substrate thickness (mm)	Device size (mm)	Mounting	Blade Matrix	Blade thickness	Diamond grit size (µm)
0.4 – 0.6	1x0.6, 1x1 up to 4x4	Tape	Resin	.008" - .012"	45 - 53
0.4 – 0.6	1x0.6, 1x1 up to 4x4	Tape	Metal Sintered	.008" - .012"	35 - 45

Table 2: General blade parameters for thin QFN packages

with a life span of about 200-300m. Today, end users are dicing standard QFN production at up to 100mm/s with a life span of about 2,000m. There is unrelenting pressure from the industry to further increase the UPH. In pursuit of higher UPH to maintain competitiveness, blade manufacturers continually invest in R&D programs aimed at developing new blade matrices, i.e., new resin formulations,

diamond types and fillers, in order to meet demanding requirements.

Recently, we developed new resin formulations (called T-T07) with better performance than currently available. **Figure 8** compares the new matrix blade wear to previous matrices and other blades. This phenolic resin matrix has been shown to comply with the quality requirements while maintaining a longer life. 

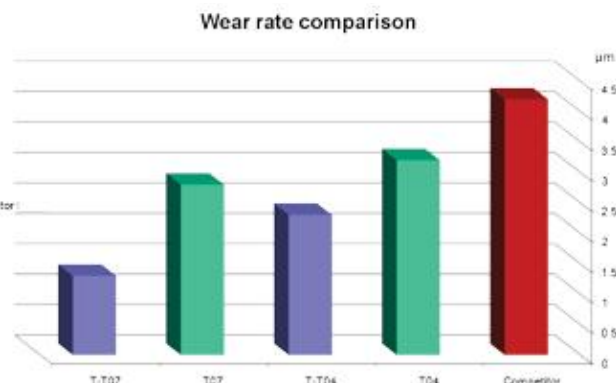


Figure 8: Wear comparison

Biography

Gideon Levinson is a practical mechanical engineer and graphic designer who studied at the Technion – the Israeli Institute of Technology, as well as at Temple U., Philadelphia. He is a senior R&D specialist, dicing consumables, at ADT - Advanced Dicing Technologies; email glevinson@adt-co.com

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