Gold Stud Sizes

Alexandra Moskaleva

June 23, 2011

Abstract

A short study was conducted on the sizes of 1 mil gold wire used for gold stud bump bonding. The uncompressed gold studs contained two features: a highly regular circle, "head," atop of a irregular and usually semi-elliptical "collar." The head was consistently 72 μm in diameter, and the collar was on average (104 ± 6) μm in diameter. Upon compression with 160 g/stud at normal bonding temperature (320 °C), the head and collar morphed together to create a plateau 143 μm in diameter. The displacement of the center of the gold ball from the center of the pad for the chip compressed at bonding temperature is (16 ± 7) μm. Please note that all errors are reported with one standard deviation.

1 Introduction

The International Linear Collider (ILC) is a proposed particle collider to complement the LHC, reaching energies of 500 GeV in the first phase and 1000 GeV in the second phase. Major goals of the ILC include understanding the mechanism behind mass generation and electroweak symmetry breaking, searching for and perhaps discovering supersymmetric particles and confirming their supersymmetric nature, and hunting for signs of extra space-time dimensions and quantum gravity. The detectors of the ILC will record and measure the charged and neutral particles produced in the ILC's high energy e^+e^- collisions and must achieve unprecedented precision to reach the performance required [**?**].

The purpose of this experiment was to investigate the characteristics of gold studs when used for bump bonding. A proposed concept for the electromagnetic calorimeter makes use of bump bonding for connecting the detector wafer, a KPiX chip, and a power/signal cable. The KPiX chip is a front-end integrated circuit chip designed to operate within the duty cycle of the ILC, tag individual bunches ditize on the sensor, minimize noise, and perform multiplexed A/D conversion. The design specifications of mounting the KPiX on the detector (close to the sensor, be powered by front end electronics, and minimize on-detector material) create a perfect atmosphere for using bump bonding because it is a way to finely bond chips together and greatly minimize space.

2 Gold Ball Sizes

To perform this study of gold stud sizes, two bonding wefer dummy chips (BWDs) where chosen and studded with 1 mil gold wire. One chip was then put through a simulated bond at room temperature (40°), and the other at operational bonding temperature (320°). The simulated bond was done by pressing a blank piece of Silicon onto the studs. Five gold balls were measured before and after the simulated bond (chosen to represent a wide variety of collar shapes such as large, small, oblong, circular, etc.). The pad numbers to which the gold balls were noted. Using the Motic microscope-mounted camera and corresponding software, the radius of the head and the horizontal and vertical dimensions of the collar were measured. Figure 1 shows examples of two gold balls before the simulated bond (one with a highly irregular collar, and one with a regular one). Figure 2 shows an example of a gold ball compressed at room temperature on and one at bonding temperature.

The chip labeled B was compressed with the Finetech under room temperature (40 °C) for the duration of a normal bond (roughly 10 min) with 94 N force (≈160 g/stud). Chip E was put through a simulated bond which ramped up to 320 °C with a force of 94 N (≈160 g/stud). Both chips were compressed with a clean piece of blank silicon to simulate a bond. In both cases, no bond was created between the chip and the blank piece of polished silicon, and the gold studs were simply coined.

