Optimisation of wirebonding for ATLAS detectors.

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Technical Report

Optimisation of wirebonding for ATLAS detectors.

Abstract

It has been observed that there have been failures of detectors that may be attributed to the wirebonding of these detectors either as modules or as detectors to ceramics for irradiation tests. Failure is shown as low current (100nA @ 450V) good detectors drawing much high current (several mA @ tens of volts) after assembly and wirebonding. A reduction in initial bond head weight is proposed which imposes lower bonding forces and results in smaller bond footprints, whilst retaining good pull strengths.

Prepared by:	*Checked by:*	*Approved by:*
JPB		

Distribution List

History of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*

Table of Contents

INSERT TABLE OF CONTENTS

Optimisation of wirebonding for ATLAS detectors.

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Aim.

This work is an attempt to establish whether it is feasible to lower the bond forces on the K&S 1470 in order to remove overbonding as a possible source of high current failure on ATLAS detectors.

General observations.

Wedge bonding has in the past produced bond foot displacement widths of 1.5 to 2.0 times wire diameter and a bond foot length of 1.5 times wire diameter. A displacement width of 1.2 to 1.7 times wire diameter is now accepted given the fine pitch wire bonding currently performed in industry, provided that the wire pull strength is adequate for the application.

The introduction of higher frequency ultrasonic generators for wirebonding machines enables devices to be subjected to lower bond head weight parameters. One of the differences that exists within the SCT module assembly sites is that some wirebonding vendors use 120 kHz ultrasonic system machines which have a bond head weight of 20 to 25 gram for 25um wire. This is compared to other establishments using say K&S 1470, 60 kHz ultrasonic system machines having a bond head weight of 25 to 35 grams for 25 um wire.

The bonding parameters of time, force and power are the main contributors to the size of the foot displacement. On the K&S 1470 the force is not only the initial bond head weight (controlled by adjusting the bond head spring pressure) but also the accelerating forces of the bond head prior to applying ultrasonic power during the bonding operation. The Z axis overtravel (additional Z pulses applied after the device bonding surface has been detected) is set in machine counts of 12.5um per pulse. The rate of controlled acceleration (after tool inflection point) is set in machine counts and controls the rate of acceleration approaching bonding surface.

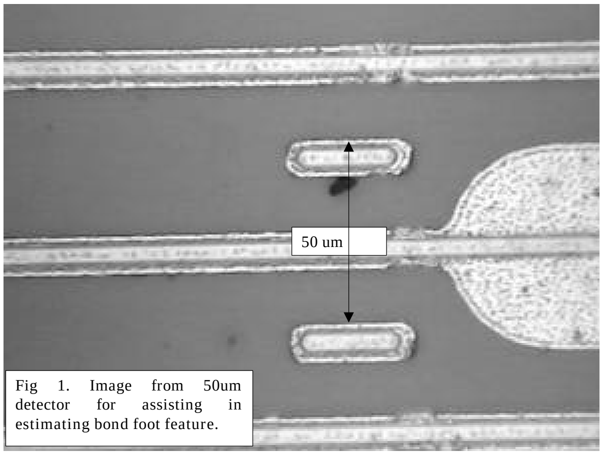


Fig 1. Image from 50um detector for assisting in estimating bond foot feature.

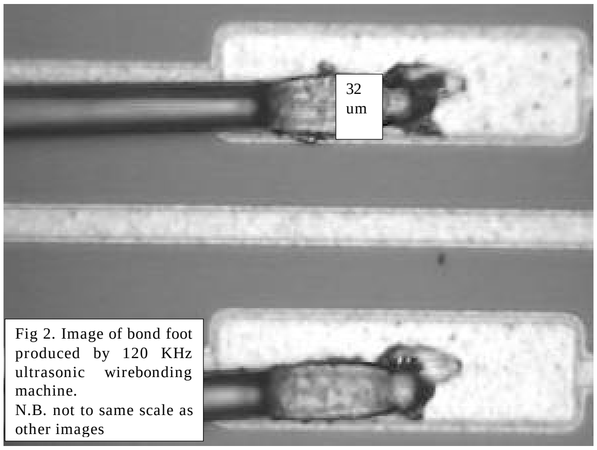


Fig 2. Image of bond foot produced by 120 KHz ultrasonic wirebonding machine.
N.B. not to same scale as other images

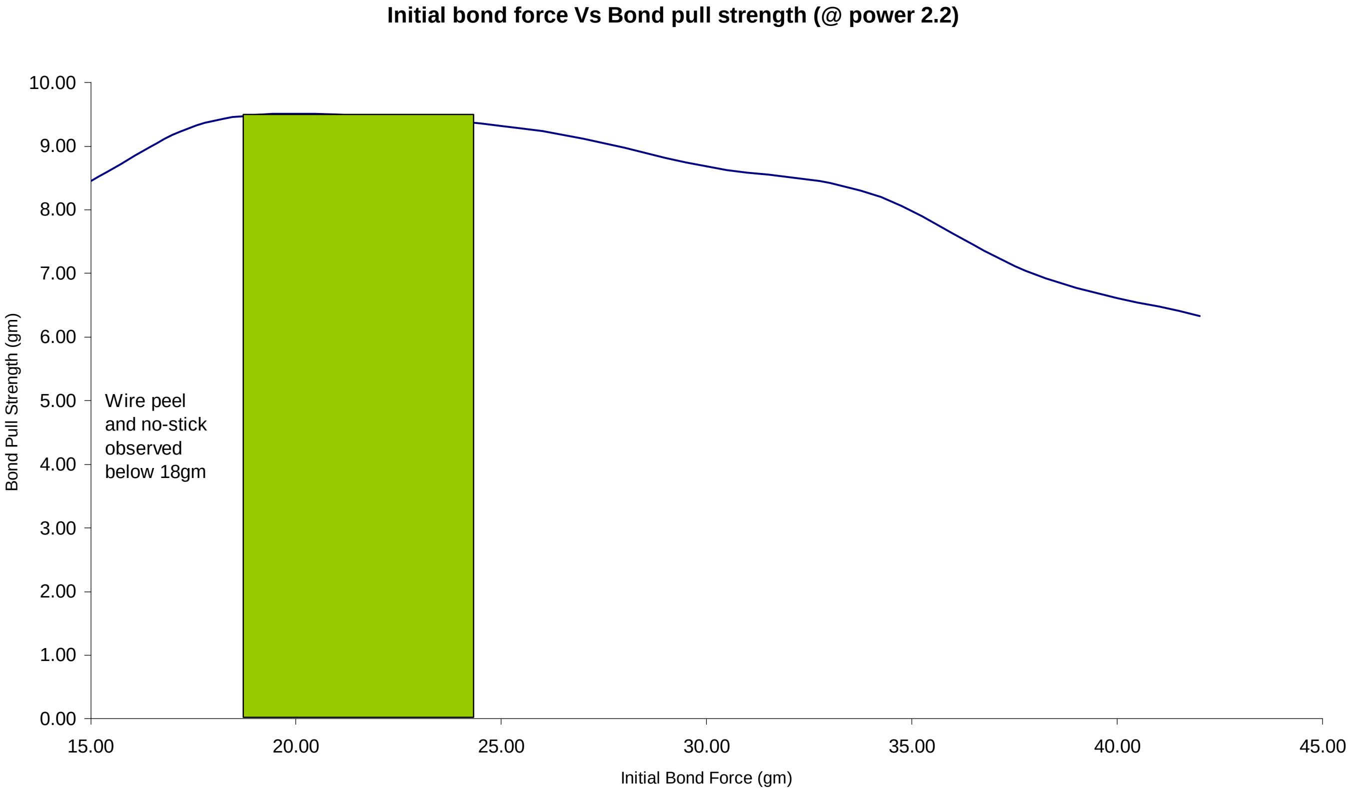
Results.

