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CONTROL PARAMETERS ANALYSIS FOR THE L3 SMD MANUFACTURING PROCESS

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Abstract

The Silicon Microvertex Detector (SMD) is designed to upgrade the central tracking capability of the L3 experiment at LEP. High performance vertex reconstruction depends, among other parameters, on the accurate knowledge of the detector position in space and on its stability in time. Each technological operation involved in SMD manufacturing process requires careful monitor of multiple geometrical parameters, at micron level, for each constitutive part as well as for the whole detector.

In this context, the present paper reports authors contributions to perform very precise measurements of the ladder components and their relative positions. We discuss the main control parameters values of the manufacturing process for ten half ladders (HL) constructed at the clean room assembly facility of the INFN and University of Perugia. Experimental data are analysed and parameters variation tendencies at different manufacturing process moments are investigated. Range variation of and correlation between different parameters are derived. Some improvements of HLs manufacturing process control are proposed. Main contributions pointed out by this analysis are reviewed in the conclusions section.

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1. Introduction

The Silicon Microvertex Detector (SMD) was designed to upgrade the central tracking capability of the L3 experiment at LEP [1]. High performance vertex reconstruction depends, among other parameters, on the accurate knowledge of the detector position in space and on its stability in time. To address this issues, during the manufacturing process, great care is being devoted to *following objectives*:

♦ To perform very precise measurements of the ladder components and their relative positions.

♦ To perform an accurate measurement of the ladder's position on the mechanical support.

♦ To monitor in time the position of the SMD with respect to Time Expansion Chamber (TEC) and other detection systems.

A full description of SMD design parameters can be found in [2]. Each technological operation involved in SMD manufacturing process requires careful monitor of multiple geometrical parameters, at micron level, for each constitutive part as well as for the whole detector [3],[4].

In this context, the present paper reports authors contributions to fulfil the *first* of the above objectives. We discuss the main control parameters values of the manufacturing process for ten half ladders (HL) constructed at the clean room assembly facility of the INFN and University of Perugia. Experimental data are analysed and parameters variation tendencies at different manufacturing process moments are investigated. Range variation of and correlation between different parameters are derived. Some improvements of HLs manufacturing process control are proposed. Main contributions pointed out by this analysis are reviewed in the conclusions section.

2. Control parameters analysis

The HL manufacturing process for SMD requires careful monitoring of a hug number of parameters. Considering the large number of measurements done during H assembling process, the present analysis was restricted to those parameters tha according to authors design, manufacturing and practical experience of the SMD, ar considered the most important. These parameters can be classified in *two categories*:

♦ *Dimensional control parameters*. The measurements were done using a hig precision coordinate measuring machine [5]. Four dimensional control parameters will b analysed: cross to cross distance on silicon sensors, precise pin coordinates, precise pi diameter, precise cut width and aluminium nitride plate orthogonality.

♦ *Wire bonding parameters*. Force, time and power of first and second bond, fo all types of bonding surfaces involved in a HL assemblig will be analysed. Wire bondin parameters values are those used for a wedge bonding machine [6].

2.1 Cross to cross distance analysis

During silicon-silicon assembling, alignment and gluing precision of the tw silicon sensors is crucial for obtaining SMD high performance, at least for the followin *geometrical reasons:*

♦ In order to realise, on the R-side, a true strip detection line, using strips o different sensors, a misalignment of the two sensors will increase the nonlinearity of HL strips, thus increasing particle position uncertainty.

♦ For the Z-side, cross to cross distance variation affects Z coordinate absolut value.

♦ The correlation between upper and lower cross to cross distance is a measure c sensors tilting. Considering sensors dimensions, we can estimate that 1μm differenc between upper cross to cross and lower cross to cross distances produce 1μm in Z an 3.5μm in R coordinate uncertainty.

In this section we will analyse the measured values of cross to cross distance during Si-Si assembling and their trend during HL assembling.

We have first calculated the difference with respect to the designed value of uppe (U) respectively lower (L) cross to cross distances, as measured on the Z-side, after Si-S alignment. It can be seen in figure 1 that experimental values are usually smaller than th designed ones. This is explained by the human tendency of the operator to approach a little bit more the sensors during gluing, in order to obtain a stronger stick. *The variatio range from the designed value is [-4μm, +2μm] and the average values are M*

0.2μm, M_L=-1.1μm for U respective L crosses. Thus $|M_U|<|M_L|$ and similar situations will be found in following.

