Wirebond challenges in QFN

by

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Introduction:

The market for the portable & handheld consumer electronic goods is growing rapidly and technological revolution is taking place in the integrated Circuit (IC) Packaging field in the miniaturization of the IC packages to supplement this. Customers are looking for lighter & smaller size electronic gadgets with advanced features and the packaging technology is shifting towards more of the Leadless IC packaging. Owing to component size and the absence of leads, the devices packaged in leadless packages could be easily used for high frequency applications and the business volumes are gaining momentum. Since the number of units/strip is very high in the leadframes and the demand is picking up, the manufacturing cost for leadless packages is getting lower than the conventional leaded packages and the productivity is also higher than the leaded packages.

Like Leaded packages, the interconnect technology for Leadless packages also uses the conventional gold wire bonding techniques and bonders. However the leadframes have half etch design beneath the leads (mainly designed in such a way to improve the lead locking) and the clamping mechanism of individual leads is not feasible in these leadframes. This poses a great challenge to the wire bond engineer in terms of design of the proper leadframe, design of suitable piece parts for clamping the leadframe, wire bond parameters, materials such as gold wire & capillary selection and equipment set up.

Spel Wire bond engineers took this challenge and adopted various design of experiments and process capability studies for improving the productivity at wire bonder and wire bond yield for the leadless packages. The various kinds of process defects were analayzed in detail and proper root cause analysis studies were carried out. The following Ishikawa drawing (fish-bone analysis) was framed which addresses the various causes (4M's) due to man, machine, material & methods for the process defects

Various improvements were done in the leadframe design, piece-parts design and a close interaction was carried out with our business partners (equipment suppliers) in arriving at the optimum design.