Using standard ESL ceramic tiles with 8881-B Au paste and Micro-Swiss fine pitch wedge type 40440-1350-169, bond foot profiles were visually inspected and measured to establish the effect on the profile when varying certain programmable parameters of the bonding machine.

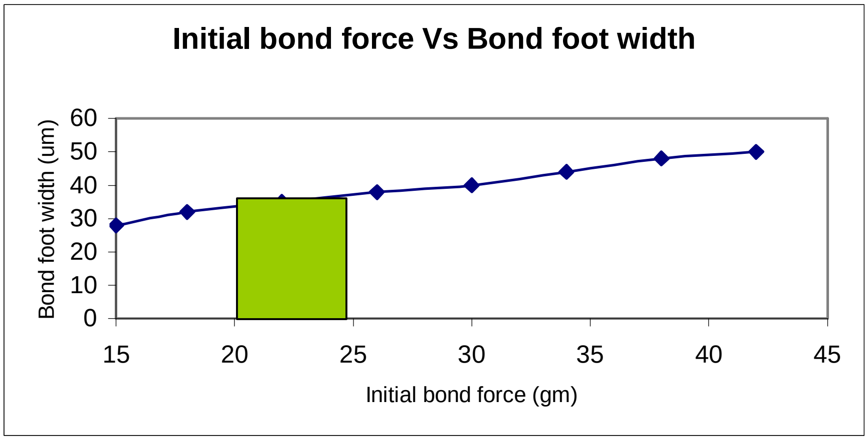
Effect of Initial Bond Force.

A range of initial bond force settings was attempted with 15 gram being the lowest reproducible weight, and 42 gram highest. Foot widths were measured and bond pull tests performed for each of the force settings.

IBF	*15*	*18*	*22*	*26*	*30*	*34*	*38*	*42*
Pull strength Average	*8.45*	*9.4*	*9.47*	*9.23*	*8.68*	*8.25*	*6.98*	*6.33*
Sigma	*0.52*	*0.31*	*0.28*	*0.43*	*0.54*	*0.42*	*0.65*	*0.63*