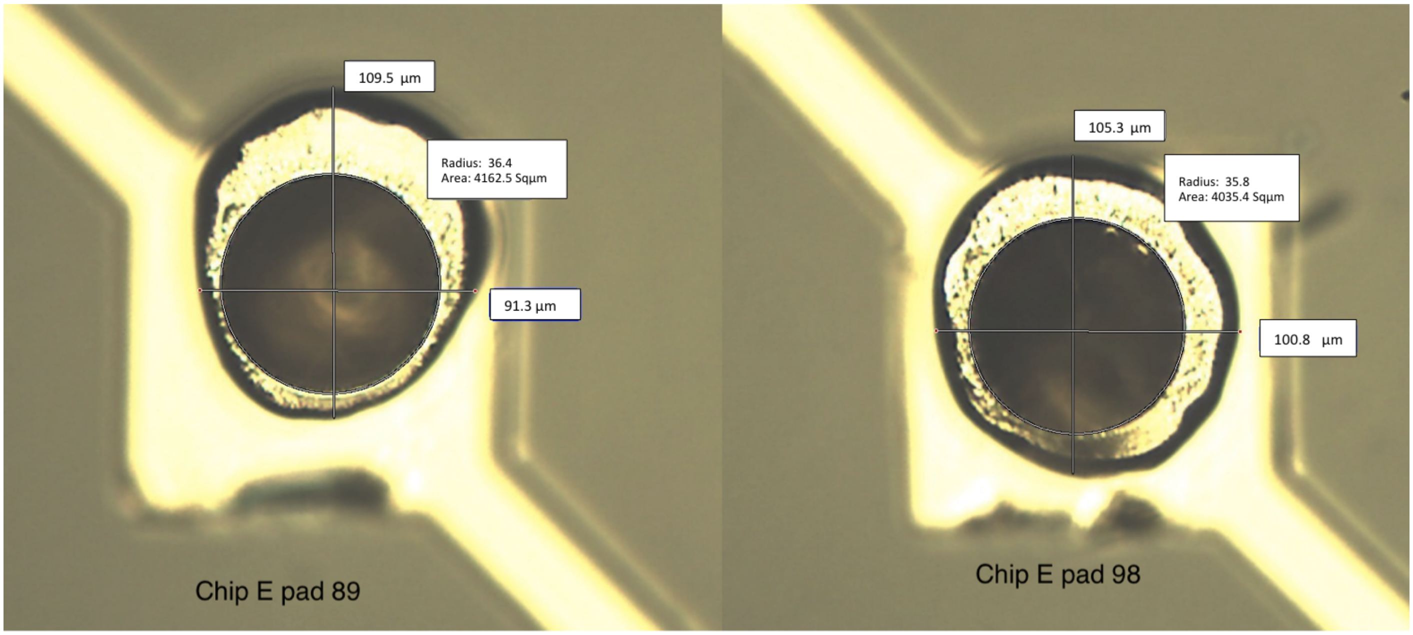

Figure 1: Examples of pads from chip E before compression. The dark circle in the middle of the capture is the head (out of the plane of focus) and the bright area around the head is the collar. Pad 89 is an example of a highly irregular collar because its thickness around the head varies greatly, it is off-center, and its height and width are not constant. Pad 98, on the other hand, is much more regular. Notice that the head's radius is approximated by the Motic software. The height and width of the collar are estimated by measuring the height and width of the collar such that the line intersects the circle at a right angle.

