Fundamentals of Contact Resistance, Part I – Contact Theory

Understanding the fundamentals of the electrical contact during wafer test provides important insights into the localized phenomena that affect the magnitude and stability of the contact resistance.

At the start of overtravel during wafer test, the probe "toe" makes initial contact with the aluminum pad. Then at the end of overtravel, contact is primarily made by the probe "heel" (Figure 1).

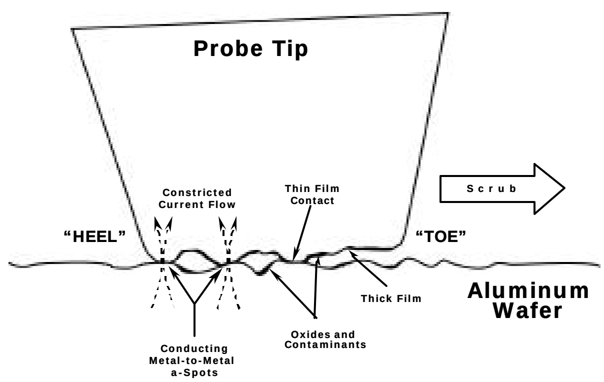

Figure 1 *- Probe tip and aluminum contact pad interface.*

Contact Theory assumes that at some scale the contact surfaces are never completely flat. During scrub, inter-metallic contact is made at the asperities across the surfaces. Initially, the deformation is elastic and as the overtravel increases, the softer material deforms plastically until the entire contact force is supported. The size of the plastically deformed regions is directly proportional to the contact pressure and inversely proportional to the material hardness. In fact, it has been shown that the contact area of a probe tip is approximately 65–85% of the tip diameter.

Generally, creating sufficient contact for current to flow between the probe tip and aluminum pad is not difficult. The difficulties arise in maintaining the "quality" of the inter-metallic contact during repeated scrubbings, i.e. the "real" contact area is affected by the contact surface cleanliness and oxidation.

There are essentially three regions within the "real" contact area of a probe tip: (1) metal-to-metal contact – the current passes through the interface without any transition resistance; (2) semi-conducting regions – thin film covered areas with resistance values higher than the metal-to-metal contacts; and (3) non-conducting regions – areas covered by thick films of oxides, sulfides, and tungstenates (Figure 2).

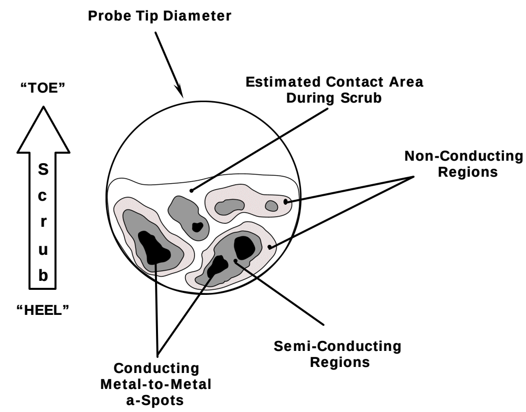

Figure 2 *- Non-conducting, semi-conducting, and conducting regions of the "real" contact area.*

Consequently, the "real" contact area of a probe needle is significantly smaller than the observed scrub mark area (Figure 2).

Current flow between the probe tip and the aluminum contact pad is constricted to the narrow inter-metallic contacts, commonly referred to as "a-Spots" (Figure 2). Any electrical contact is believed to contain some number of a-Spots.

The contact resistance (C_{RES}) across the contact pad and probe tip is comprised of the constriction resistance and the interfacial film resistance. During wafer test, current flow lines are forced to pass through the a-Spots and across any thin conductive films. Distortion in the current flow causes the constriction resistance to increase. The contribution of the film resistance depends on the thickness of the contaminants on the contact pad and probes as well as any trapped wear debris.

The increased C_{RES}, results in localized Joule heating at the probe tip and can cause a considerable rise in the localized temperature and oxidation growth at the a-Spots. Although these areas cover a very small fraction of the contact area, the localized processes that occur dramatically affect the reliability of the electrical contact. Thus, the metal-to-metal conducting "a-Spots" will solely determine the quality and stability of the electrical contact.

Selected References –

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