IBF	*Foot width*
15	*28*
18	*32*
22	*35*
26	*38*
30	*40*
34	*44*
38	*48*
42	*50*



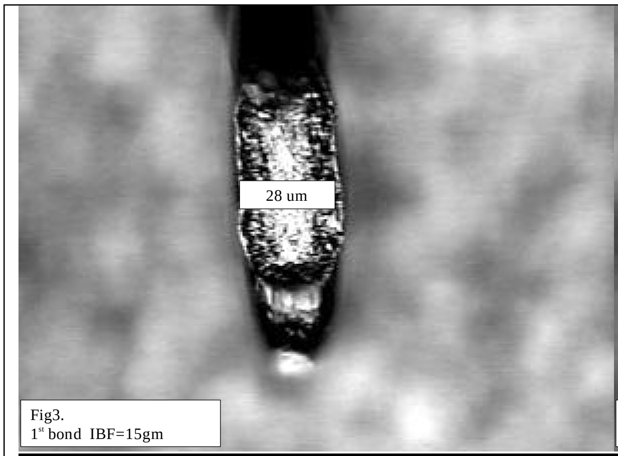


Fig3.
1st bond IBF=15gm

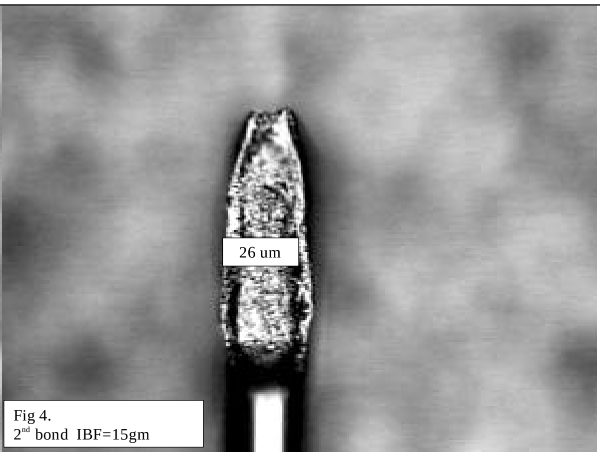


Fig 4.
2nd bond IBF=15gm

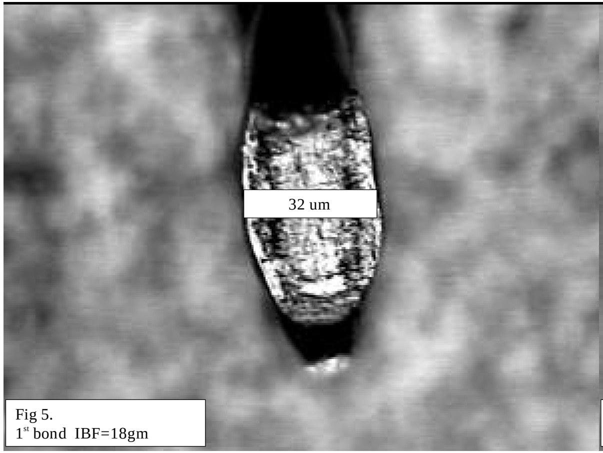


Fig 5.
1st bond IBF=18gm

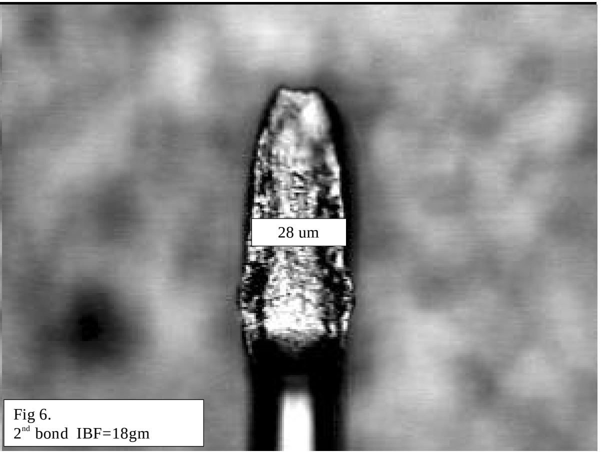


Fig 6.
2nd bond IBF=18gm

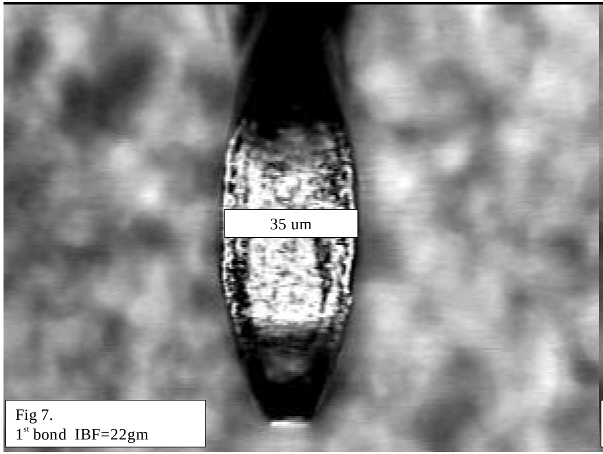


Fig 7.
1st bond IBF=22gm

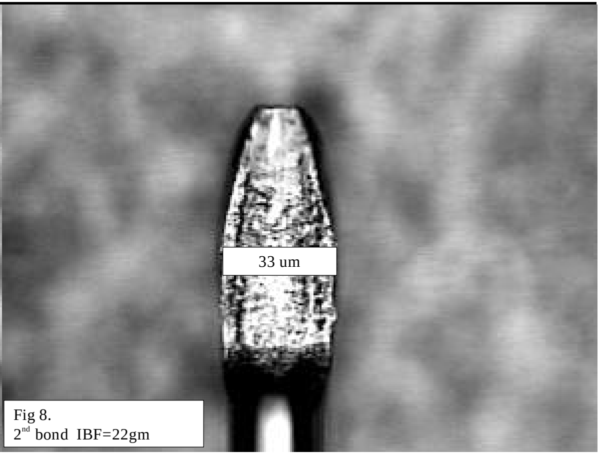


Fig 8.
2nd bond IBF=22gm

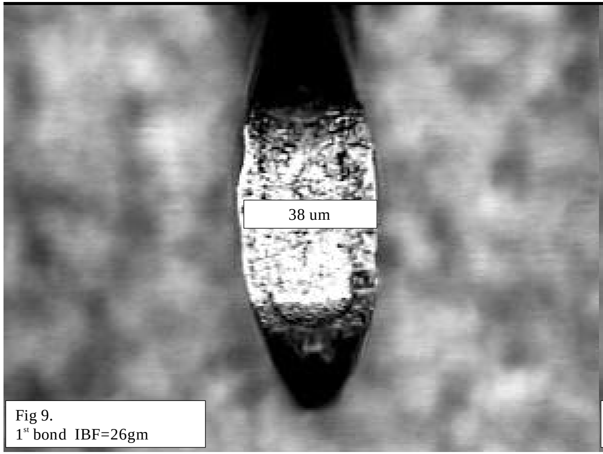


Fig 9.
1st bond IBF=26gm

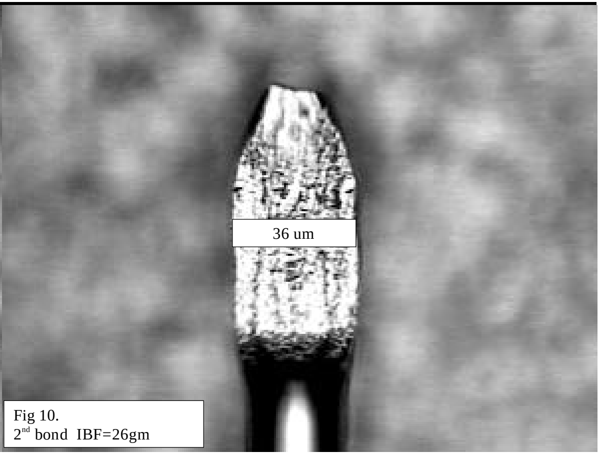


Fig 10.
2nd bond IBF=26gm

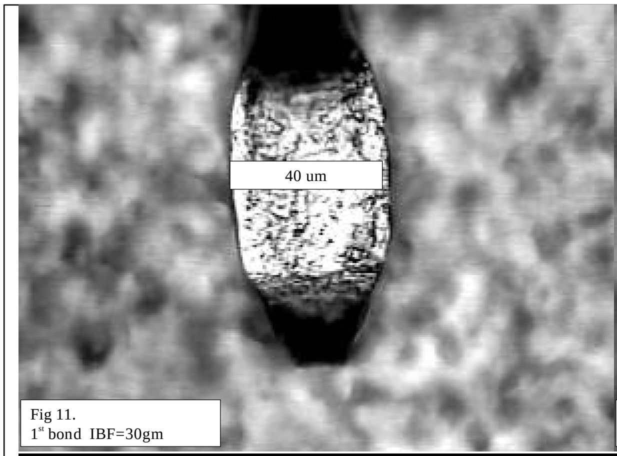


Fig 11.
1st bond IBF=30gm

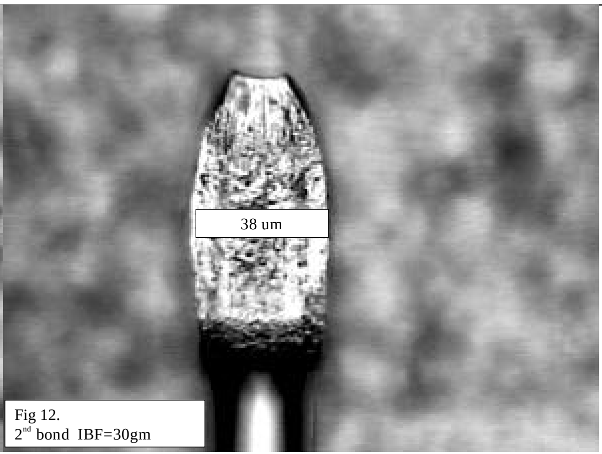


Fig 12.