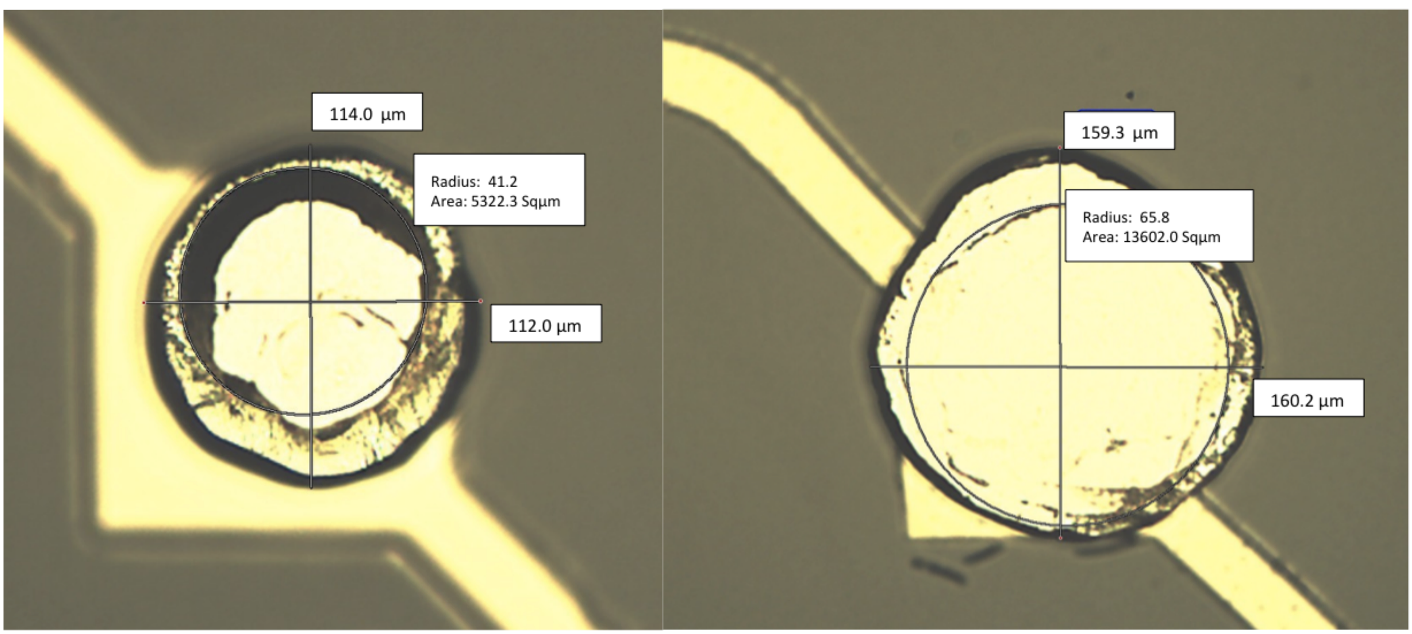

Figure 2: Examples of pads after compression. The stud on the left was flattened with the Finetech at room temperature, while the stud on the right was compressed at bonding temperature. Notice that the stud flattened at room temperature exhibits much less deformation than the one at bonding temperature, while the one studded at bonding temperature exhibited a complete merger of the head and collar. This was consistent throughout the studs.