The effect of thermal stress during Si-Si gluing thermal treatment is shown in figure 2 where the difference of cross to cross distance, measured before and after Si-Si gluing thermal treatment is presented. It can be seen that *glue thermal treatment increased the distance between crosses with an average value of M_U=+1.0μm respectively M_L=+3.2μm. Again* $|M_U|<|M_L|$. The alignment temperatures were about 22°C and the treatment temperature was always kept at 30°C. It can be expected that *lowering the treatment temperature will decrease the thermal deviation introduced but the drawback is the lowering of the Si-Si gluing strength.*

The variation tendency of cross to cross distance during assembling process will be analysed in following. All four U and L, Z- and R-sides distances are investigated.

Figure 3 presents, for the Z-side, the U cross to cross distance, as a difference from the designed value, at three manufacturing moments: after Si-Si gluing, before first side gluing and after first side gluing thermal treatment. The variation range for all HLs is *[-7μm, +4μm]* but for only one HL does not exceed *4μm*. This is a proof of reliable measurements and of absence of major failures appeared during assembling (like uncontrolled misalignment, glue cracks, etc.). We can also observe a *good zero approach (less than 1μm) of the average value: M_{ZU}=-0.1μm.*

The same parameter, but monitored for lower crosses, is shown in figure 4 after Si-Si gluing thermal treatment. Now the variation range *[-1μm,+6μm]* is more or less similar, but *the average value is less approached to zero and higher than the previous one: M_{ZL}=+2.3μm.*

Similar, for the R-side, the lower cross to cross distance, calculated as a difference from the designed value, is presented in figure 4, at two manufacturing moments: after Si-Si gluing and after second side gluing. The variation range is similar, *[-4μm,+9μm]* and *the average value is again less approached to zero: M_{RL}=+3.0μm.*

The last investigated distance (see figure 6, upper cross to cross distance) provides similar conclusions: *variation range [-5μm,+8μm] and average value well approached to zero: M_{RU}=-0.9μm.*

In brief, the cross to cross distance, as measured in the above four cases, leads to the *following conclusions:*

♦ There is an *increasing tendency* of cross to cross distance due to the glue thermal treatment during Si-Si gluing. The increasing average values, measured on the Z-side are M_U=+1.0μm and M_L=+3.2μm for U respectively L crosses.

♦ The *maximum variation range* from the designed values is *13μm* for all HLs manufactured and less than *4μm* for only one HL.

♦ *The upper cross to cross distance is well approached (less than 1μm difference) with respect to the designed value.* The difference average values are M_{ZU}=-0.1μm and M_{RU}=-0.9μm for the Z- respectively the R-sides.

♦ *For the lower cross to cross distance, the approaching is worst,* difference average values being M_{ZL}=+2.3μm and M_{RL}=+3.0μm for the Z- respectively the R-sides. This permanent relation $|M_U|<|M_L|$ *is explained* by the uncertainty in sensors positioning on gluing jigs, after manual removing for glue deposition. Two longitudinal pins and one transversal pin, edge centred, are used. The lower the distance between the lateral pin and the upper sensor edge, the lower the precision of sensor positioning will be. *Thus, it is necessary to place the lateral alignment pin as far as possible from the upper longitudinal silicon edge.*

2.2 Precise pin coordinates analysis

Like in the case of cross to cross distance, the precise pin position is also very important in metrology performances of the SMD. This is because all the assembled components of each HL are position controlled with respect to precise pin centre coordinates, because these ones are high precision coordinates on the SMD mechanical structure. Thus this parameter was carefully monitored, measuring 8 points on the pin edge and interpolating them with a circle. Both circle centre and diameter were calculated.

Precise pin centre coordinates difference from the designed values is reported in figures 7 and 8, at two manufacturing moments: before and after first side gluing. Analysing experimental data leads to the following conclusions:

♦ *Before first side gluing thermal treatment*, both X and Y coordinates are well centred around designed values, difference average value being M_X=-2.0μm respectively M_Y=+0.8μm.

♦ *After first side gluing thermal treatment*, both coordinates values are increasing, the difference average values reaching M_X=+9.9μm, M_Y=+8.9μm, thus an increase of +11.9μm respectively +8.1μm. The origin of this coordinates deviation is *the thermal expansion of the HL* during first side gluing. To lower this thermal deviation, some of *the following solutions will be used for future HL manufacturing:*

1. Make alignment and gluing at same temperatures.
2. Use a glue with zero volume change during hardening.
3. Compensate the thermal deviation during first side alignment procedure with a -11μm respectively -8μm imposed misalignment on X respectively Y coordinates.

2.3 Precise pin diameter and precise cut width analysis

During precise pin measurement procedure, the diameter of the precise pin is also calculated. If the HL has a moving termination, then the precise cut width is measured.