2nd bond IBF=30gm

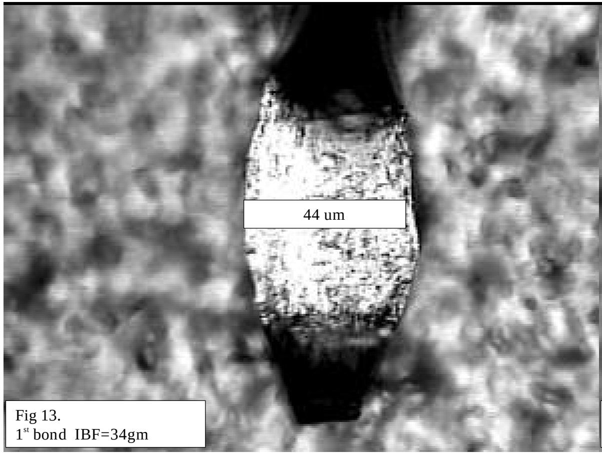


Fig 13.
1st bond IBF=34gm

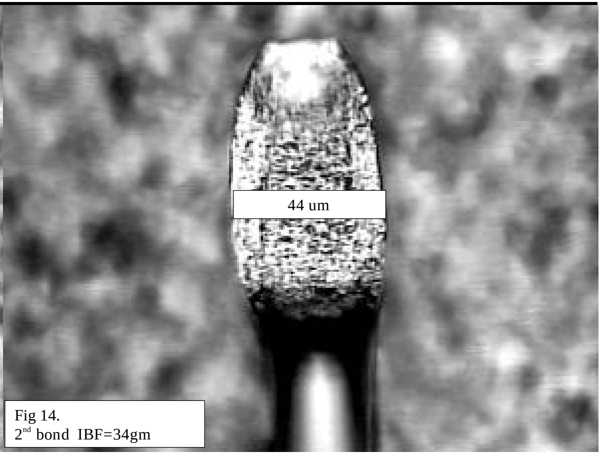


Fig 14.
2nd bond IBF=34gm

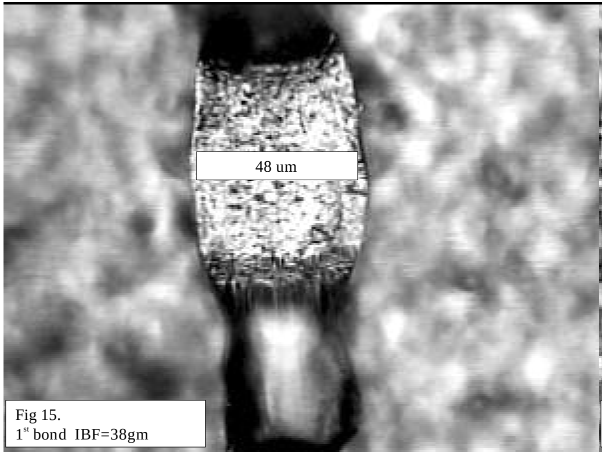


Fig 15.
1st bond IBF=38gm

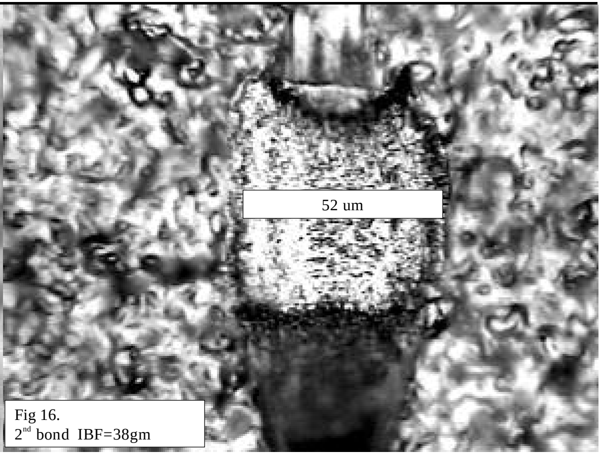
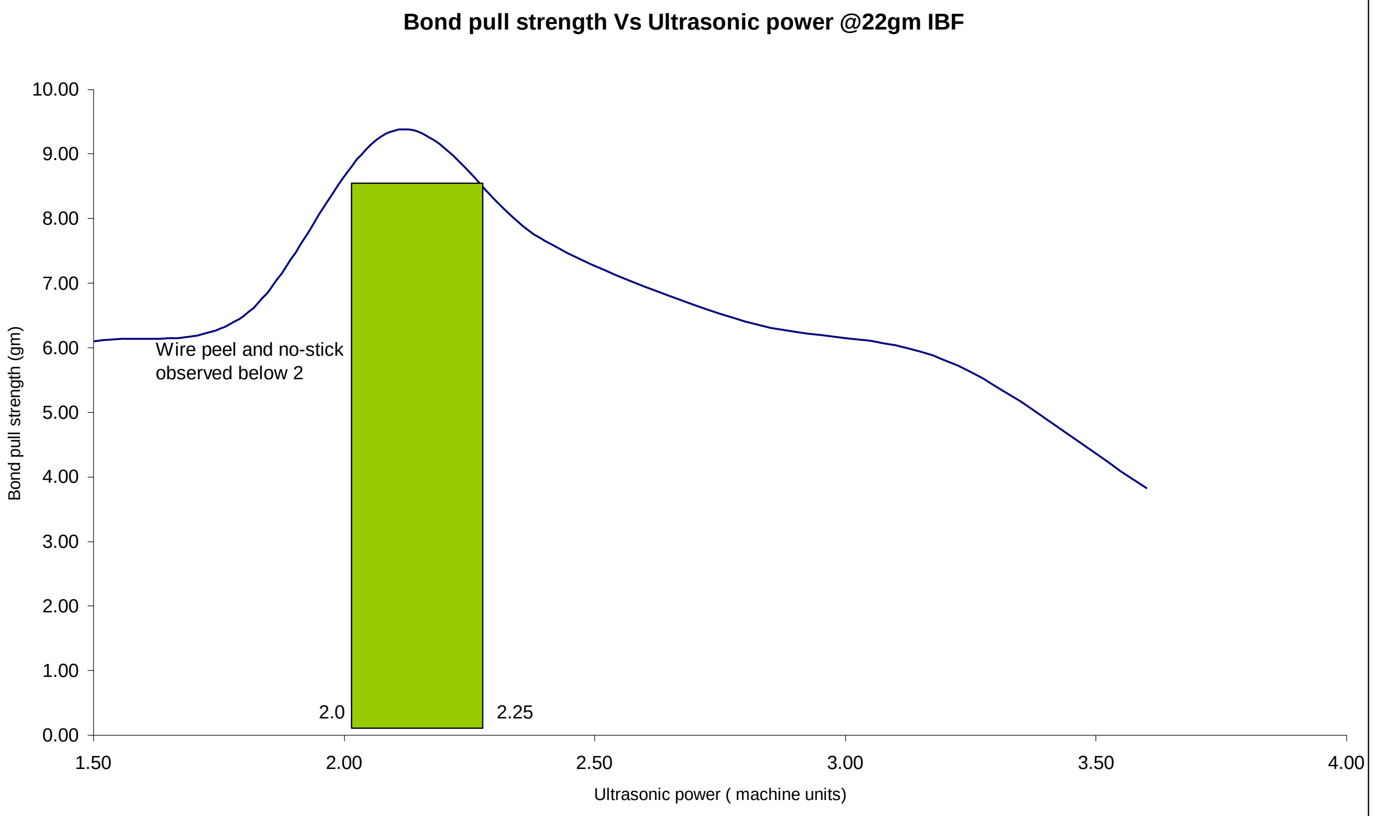


Fig 16.
2nd bond IBF=38gm

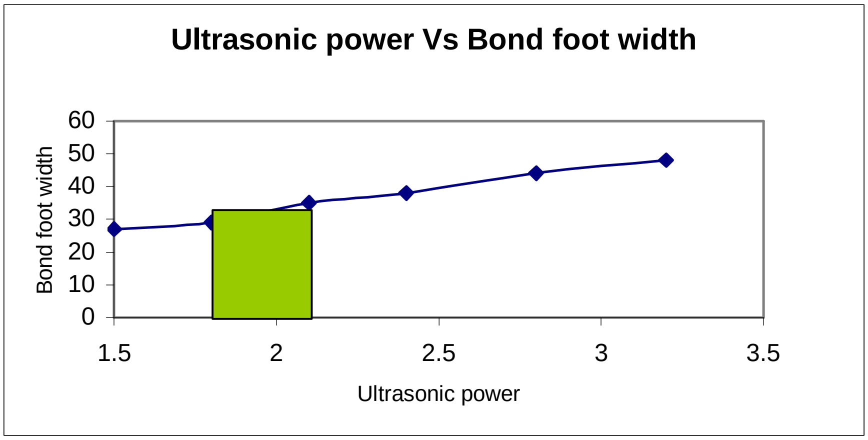
Effect of Ultrasonic power.

Bond foot widths and pull strengths were measured for a range of applied ultrasonic power.

Ultrasonic power	*1.5*	*1.8*	*2.1*	*2.4*	*2.8*	*3.2*	*3.6*
Pull strength Average	*6.1*	*6.5*	*9.37*	*7.65*	*6.41*	*5.81*	*3.83*
Sigma	*1.45*	*1.34*	*0.4*	*0.34*	*0.62*	*0.46*	*0.76*



Ultrasonic power	*Foot width*
1.5	*27*
1.8	*29*
2.1	*35*
2.4	*38*
2.8	*44*
3.2	*48*



