Measuring the mechanical behavior of wire bonds

SmarAct | metrology

INTRODUCTION

Wire bonding allows to connect a semiconductor device to its packaging, see 1, and is widely used in production due to its simplicity, flexibility and high automation. While adequate bonds are critical for the good functioning of the end-device, their reliability remains however questionable. Indeed, research showed that environmental condition changes can easily affect the bond integrity. To overcome this limitation, multiple bonding techniques, such as polymeric coating, have been developed to better secure and protect the bonds. Yet, the benefits of each technique remain difficult to evaluate because most testing processes are intrusive and cannot be implemented during in-line quality control: the wire is pulled until its breaking point is reached and the process is repeated after changing the environmental conditions.

Optical metrology is the method of choice for the characterization of the mechanical properties of a device as it is contactless, non-intrusive and more importantly non-destructive. However, because of the often large bending radius of the wires and their sub-millimeter diameters, it is required to use strong focusing optics to achieve a small beam waist and a large angular tolerance. In turns, it makes the alignment of the laser beam on the wire and wire bonds challenging and unpractical for most standard optical techniques.

Here, SmarAct's **PICO**SCALE *Vibrometer* shines as the must-have optical instrument for investigating wire bonds thanks to its closed-loop positioning system, large working-range and micrometer optical resolution.

In this application note, we demonstrate how the **PICO**SCALE *Vibrometer* was used to investigate the effect of different bonding techniques on the mechanical properties of the created wire bonds.

RESULTS

The device under test is an optical measurement system that includes a photodiode. The photodiode is connected to the substrate with 25 µm diameter gold wires (Heraeus, Germany). The wire bonder Fs bondtec 5810 (F&S Bondtec, AT) was configured to produce three different bonds but with similar wire length:

- Standard ball wedge bonding,
- Advanced security ball bonding and,
- Standard ball wedge bonding with added low silicone gel (NEA 123HGA, Norland, USA) dosing on both the wedge and ball bonds.

The optical measurement system was fixed on the standard shaker stage of the **PICO**SCALE *Vibrometer* using grease (Apiezon H, Apiezon, UK). The shaker stage was used to generate vibration with up to 100 nm amplitude into the system. To image the wires, an objective with a 0.25 numerical aperture was used. The beam radius at focus is 4 µm.

The main challenge for investigating bent structures, here the wires, is that only a small portion is aligned with the optical axis of the objective. Here, successive auto-focus routines using the **PICO**SCALE *Vibrometer* were performed along the wire, starting at the bondpad, until the location of maximum reflected intensity was found. Then, a microscopy image was recorded by raster-scanning the laser beam over the wire to ensure that its apex was properly found. Finally, the laser beam was positioned on the wire, at the location of maximum intensity, for the subsequent out-of-plane vibration analyses, as in 2.

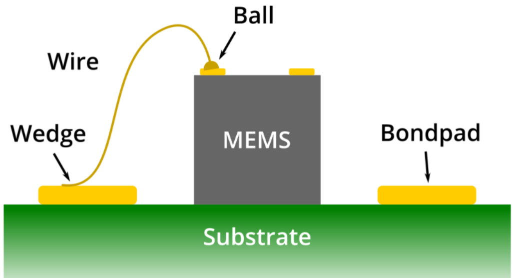

Figure 1. *Standard ball wedge bonding description.*

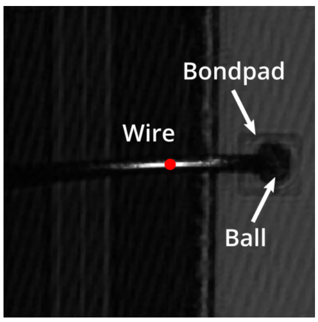

Figure 2. *Microscopy image recorded with the **PICO**SCALE Vibrometer. The bondpad and wire are clearly visible. The red circle localizes the position of the laser beam during the vibration measurements.*

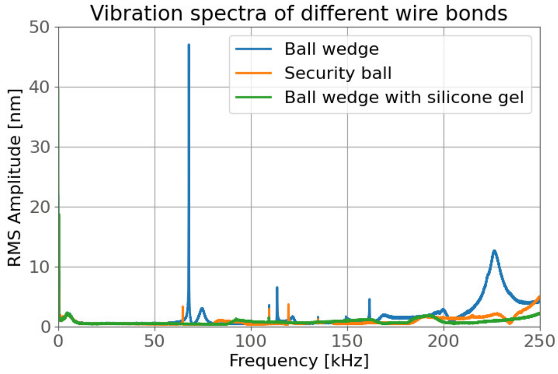

Figure 3. *Vibration spectra recorded on the wires with different bonding techniques. 100 spectra were averaged per wire.*

The optical measurement system was mechanically actuated by a linear sweep from 1 kHz to 500 kHz. The resulting vibration spectra recorded on the wires with a sampling rate of 5 MHz are shown in 3.

It can be seen that the standard ball wedge technique is considerably more sensitive to the transduced vibrations as compared to the security ball and silicone gel dosing. Indeed, large vibrations, especially at 67 kHz (47 nm RMS amplitude) and 227 kHz (12.5 nm RMS amplitude), are only visible for the standard ball wedge, which suggests that this technique creates bonds that will break relatively easily if the transduced vibrations are large. It should be noted that according to the manufacturer, the operating frequency of the wire bonder is 67 kHz which unfortunately matches the resonance of the wire measured. This means that even during the production process of the optical measurement system, the bonder itself already weakens the bonds which is detrimental for the longevity of the end-device.

Both the security ball and silicone gel show a flat response over the measurement bandwidth with a maximum amplitude of 5 nm and 2.3 nm respectively. The transduced vibrations are almost 10 times less pronounced than for the standard ball wedge bonding and infers that they are consequently less sensitive to mechanical fatigue. Because there is no resonance at the operating frequency of the bonder, it also infers that the optical measurement system will be in general more robust.

CONCLUSION

In this application note, we showed that the **PICO**SCALE *Vibrometer* can be used to measure bent structures. More specifically, the auto-focusing routine implemented in the instrument facilitates the positioning of the interferometric laser beam at the apex of a wire and the measurement of its vibrational behavior. We showed that the choice of the bonding technique greatly impacts the mechanical properties of the bonds: the standard ball wedge technique generates weak bonds, while more advanced techniques such as security bonding and silicone gel coating can circumvent this limitation.

While this example demonstrates the use of the **PICO**SCALE *Vibrometer* in the R&D context, it is possible to implement such routines during quality control processes with the main advantage of being contactless and in-line.

In parallel to out-of-plane vibration measurements, it is also possible to study the in-plane mechanical behavior of wires with the **PICO**SCALE *Vibrometer*.

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