Considering the precise pin diameter, the differences between the measured and designed values are presented in figure 9 at two moments of the manufacturing process: before and after first side gluing. Despite variations between HLs, small differences are registered for the same HL. This is natural, since pin diameter does not change after a thermal treatment. Difference average values are $M'=-10.9\mu m$ before and $M''=-10.4\mu m$ after thermal treatment. *The pin diameter was measured with a circle interpolation precision of* $M_{CIRCLE}=5.0\mu m$

When the HL has a moving termination, the difference between measured and designed values of the precise cut width is presented in figure 10. Average values of $M'=+8.2\mu m$ before and $M''=+7.2\mu m$ after first side gluing thermal treatment are obtained, which confirm the lack of thermal deviation.

2.4 Aluminium nitride plate orthogonality analysis

This parameter is measuring the tilt of the electronic subunit with respect to the Si-Si sensors subunit. In figures 11 and 12 we present orthogonality measured values, in seconds respectively microns, at three manufacturing moments: before first side gluing, after first side gluing and after second side gluing. At this three moments, *the average value increases from -17.5sec (-2.7μm) to +16.2sec (+2.4μm) and then decrease to +1.4sec (+1.7μm).* This is a quite small fluctuation of the average value. Yet a large variation range of *[-74sec, +86sec]* or *[-12μm, +15μm]* was observed for row data, which suggests *a less controlling of this parameter. This is explained* by the dimensional variation of both quartz thermal breaker and middle plate aluminium nitride peaces, together with a less control of their relative alignment. Anyhow, this orthogonality error does not affect HL tracking performances.

2.5 Wire bonding parameters analysis

Design considerations of SMD impose restrictions on wire bonding process, related to small pad dimensions (50μm width), small distance between wires (50μm), wire placement on two overlapped rows, small wire loop heights and bonding on different surface types, placed at different heights and distances. All these problems make the wire bonding process a critical one in HLs manufacturing technology.

Wire bonding for HLs manufacturing involves *five categories* of wire interconnections: capacitor chips to SVX chips, silicon sensors to kapton strips, kapton strips to capacitor chips, silicon sensor to silicon sensor, silicon sensor to capacitors. The force (F1, F2), time (T1, T2) and power (P1, P2) values used on first and second bond, expressed in the relative units of our wedge bonding machine [6], are presented in figures 13-18 for each type of bonding surface involved. These values represent the average values used during wire bonding which assure a good quality of the bond.

The analysis of wire bonding experimental data leads to the *following conclusions:*

♦ *Bonding surfaces are of relatively good quality.* This is sustained by the small variation range of force, time and power on all three surface types investigated.

♦ *In few cases bonding operation was difficult* (HLs #1 and #5 from figures 14 and 17), with many reworked wires and *using extreme values* for bonding parameters: power at high level and time practically set to zero. This was an indication of poor surface quality.

♦ *A relative small correlation in bonding parameters values can be noted*: the increasing (decreasing) of ultrasound power is accompanied by the decreasing (increasing) of bonding time. Similar, the increasing (decreasing) of bonding force is related to increasing (decreasing) of bonding time These correlations are important in practice, for bonding parameter optimisation.

3. Conclusions

We have discussed the main control parameters values of the manufacturing process for ten half ladders (HL) constructed at the clean room assembly facility of INFN and University of Perugia. The principal conclusions derived from this analysis are the followings:

♦ *There is an increasing tendency* of cross to cross distance on silicon sensors after Si-Si gluing thermal treatment. The average increase measured on Z-side is $M_U=+1.0\mu m$ and $M_L=+3.2\mu m$ for upper respectively lower crosses.

♦ *The variation range* from the designed values of the cross to cross distances is *less than 13μm* for all ten HLs investigated. For only one HL, the variation range is *only 4μm*.

♦ *For the upper crosses, there is a good zero approaching (less than 1μm difference) with respect to the designed value* of the measured cross to cross distance. The average of difference observed was $M_{ZU}=-0.1\mu m$, $M_{RU}=-0.9\mu m$.

♦ *For the lower crosses, there is a less zero approaching* of the measured cross to cross distance with respect to the designed value. The average of difference observed was $M_{ZL}=+2.3\mu m$, $M_{RL}=+3.0\mu m$. To improve it, *a modification of the alignment pin position on Si-Si gluing jig was proposed.*

♦ *The thermal deviation of the precise pin coordinates* was found to be in average $+11.9\mu m$ and $+8.1\mu m$ for X respectively Y coordinates. *Three methods were proposed to decrease this thermal deviation.*

♦ It was found that *the precise pin diameter* was measured with a circle interpolation precision of $M_{CIRCLE}=5.0\mu m$.

♦ *Orthogonality error of aluminium nitride plate* has a quite small fluctuation of the average value. Yet a relative large variation range was observed for row data, which suggests a *less control* of this parameter. Anyhow, this orthogonality error does not affect HL tracking performances.