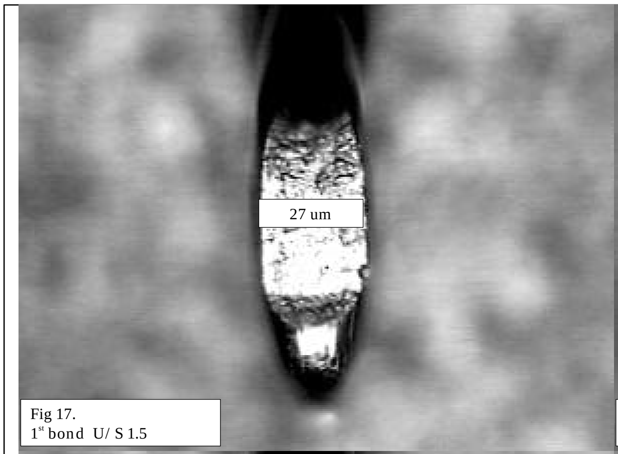


Fig 17.
1st bond U/ S 1.5

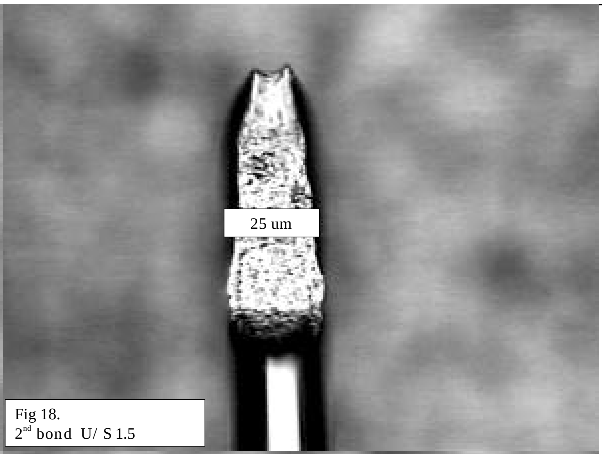


Fig 18.
2nd bond U/ S 1.5

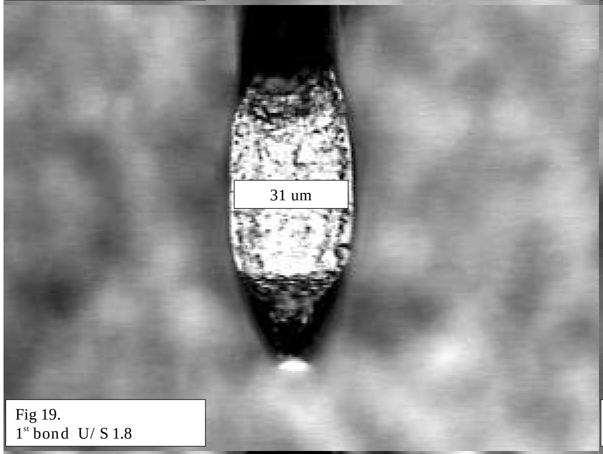


Fig 19.
1st bond U/ S 1.8

Fig 20.
2nd bond U/ S 1.8

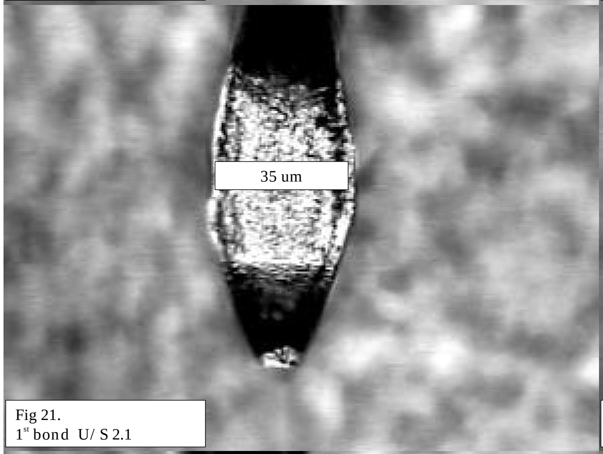


Fig 21.
1st bond U/ S 2.1

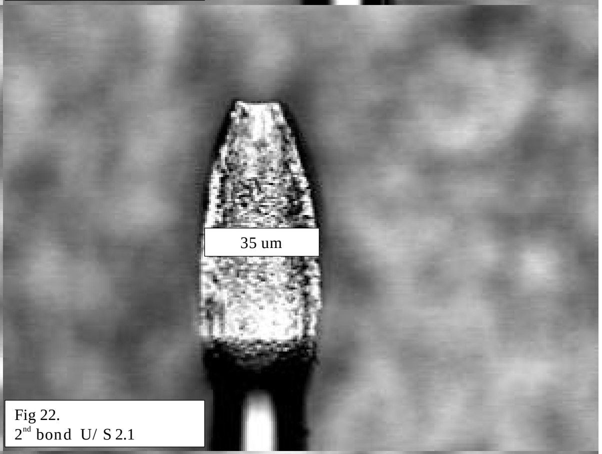


Fig 22.
2nd bond U/ S 2.1

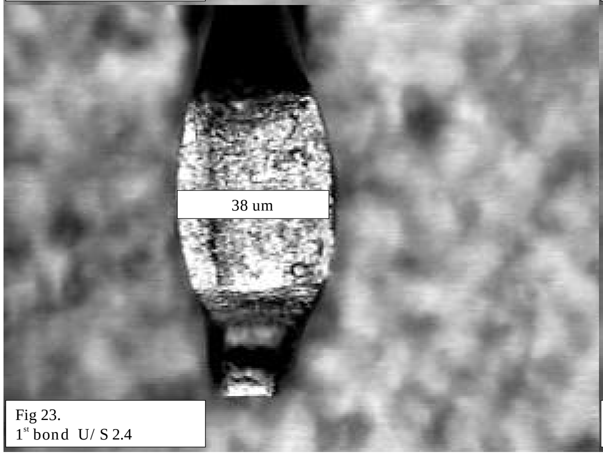


Fig 23.
1st bond U/ S 2.4

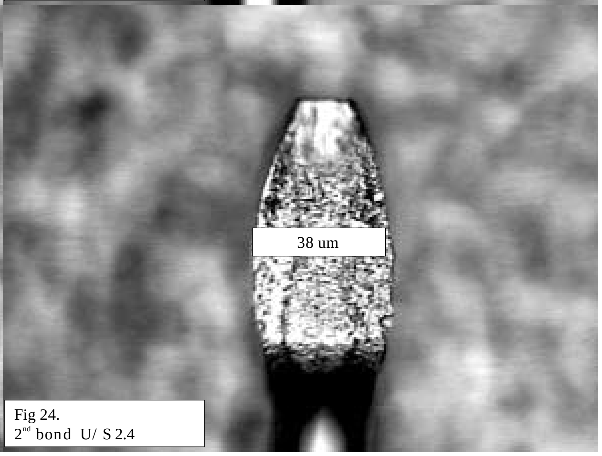


Fig 24.
2nd bond U/ S 2.4

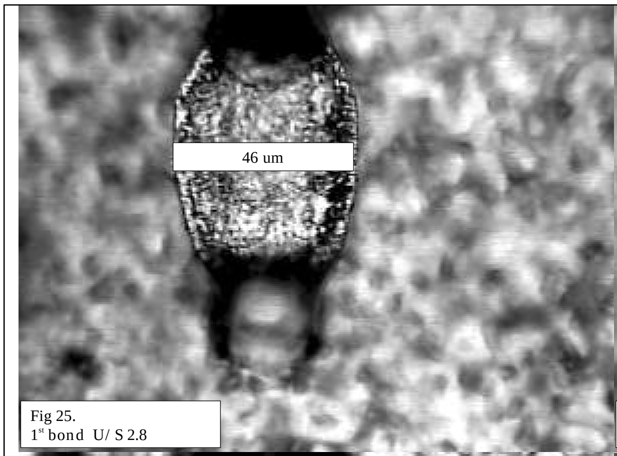


Fig 25.
1st bond U/ S 2.8

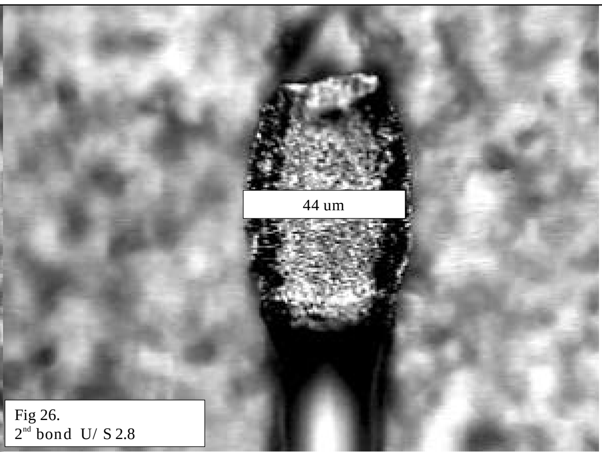


Fig 26.
2nd bond U/ S 2.8

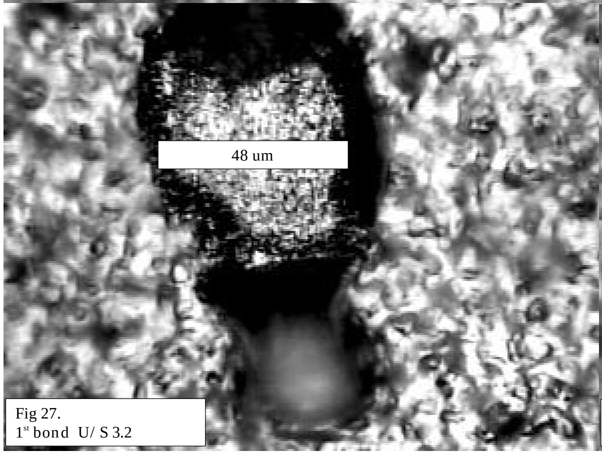


Fig 27.
1st bond U/ S 3.2

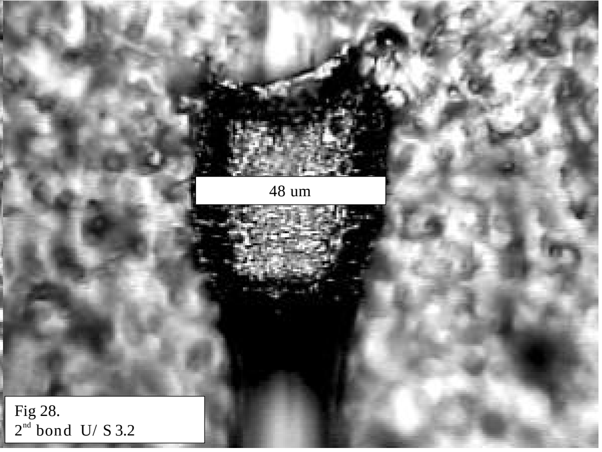


Fig 28.
2nd bond U/ S 3.2

