Material Characterization of Test Contact Pin

Praveen kumar Ramamoorthy[1], Florian Fischer[2], Han Guan[1] and Murad Hudda[1]

[1] *Infineon Technologies, 168 Kallang Way, Singapore- 349253*
[2] *Department of Mechanical Engineering, Technical University of Munich, Munich- 80333, Germany*

Abstract. Test Contact Pin is used for testing the functionality and quality of the micro-devices at extreme temperatures before shipping to customers. The contact pin transfers current & signal to the device tested through dynamic contacting where the material resistance of the pin and the contact resistance between the pin and the device plays a significant role in influencing the effectiveness of the test process. Available material specifications for these pins in the market are for ambient temperature only. The test contact pin was characterized across temperatures onto matte Sn leadframe for its contact resistance and force with respect to number of touchdowns. Contact resistance and pin force are the key variables used to understand the mechanism of the process which is also used for determining the lifespan of the contact pin. An automated and sophisticated contact tester tool (CTT) was used to characterize the test contact pin on the mattes Tin leadframe across temperatures (-43 ℃, 25 ℃ and 150 ℃) and at fixed pin deflection. Based on the results, it was observed that the contact resistance was higher at higher temperatures. Further data analysis revealed that this phenomenon was due to influence of various factors such as temperature, leadframe material type and the material migration of Sn from leadframe to the test contact pin tip.

1 Introduction

Testing is a dynamic process in which the micro-devices are checked for their functionality and quality by pumping current and signal to the devices before shipment to the customer. This is possible by dynamic material contact between the lead of the package and the contact pin (Figure 1).

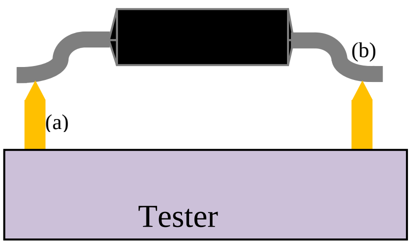

Figure1. Device under Test. (a) contact pin (b) device lead

At micro level real surfaces are rough. During contact between the lead and the pin conducting paths are formed through localized metallic contacts [1]. As the force increases, the number and the area of these small metal–metal contact spots or a-spots will increase (Figure 2).

a-spots are the only conducting paths for the transfer of electrical current and the real contact area is only a fraction of the apparent contact area as illustrated in Figure 2. The relationship between the applied normal load *L*, hardness of the metal, *H*, and the apparent contact area, A_a, is given by the following expression:

$$L = xHA_a. \quad (1)$$

Where *H*, the hardness is the measure of the ability of a metal to resist deformation due to point loading; x is the pressure factor and is equal to 1 in most practical contact systems [2].

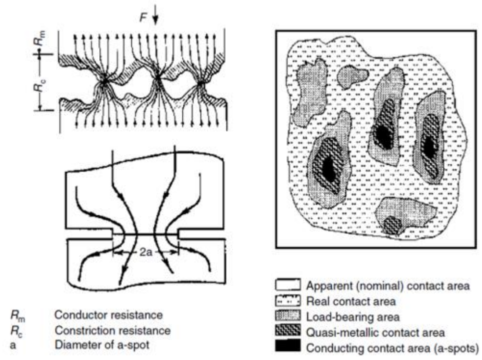

Figure 2. Schematic of current constriction and real contact area.

a-spots are the constricted contact interface through which current passes. The electrical resistance of the contact at *a*-spots is called *constriction resistance* and is related to the basic properties of metals such as hardness and electrical resistivity. Constriction resistance for a single *a*-spot can be expressed as

$$R_s = (r1 + r2)/4a \quad (2)$$

where r1 and r2 are resistivities of the contacting metals, and *a* is the radius of the metal-to-metal contact area [3]. If two same metals are contacting, then the constriction resistance becomes

$$R_s = r/2a. \quad (3)$$

Usually the metals are contaminated or an oxide layer formed above it due to reaction with oxygen. Thus, the passage of electric current may be affected by thin oxide, sulphide, and other inorganic films present on the metal surfaces. Hence, the total contact resistance of a joint is a sum of the constriction resistance (R_s) and the resistance of the film (Rf)

$$R_c = R_s + R\text{f} \quad (4)$$

$$R\text{f} = s/\pi a^2; \quad (5)$$

where *s* is the resistance per area of the film. Both tunnelling and fritting are considered operative mechanisms for the current transfer across the film. In most practical applications, the contribution of these films to the total contact resistance is of minor importance because the contact spots are usually created by the mechanical rupture of surface films. The contact resistance is the most important and universal characteristic of all electrical contacts [4].