♦ Wire bonding parameters analysis pointed out a *relative constant and good quality of bonding surfaces*. In some cases, on poor quality surfaces, it was possible to make wire bonding only using *extreme values* of bonding parameters.

♦ *A relative small correlation in bonding parameters values* was noted which is important in practical applications and for bonding parameter optimisation.

4. Acknowledgements

We wish to express our gratitude to all the technicians of Perugia clean room facility for their work during the half ladders assembly. This work is partly supported by the Swiss National Foundation for Scientific Research, by the Italian Institute for Nuclear Physics, by the German Bundesministerium fur Forshung and Technologie, by the Taiwanese National Science Foundation and by the U.S. Department of Energy under grant DE-FG05-84ER40141.

4. References

1. B. Adeva et.al., Nucl. Instr. and Meth., A289, (1990), 35-102.
2. M. Acciarri et. al., CERN-PPE/94-122, July 27, 1994.
3. O. Adriani et.al., Nucl. Phys. (Proc. Suppl.), B32, (1993), 202-207.
4. B. Aplat et.al., Nucl. Instr. and Meth., A315, (1992), 192-200.
5. BHN 506 Coordinate Measuring Machine, Mitutoyo Corporation 31-19, Shiba 5-chome, Minato-ku, Tokyo 108, Japan.
6. Model 4123, Kulicke and Soffa Industries, Inc. 507, Prudential Road, Horsham, PA 19044, USA.

Figure 1. Upper and lower cross to cross distances, as a difference from the designed values, measured before Si-Si gluing thermal treatment (Z side)

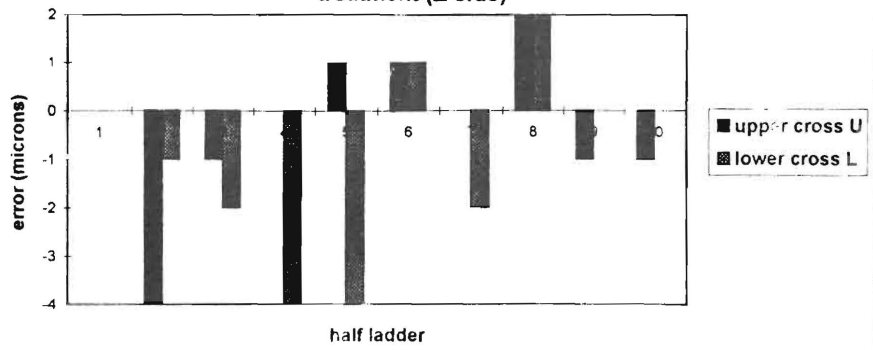

Figure 2. Upper and lower cross to cross distance differences, measured before and after Si-Si gluing thermal treatment (Z side)

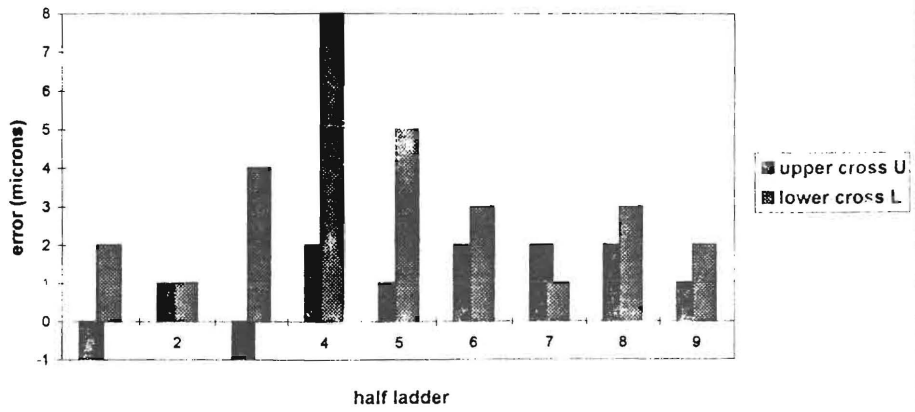

Figure 3. Upper cross to cross distances as a difference from the designed values, at different half ladder manufacturing moments (Z-side)