Effect of Z overtravel (OTV)

By setting the initial bond head weight to 22 gram and Ultrasonic power to 2.1, it was possible to observe that Z overtravel had no effect on the width of the bond foot. Below OTV=2, there was evidence of unsuccessful bonding due to the wedge not making good contact with the bonding surface. The machine default of OTV=5 was selected.

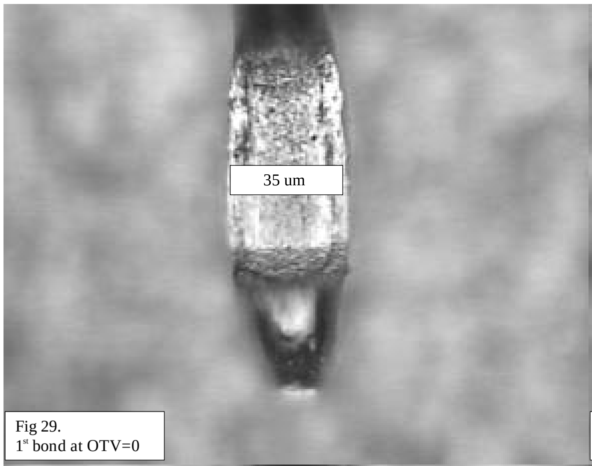


Fig 29.
1st bond at OTV=0

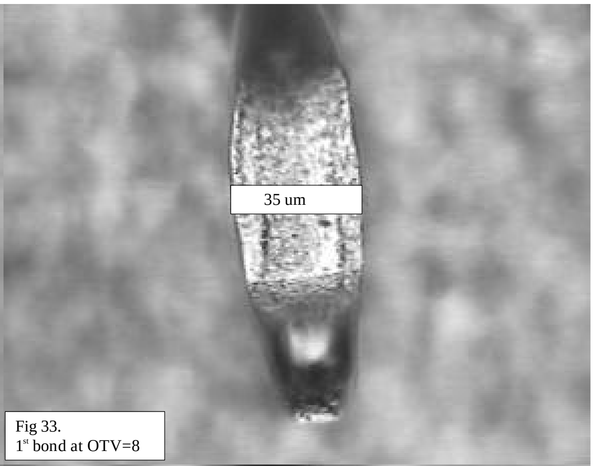


Fig 33.
1st bond at OTV=8

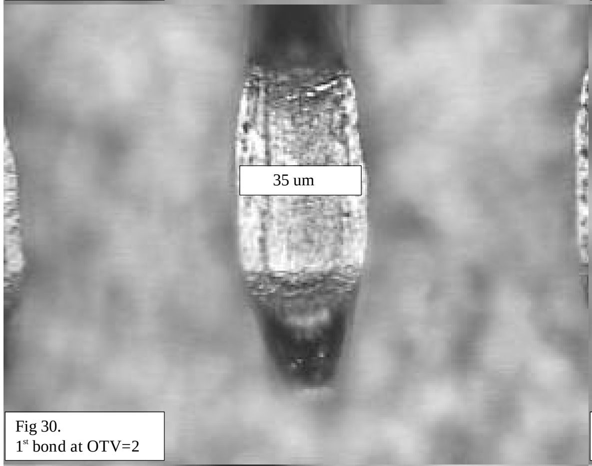


Fig 30.
1st bond at OTV=2

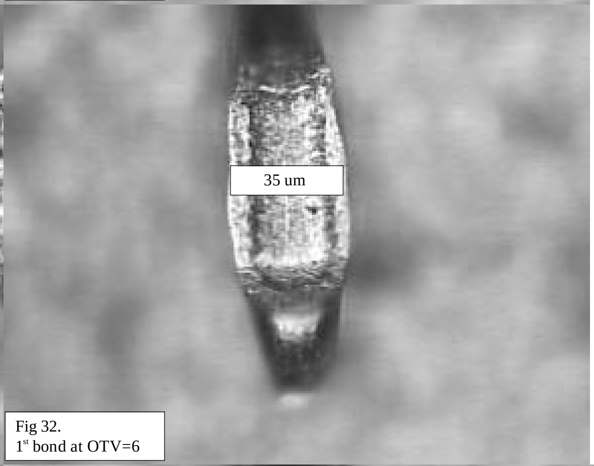


Fig 32.
1st bond at OTV=6

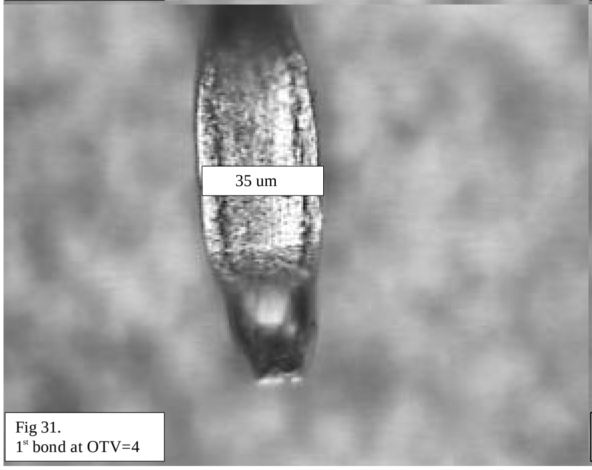


Fig 31.
1st bond at OTV=4

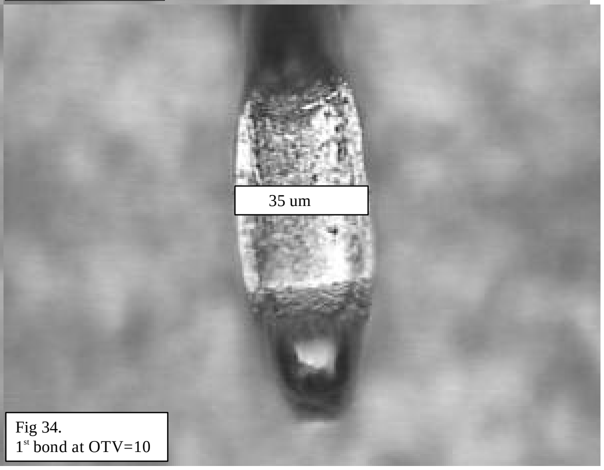


Fig 34.
1st bond at OTV=10

Effect of Tool Impact Point (TIP).