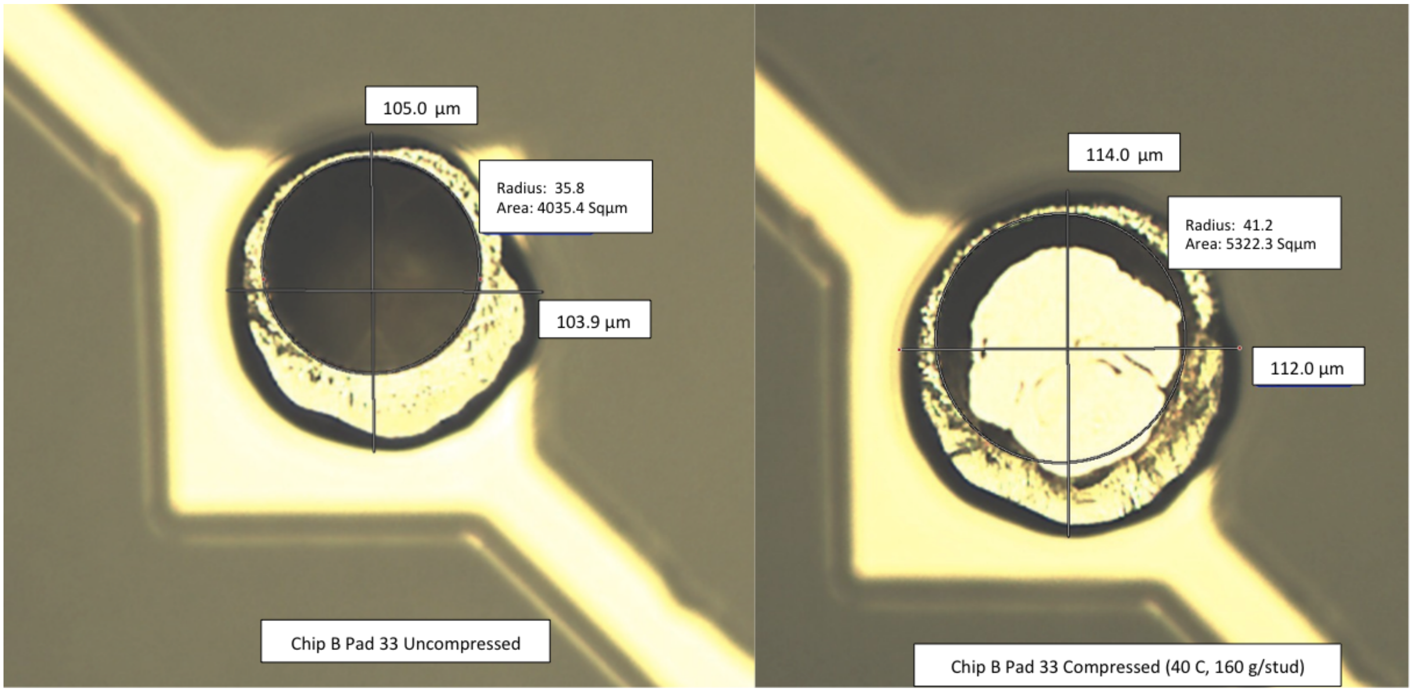

Figure 3: Stud before and after a simulated bond under room temperature. Notice that the collar of the stud is undisturbed, and the head is flattened on the top (yet appears to retain its shape below the coining).