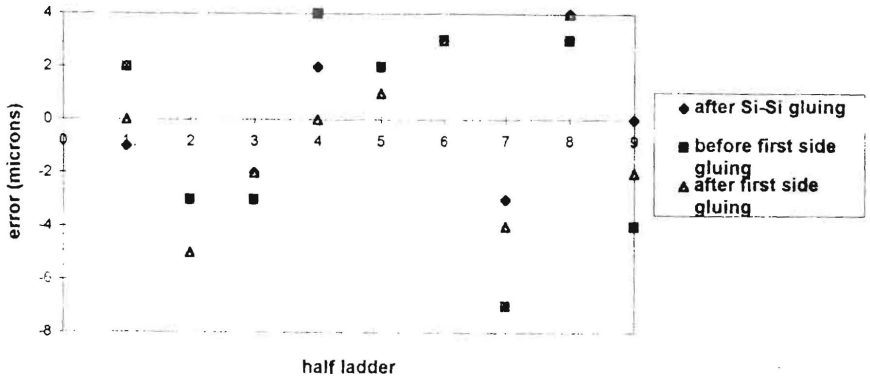

Figure 4. Lower cross to cross distances, as a difference from the designed values, after first side gluing (Z-side)

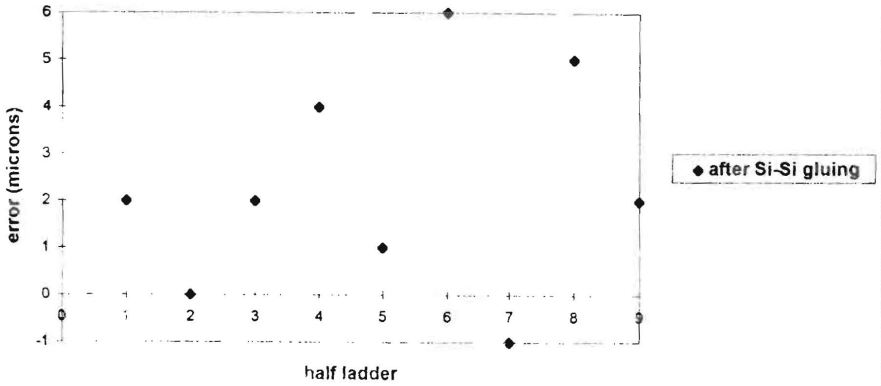

Figure 5. Lower cross to cross distances, as a difference from the designed values, at different half ladder manufacturing moments (R-side)

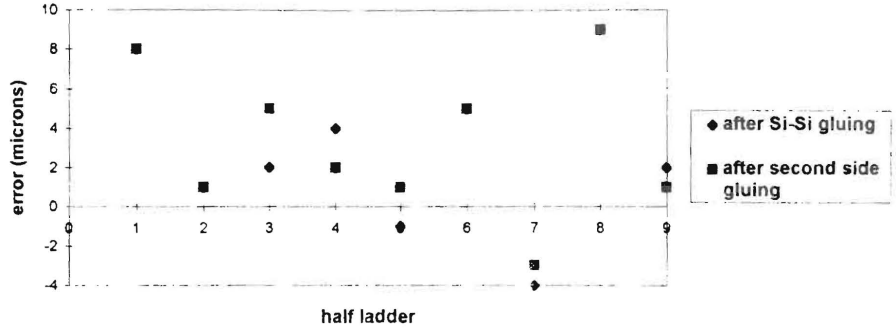

Figure 6. Upper cross to cross distances, as a difference from the designed values, after Si-Si gluing thermal treatment (R-side)

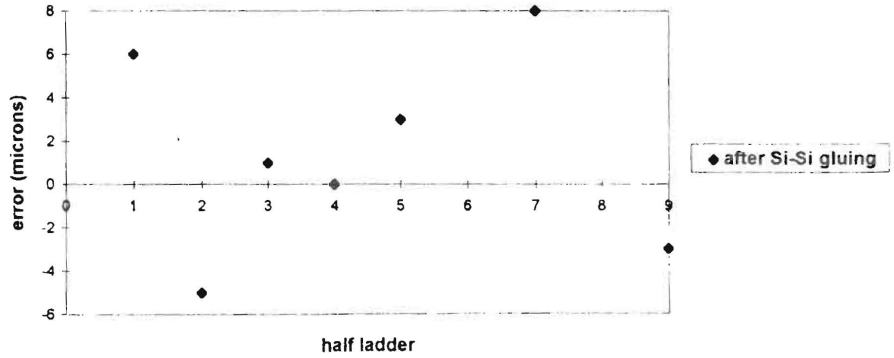

Figure 7. Precise pin X coordinates, as a difference from the designed values, at different half ladder manufacturing moments