Ishikawa Diagram framework adopted for analyzing the wirebond challenges in QFN

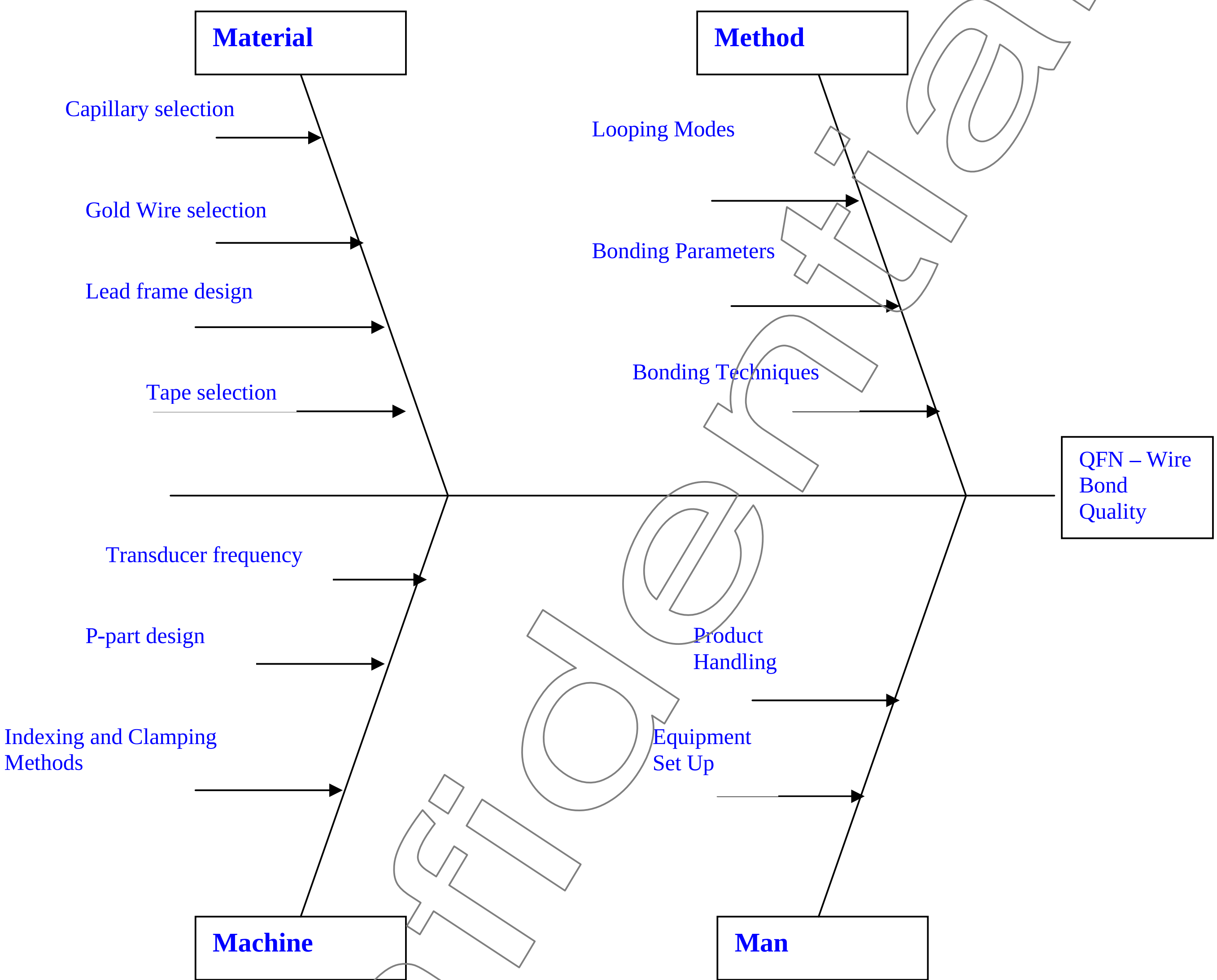

Fig A: Ishikawa diagram for QFN Wire Bond Process Quality

Piece-part design:

Leadframe clamping in Leadless packages is not like the conventional leaded clamping given below.

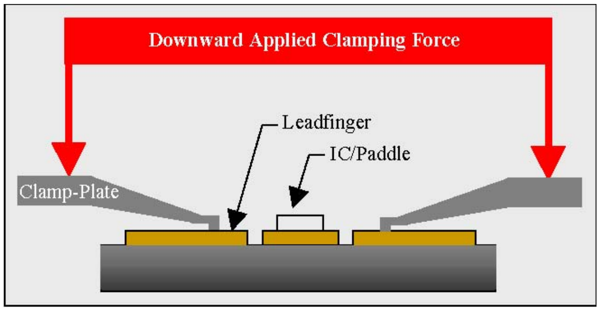

Fig B : Conventional Lead clamping Mechanism.

In QFN leadframes the lead pitch is so small that makes it difficult to support by mechanical clamping means. For these cases, individual lead clamping is not feasible and frame claming mechanism may be applied to the outer perimeter only. Interior sites (leads) will not be clamped. Wire bonding on the unclamped surfaces will result in poor bonding due to the bouncing effect on the leads. To worsen the situation, the leads generally have half etch design and the bonding is still complicated.

Fig C: QFN Lead clamping Mechanism

Porous type heater plate is generally used to clamp the QFN leadframe or heat block with vacuum hole provision below the individual site could also be used. Vacuum in the heater plate will hold the leadframe firmly to enable better bonding. Although the tape beneath the QFN leadframe can help dampen vibrating sites during bonding, leads will deflect when bond forces are applied at high temperature.

Porous Plate:

Fig D : Porous plate used for wire bonding purposes.

The porous or vacuum hole size matters and if it is going to be bigger than the lead size vacuum will deflect the lead while bonding as given below.

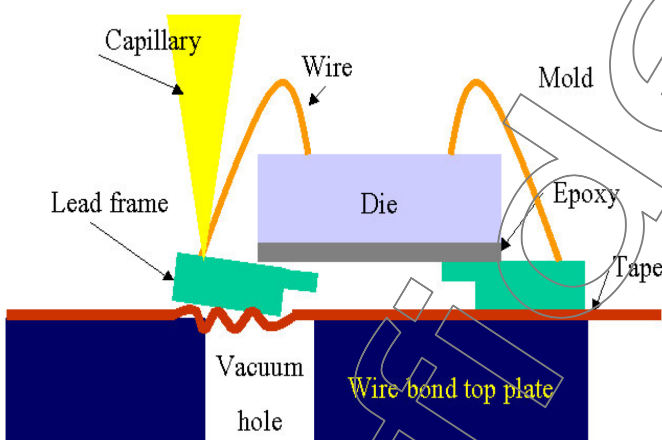

Fig E : Improper design of Heat plate with vacuum provision

Leadframe design:

Leadframe design plays a critical role in QFN. Leadframe matrix density is the primary factor affecting the wirebonding process. Width of the tie-bar and the etch depth on the underside of the land-site have significant impact on tail bond performance. When one unit is getting wire bonded the vibration transfers to the surrounding sites due to resonance effect and units that are already bonded could be disturbed due to application of ultrasonic energy on the leads during bonding. . The package sharing the same tie bar location and neighboring IC will experience the second highest level of displacement. If the neighboring device is already bonded there are more tendencies for the wires to be directly affected. This energy transfer will degrade the bonded stitch or looping.