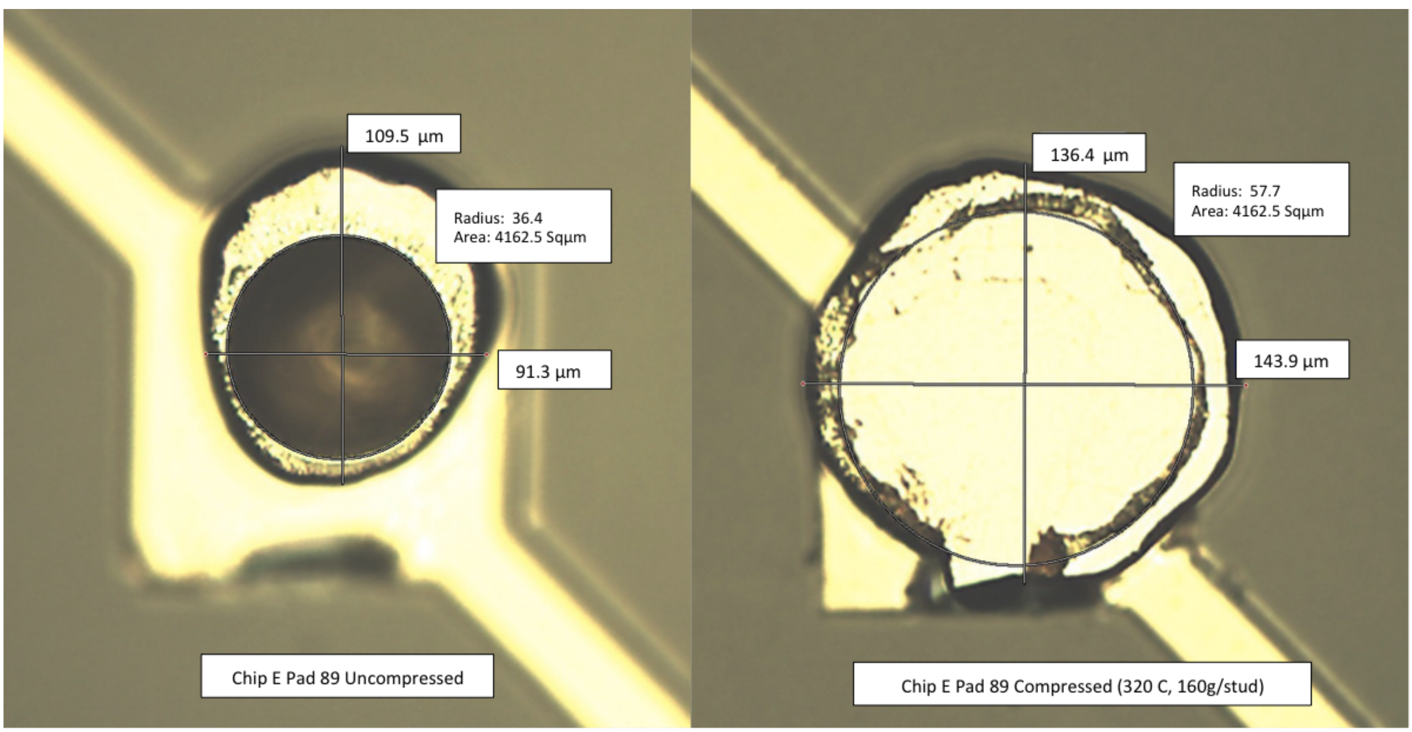

Figure 4: Before and after a simulated bond that plateaued at 320 °C. Notice that the whole gold head is absorbed into the collar, and the top of the structure is completely flat. While the collar is still distinguishable from the gold head, they are in the same plane. Also, most of the structure of the collar has disappeared and the coined stud has morphed into a more regular shape.

Table 1: Summary of obtained results.

Compressed and Uncompressed Gold Stud Data

	Head Diameter		Collar (Horizontal)		Collar (Vertical)	
	Average (μm)	Standard Deviation (μm)	Average (μm)	Standard Deviation (μm)	Average (μm)	Standard Deviation (μm)
Chip B Uncompressed	72	0	101	7	107	8
Chip B Compressed (40 C)	85	4	114	6	118	10
Chip E Uncompressed	72	0	100	15	108	6
Chip E Compressed (320 C)	116	14	143	24	144	24

3 Displacement of Gold Balls from Center of Pad

The displacement of the center of the ball away from the center of the gold pad was also measured for the same five gold balls. Again, this was done with the calibrated Motic software. To do this, a square was drawn to approximate the area of the square pad. Then, two diagonals were drawn in. The distance from the center of the head to the intersection of the diagonals is the displacement of the center of the gold ball from the center of the gold pad.

The average center to center distance between gold ball and pad for an uncompressed gold ball is (14 $\pm$ 7) μm. The average displacement for the compressed at room temperature is (13 $\pm$ 5) μm. The average displacement for the compressed at bonding temperature is (16 $\pm$ 7) μm. The displacement of the chip compressed at bonding temperature after compression may be less accurate than the other two because the pad is often times hidden underneath the large gold ball, and had to be approximated.

4 Conclusions

There are a few interesting things to note from the above data. First, the uncompressed sizes will vary between different capillaries. Even so, the head radius was consistent for every uncompressed measurement, but the collar varied somewhat. After compression at room temperature, the gold stud retains features of the collar and head. Yet after compression at bonding temperature, the gold studs become very regular in that the head is absorbed into the neck to create a flat, wide plateau. On average, the diameter of this plateau is (143 $\pm$ 12) μm. The displacement of the center of the gold ball from the center of the pad for Chip E (compressed at bonding temperature) is (16 $\pm$ 7) μm. Thus, the absolute minimum pitch that can be bonded with 1 mil gold wire is 185 μm. This includes the combined size of the ball, as well as the average displacement (and their respective errors).

References

[1] ILC GLobal Design Effort and World Wide Study, *International Linear Collider Reference Design Report, Vol. 4 – Detectors.* ¡ilcdoc.linearcollider.org/record/6321/files/ILC$_R DR_V olume_4 - Detectors.pdf?version = 4 >$ 2007.