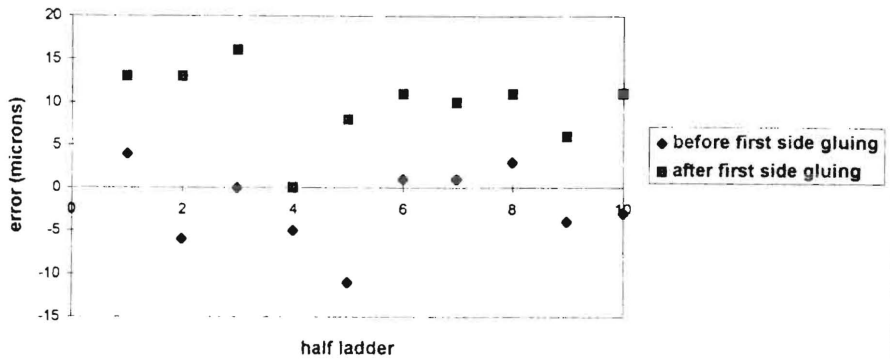

Figure 8. Precise pin Y coordinates, as a difference from the designed values, at different half ladder manufacturing moments

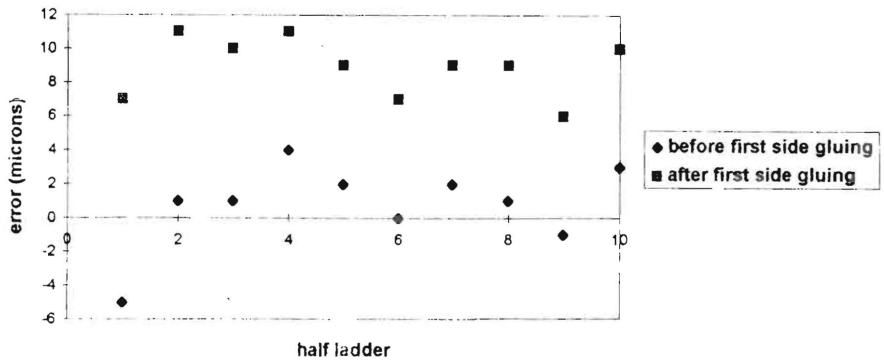

Figure 9. Precise pin diameter, as a difference from the designed value, at different half ladder manufacturing moments

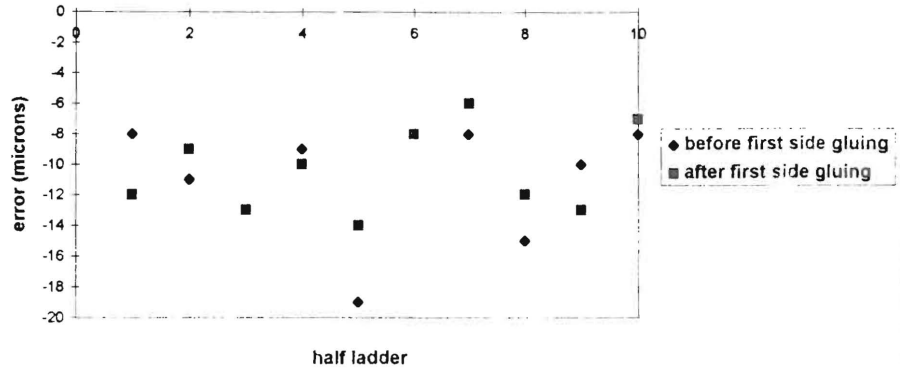

Figure 10. Precise cut width, as a difference from the designed value, at differrent half ladder manufacturing moments

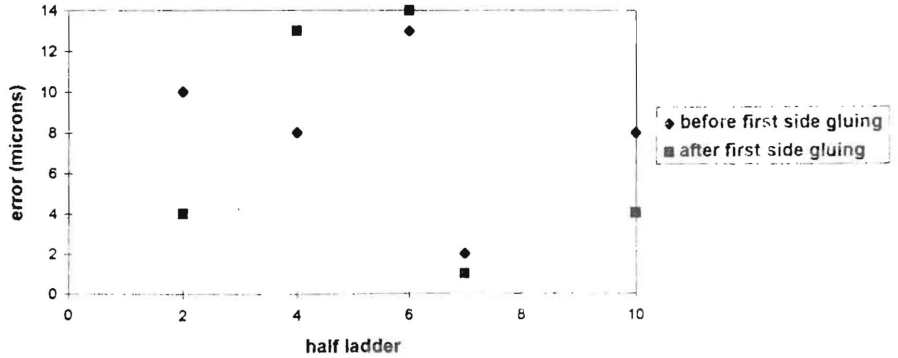

Figure 11. Aluminium nitride plate orthogonality, measured in seconds, at different half ladder manufacturing moments