Leadframe material also plays a key role in the proper selection of the capillary type. For Nickel-Palladium-Gold (Ni-Pd-Au) based substrates, capillary life is generally shorter and hence selection of robust capillary for all kinds of substrate materials is a key factor.

Leadframe surfaces come with special treatment process which roughens the surface and if the final cleaning process is not good enough, wire open errors are not uncommon in the wire bonding process.

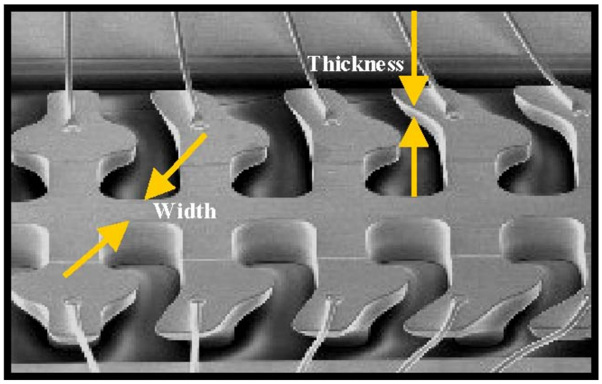

Fig F : Half etch leadframe

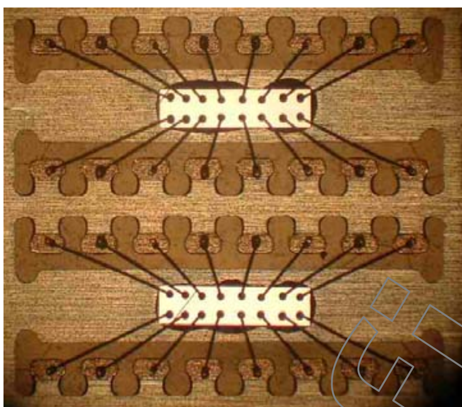

Fig G : Leadframes with Horizontal pad design

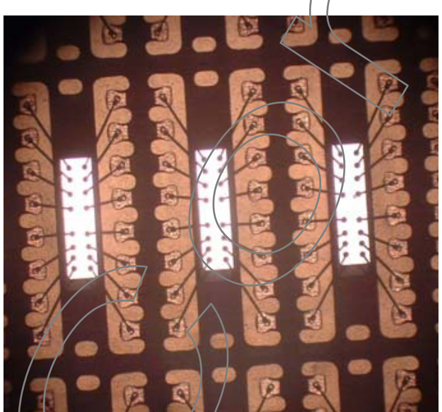

Fig H : Leadframes with Vertical design of Die pad.

Hence the design of tie bar width and half etch depth and consistency needs to be optimized & ensured in the leadframe design and actual production. Leadframes with the vertical design yielded better result due to uniform distribution of ultrasonic energy. But latest wirebonders are capable of handling horizontal design equally with use of special parameters, loss of energy can be compensated.

Tapes are used beneath the QFN leadframes to prevent the mold compound leak to the bottom surfaced during molding. The constituents of the tape and the adhesion of tape to the leadframe surface is a key factor that could influence the wire bonding quality. Mostly silicone based tape is used in the industry even though Polyimide based tape can yield better results. Special heating methods and compression techniques are required during the attachment of the polyimide tape to the leadframe and hence silicone based tape is used widely due to economy. Silicon based tape have the tendency to give out siloxane as outgas material during Die attach cure process which could form a organic contamination on the lead surface thus inhibiting better bond quality.. Hence plasma cleaning before wirebonding becomes mandatory for QFN package. Still tape will give out gassing during wirebonding due to long exposure of the leadframe at wirebond at temperature exceeding 170 deg.C.

Parameter optimization:

Bond parameter optimization could be a nightmare even though the material selection is carefully done. Looping modes, bond force, bond power, bond temperature, bond time are crucial parameters that have a significant influence on the bond quality.

Ball bond neck may get damaged if the looping mode is not optimized and could become weaker if the tail bond parameters are not optimized fully. Higher power due to application of ultrasonic energy could stress the ball neck or the heel of the adjacent bonded device and weaken the stitch bond pull strength value. Hence higher bond force is mostly used with shorter ultrasonic energy for wire bonding of QFN leadframes.