By setting the initial bond head weight to 22 gram and Ultrasonic power to 2.1, it was possible to observe that the Tool Impact Point (TIP) had no effect on the width of the bond foot but bond quality, by visual inspection and pull strength, was affected. From these observations a first bond TIP of 20 was selected (2nd bond was chosen to be 30).

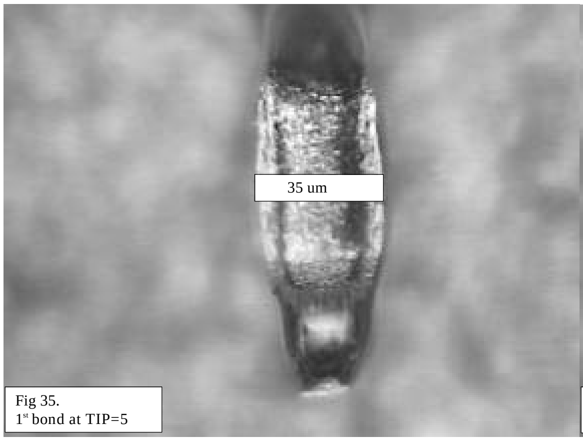


Fig 35.
1st bond at TIP=5

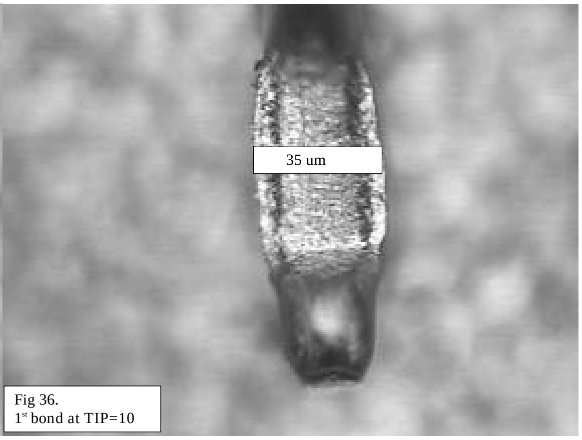


Fig 36.
1st bond at TIP=10

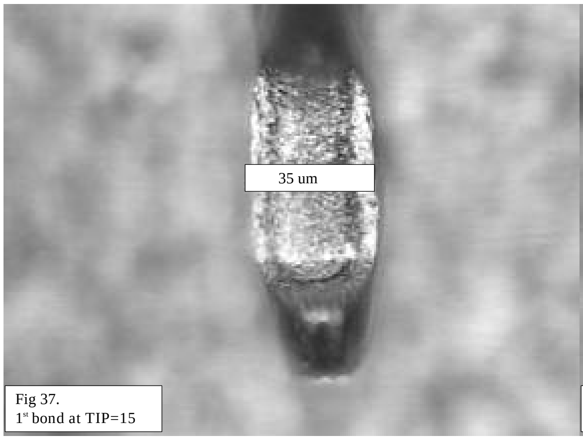


Fig 37.
1st bond at TIP=15

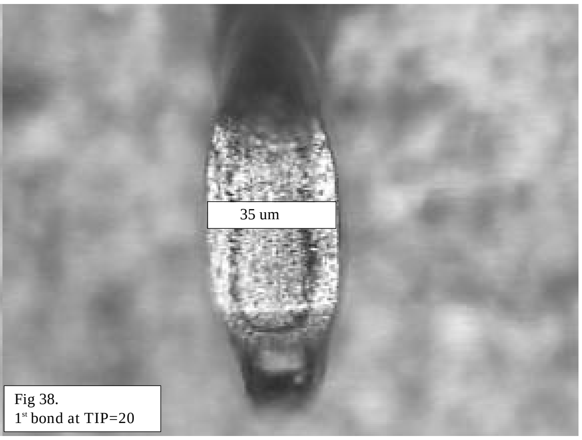


Fig 38.
1st bond at TIP=20

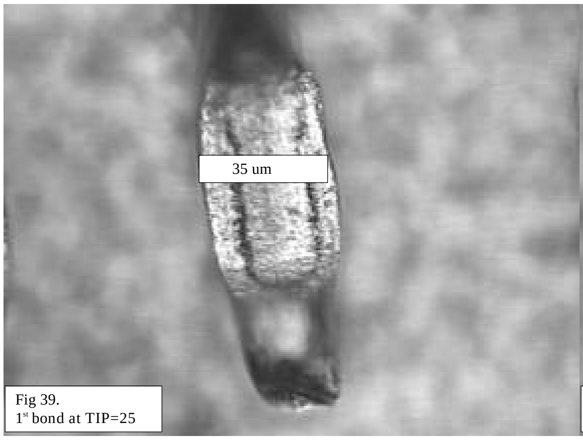


Fig 39.
1st bond at TIP=25

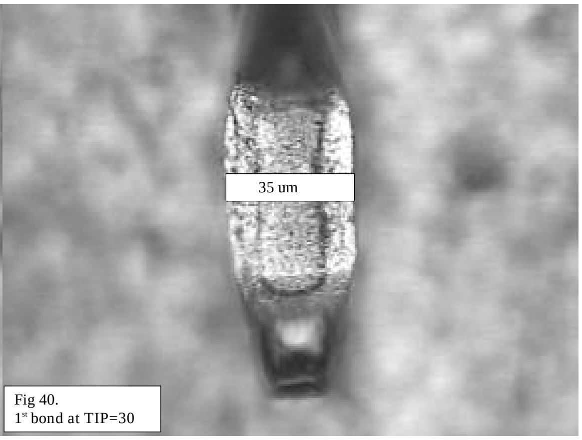


Fig 40.
1st bond at TIP=30

The two images below are what were judged to be the best bond foot profiles for a variation of the two parameters OTV and TIP.

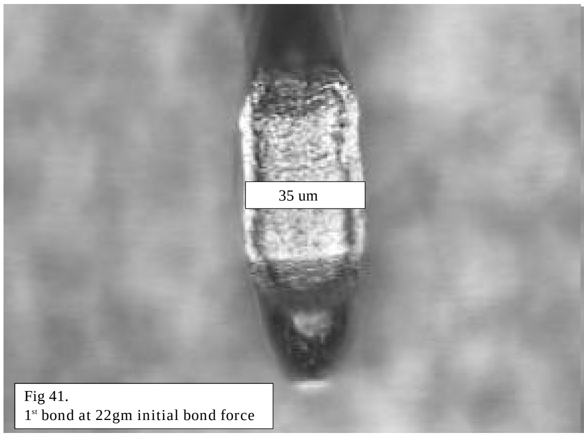


Fig 41.
1st bond at 22gm initial bond force

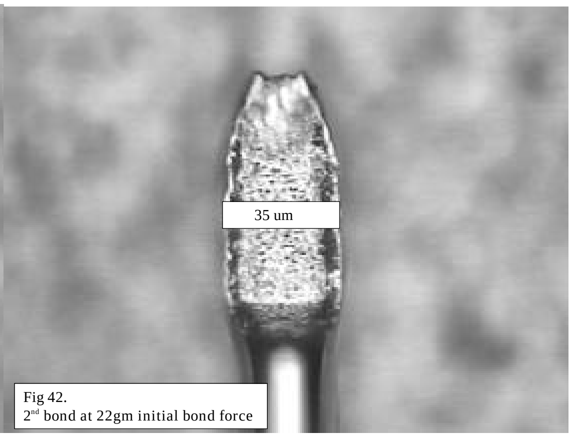


Fig 42.
2nd bond at 22gm initial bond force

These profiles show a bond foot width of approx. 35um with no signs of heel crack.