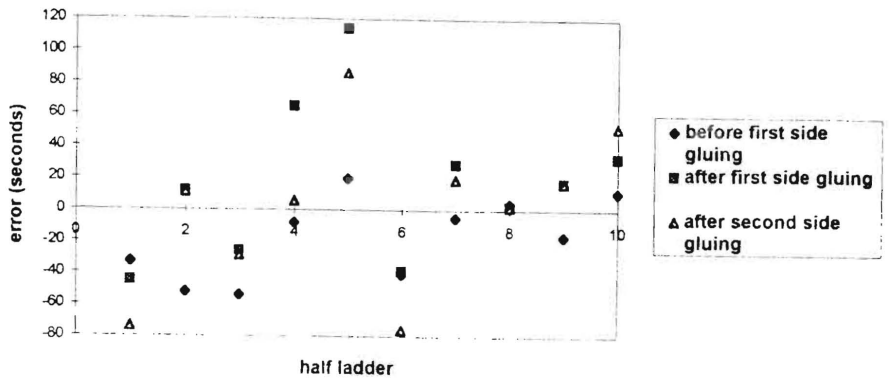

Figure 12. Aluminium nitride plate orthogonality, measured in microns, at different half ladder manufacturing moments

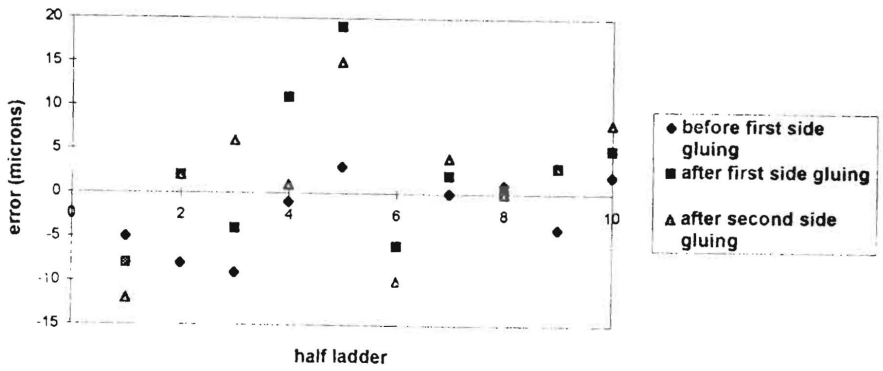

Figure 13. Wire bonding parameters for first bond on capacitors chips

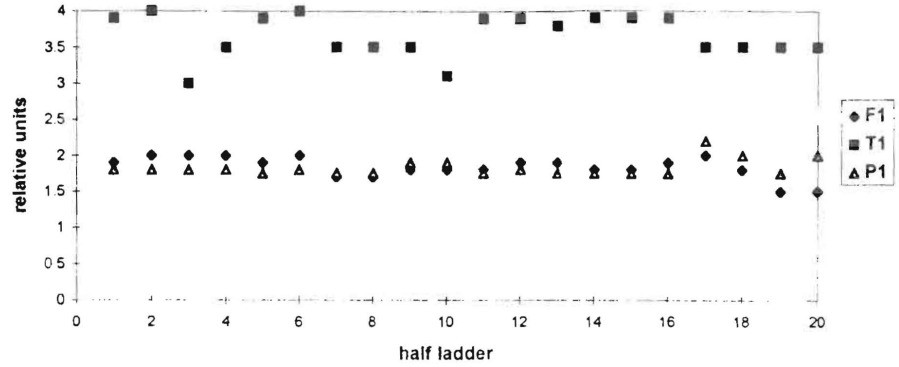

Figure 14. Wire bonding parameters for second bond on capacitors chips

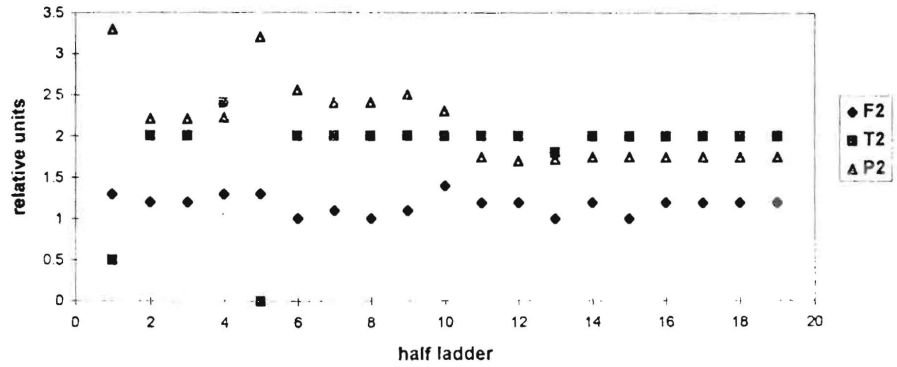