Depending on the thermal conductivity or heat transfer capacity of the tape, bond site temperature could drop down than the actual setting. Hence temperature required for bonding site need to be suitably compensated. Since QFN leadframes are high density leadframes, care should be taken for ensuring uniform distribution of heat over the entire bonding area.

Pre-clamp delay time is set to ensure the uniform transmission of heat and proper expansion of the leadframe tape before clamping. Similarly post clamp delay time is added to eliminate the problem due to sudden cooling of the leadframe.

Bond Time plays a critical role in making consistent & reliable second bond and in hard leadframes like NiPdAu. Thermo-compression bonding will have higher bond time compared to thermo sonic bonding. Optimum time can give better pull strength values and good process stability.

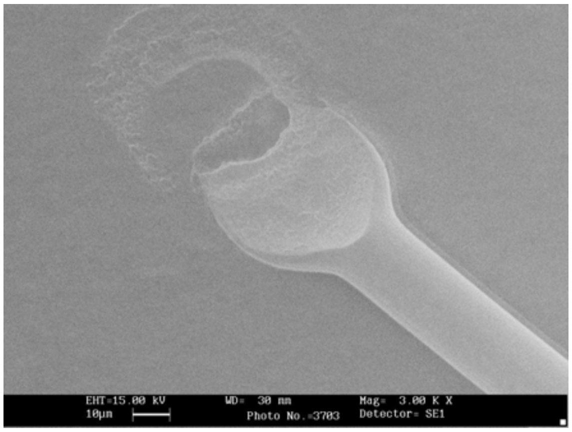

Fig I : Good Stitch Bond

Capillary:

Capillary dimensions and material of construction also plays a key role in influencing the wire bond quality of QFN devices. Depending on die geometry, substrate frame material and process parameter capillary life will vary. Since thermo compression bonding is preferred in taped leadframe it is preferred to use a capillary with higher Face Angle and with required Tip Diameter to with stand the bond force. For better capillary life, Capillaries with Special coating in the lead tip can be used with optimal dimension.

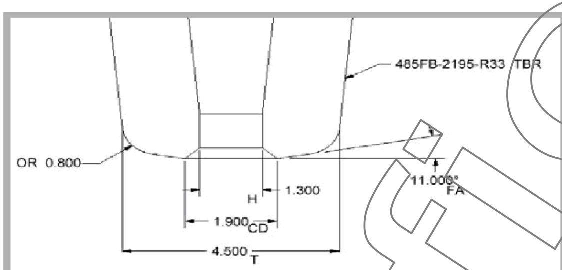

Fig J : Key Capillary dimensions for QFN packages.

Gold wire:

Gold wire plays a vital role in QFN bonding. The criteria to establish good II bond are

- Higher pull strength
- No NSOL, no short tail & visually acceptable crescent shape
- Should be able to withstand the various reliability & endurance tests done on the IC packages.

This can be achieved by using harder wire with optimum tensile strength. Wires that have the resistance to sweep during the molding process need to be selected.

While using softer wire, heel cracks are observed due to higher bond force at stitch. This will affect the reliability.

The below image shows heel crack and the stress formation by using softer wire.

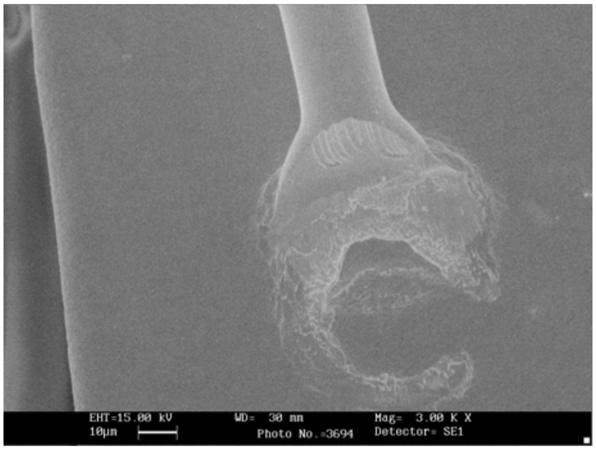

Fig K: Softer Gold wire – Heel crack.

Conclusion:

Due to the unique design of QFN packages the following factors play a key role in ensuring consistent and reliable wire bond quality.

a) Leadframe design & compliance of key dimensions to the actual design specs.
b) Optimum design of piece-parts.
c) Selection of the right gold wire & optimum selection of capillary type.
d) Bond parameter optimization through design of experiments techniques.
e) Optimization of Plasma cleaning process.
f) Better equipment set up methods, product handling techniques and periodic monitoring of process quality.