The contact resistance is the most important and universal characteristic of all electrical contacts and is always taken into account as an integral part of the overall circuit resistance of a device. Therefore, although it is significantly smaller as compared with the overall circuit resist¬ance, the changes in the contact resistance can cause significant malfunctions of the device.

This is because the contact resistance can vary significantly with the changes in the real contact area, contact pressure variations, resistive film nonuniformity, and other factors. This results in large voltage increases, thus making the fine adjustment or good operation of devices difficult. For instance, the instability and high values of contact resistance are especially noticeable in bulk DC potentiometers, whose resistive members are relatively thick and have a high specific resistance.

There are many parameters that can be used to assess the operating efficiency of electrical contacts. Among these parameters, perhaps the most important are electric (the transition voltage drop, commutation noise, erosion resistance), tribological (the wear resistance and friction coefficient) and chemical (corrosion resistance).

Another important factor affecting the contact behavior is the presence of various films (such as oxides, contaminants, and reaction products). The current passes through the "*a*-spots" that are smaller than the real contact spots (Figure 5.1). Since the electrical current lines are constricted to allow them to pass through the *a*-spots, the electrical resistance increases. This increase is defined as the constriction resistance. Contaminant films on the mating surfaces increase the resistance of *a*-spots. The total resistance due to constriction and contaminant films is termed the *contact resistance*.

The fundamental monograph of Holm[1] considered most of the contact phenomena important for mechanical and electrical engineers. Timsit's review updated this topic within the framework of a general Holm's approach describing the factors of either electrical or thermal origin affecting the contact resistance. In the following sections, this approach will be followed with the addition of more recent research data.

In the case of isotropic roughness topographies, the *a*-spots are assumed to be circular or noncircular when the roughness has a directional characteristic (e.g., in rolled-metal sheets or extruded rods). The current passes through the "*a*-spots" that are smaller than the real contact spots.

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2 Experimental Section

An industry standard test contact pin was characterized for its force and contact resistance (Cres) with respect to number of touchdowns using a sophisticated tool i.e., contact tester tool. The arrangement of the tool is such that the pin to be characterized is mounted on the Z-drive which moves vertically up and down. The leadframe on which it is to be characterized is mounted onto a XY movable chuck (Figure 3). The entire mechanism is inside a oven which has an operating range of -70 ℃ to 180 ℃. Experiments were run at three temperatures -43 ℃, 25 ℃ and 150 ℃ similar to that of testing conditions at production. The deflection of the pin was kept constant and the reactive force and resistance were measured with the help of the tool. Fresh pin was subjected to 1 million touchdowns on the leadframe for each temperature and the experiment was repeated 3 times for repeatability check.

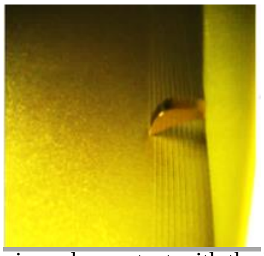

Figure 3. Contact pin under contact with the Leadframe

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3 Results & Discussion

3.1 Ambient Run

Test contact pin that was run at ambient exhibited the trend of force and contact resistance (Cres) measurements as shown in the graph below (Figure 5). It was observed that the contact resistance increased from 21mOhms to 78 mOhms after 1 million touchdowns. Examination of the pin tip after each and every run with leadframe revealed the wearing out of the pin and the migration of Sn material from the leadframe to the pin. The reactive force of the pin was observed to be dropping from 38gf to 30gf within the same number of touchdowns.

The increase in contact resistance may be due to multiple factors such as tin migration from the lead to the pin, electron migration at the pin tip etc. The drop in pin force with respect to number of touchdowns maybe due to increased fatigue of the pin, wear and tear of the pin tip which was observed to be upto 50ums in height. Abrasive wear, also known as *abrasion*, is one of the most common forms of wear [5]. The key aspect of abrasive wear is its association with the cutting or ploughing of the surface by harder particles or asperities (Figure 4). These cutting points may either be embedded in the counterface, or lost within the contact zone.

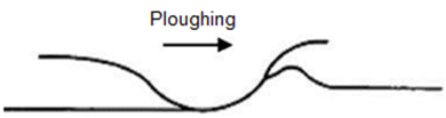

Figure 4. Abrasive Wear Mechanism

Abrasive wear is defined by the ASTM G 40–83 terminology standard as a wear due to hard particles or hard protuberances forced against and moving along a solid surface. Abrasive wear, also known as *abrasion*, is one of the most common forms of wear.