Figure 15. Wire bonding parameters for first bond on silicon sensors

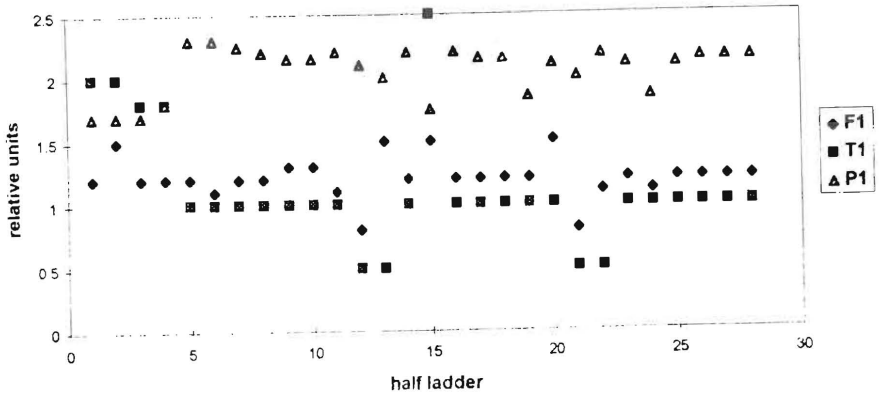

Figure 16. Wire bonding parameters for second bond on silicon sensors

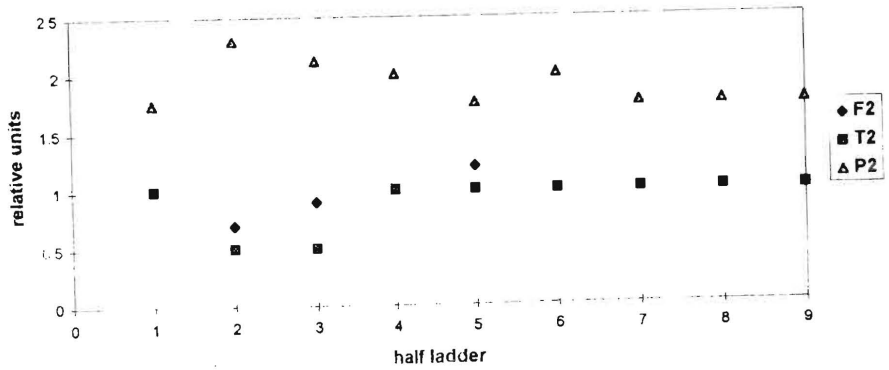

Figure 17. Wire bonding parameters for first bond on kapton strips

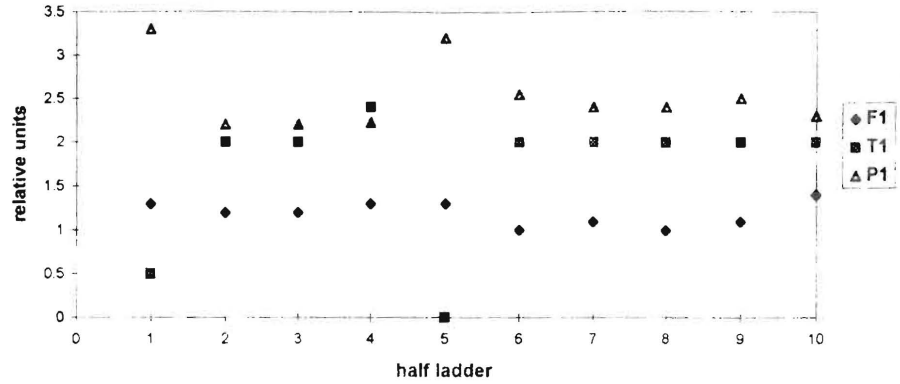
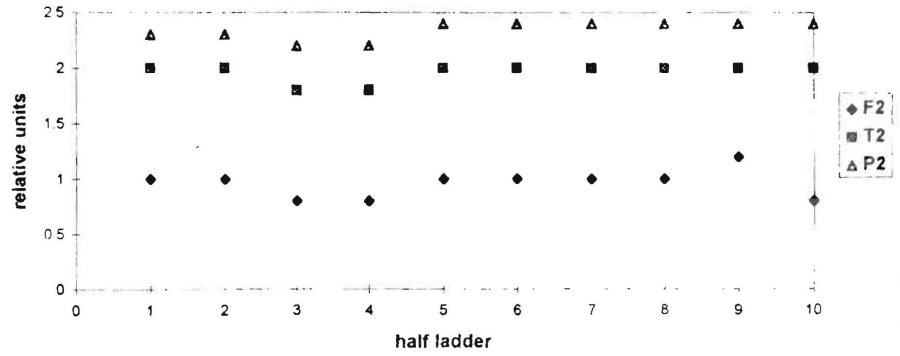
Figure 18. Wire bonding parameters for second bond on kapton strips