The key aspect of abrasive wear is its association with the cutting or plowing of the surface by harder particles or asperities. These cutting points may either be embedded in the counterface, or lost within the contact zone. The former case is commonly called two-body abrasion; the latter case is three-body abrasion. Sometimes, the abrasion may be classified in terms of the force acting on abrasive material. If the force is so large that the abrasive particles are crushed and the working surface experiences significant cutting and deformation, then *high-stress abrasion* takes place. This form of abrasion is observed, for example, in high-load bearings, where hard particles are trapped between mating surfaces. A particular case of high-stress abrasion is *gouging abrasion*.

This term is used for abrasion by large hard lumps that remove material from the worn surface in large fragments. Yet, the situations when the term may be applied are described ambiguously. When the pressure on the abrading particles or asperities is relatively low and the particles remain unbroken, the abrasion is called *low-stress abrasion*.

Abrasion displays scratches, gouges, and scoring marks on the worn surface, and the debris produced by abrasion frequently takes on the appearance of fine cutting chips similar to those produced during machining, although at a much finer scale. Most of the models associated with abrasive wear incorporate geometric asperity descriptions, so that wear rates turn out to be quite dependent on the shape and apex angles of the abrasive points moving along the surface.

The sources of the abrasive solids are numerous, and the nature of the abrasive wear in a given tribosystem will depend to some extent on the manner in which the abrasives enter the tribo-system: whether they are present in the original microstructure as hard phases, enter the system as contaminants from outside, or are generated as debris from the contact surfaces as they wear.

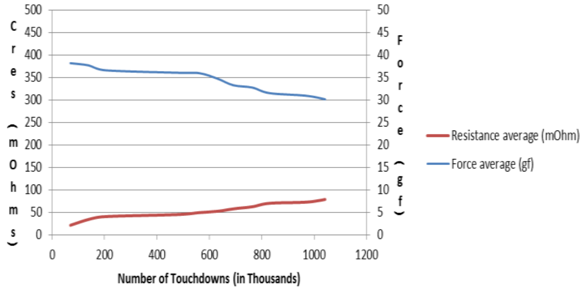

Figure 5. Force and Contact Resistance graph at Ambient temperature

3.2 Hot Run

Figure 6 shows the force and contact resistance measurements at hot (150 ℃). Drop in force of the pin at 1 million touchdowns was observed to be 20% higher than that at ambient. For resistance it was threefold increase when compared with that of ambient. It’s well established that higher temperature accelerates the wear and tear of the contact pin and offers resistance to the flow of electrons thereby increasing the contact resistance [6].

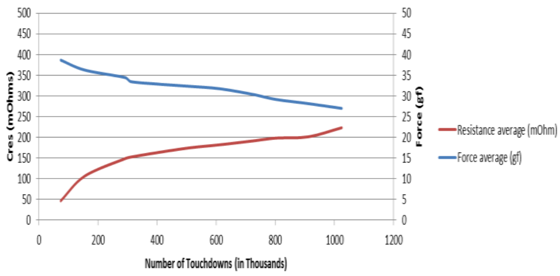

Figure 6. Force and Contact Resistance graph at Hot temperature

3.3 Cold Run

Figure 7 shows the force and Contact resistance measurements at cold (-43 ℃). Based on the data, it was observed that the force and contact resistance measurements at 1 million touchdowns lie in-between hot and ambient. The reason behind this phenomenon is due to the tin surface of the lead getting harder at lower temperatures [7].

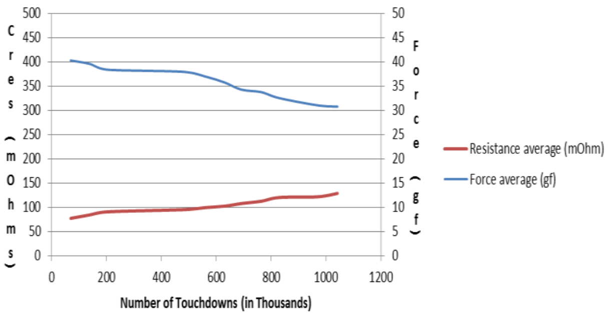

Figure 7. Force and Contact Resistance graph at Cold temperature

4 Conclusion

A detailed characterization of the test contact pin across temperatures was performed. The data exhibited that the contact pin force reduces with respect to number of touchdowns while the contact resistance increases. Based on data analysis and observation pin tip abrasive wear out due to contacting with the leadframe was found out to be the reason behind this phenomenon. It was concluded that the pin tip wear and tear is a function of temperature and the hardness of the contacting surface thereby affecting pin force and contact resistance. The quantified results were used as a reference for troubleshooting at production and also for the selection of prospective pins with better performance.

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