Machine parameters….

Weight 22 gram   Power=2.1   OTV=5 TIP=20,30

54 wires, per pad location on bonding tile, were taught and below are images of bond foot profiles during automatic bonding of a total of 432 wires. Wire pull tests on part of this group of 54 wires return a MEAN of 9.96 gram with a STDEV of 0.29.

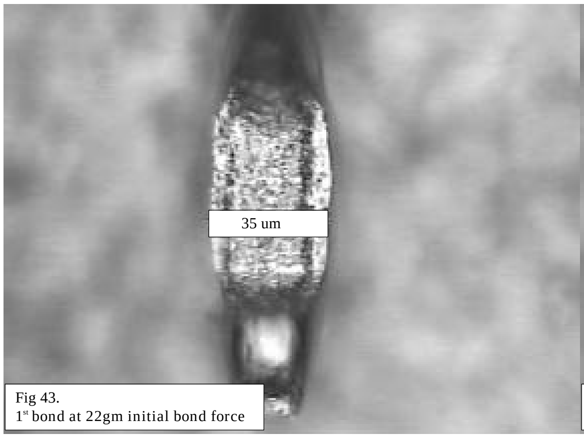


Fig 43.
1st bond at 22gm initial bond force

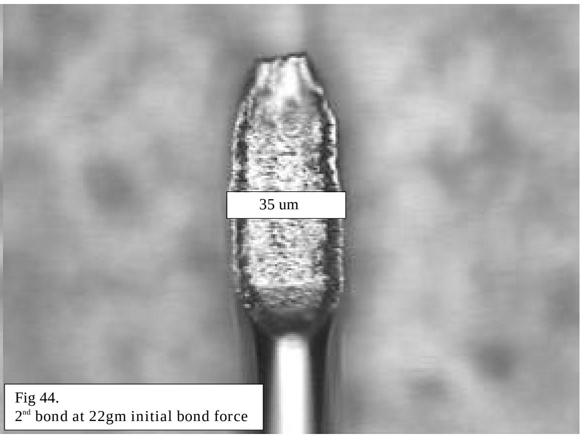
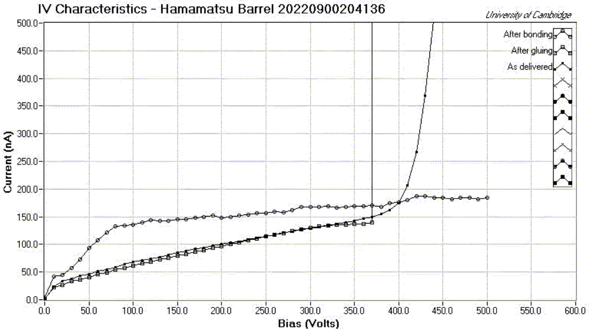


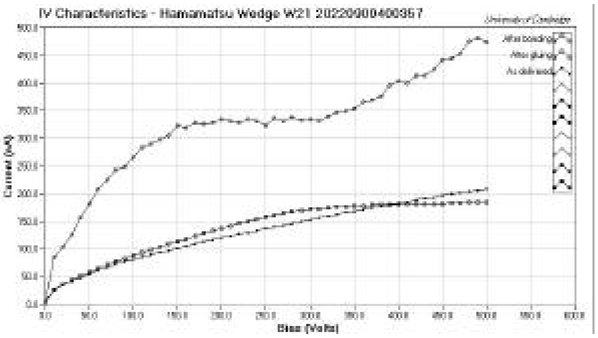
Fig 44.
2nd bond at 22gm initial bond force

Work at Cavendish Lab, Cambridge.

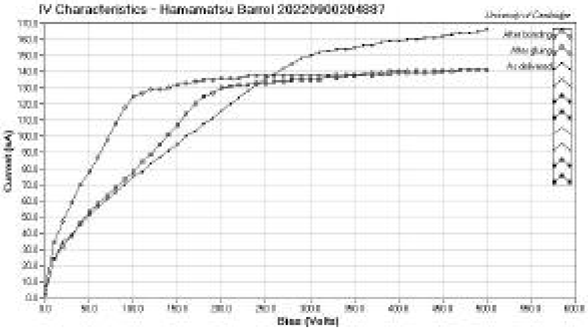
Some time was spent bonding detectors for irradiation test using the 1470 of the Physics Dept. at Cambridge University. Four detectors were bonded and little difference in detector current was noted, for voltages below 350V.



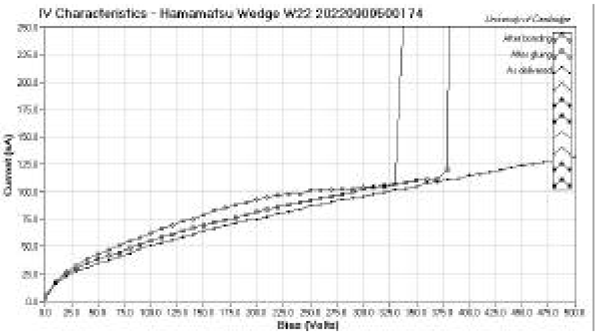
IV Characteristics - Hamamatsu Barrel 20220900204136



IV Characteristics - Hamamatsu Wedge W21 20220900400357



IV Characteristics - Hamamatsu Barrel 20220900204887



IV Characteristics - Hamamatsu Wedge W22 20220900500174

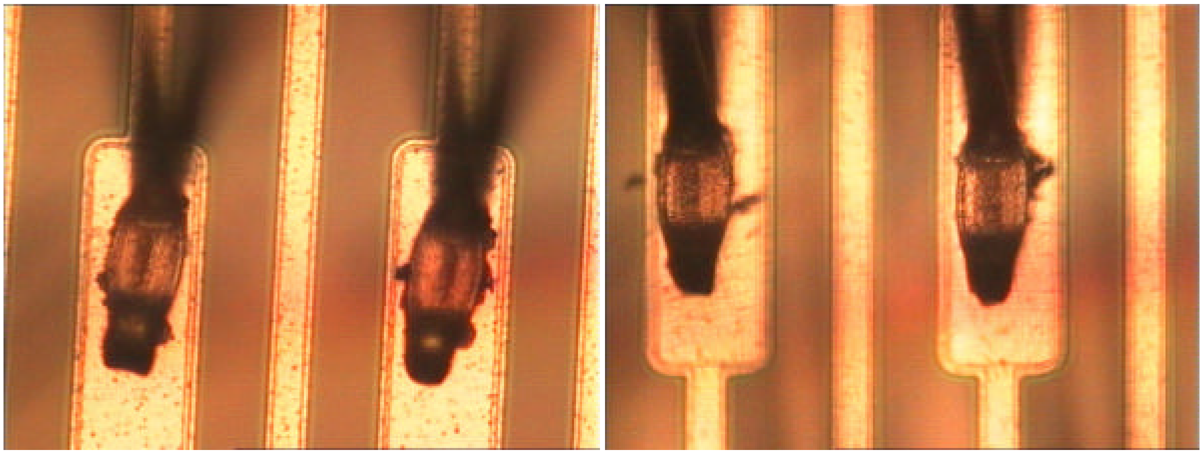
Some notes on interpreting the plots:(from Dave Robinson e-mail)

4136 - this showed breakdown above 350V before and after gluing,
but grounding the strips via the bonds seems to have cured this.

4887 - this looks good at all 3 stages

174 - Detector tested at Lancaster, who measured breakdown at ~375V,
confirmed in Cambridge data (only after gluing!)
Current below 350V looks good at all 3 stages.

357 - ok but modest increase in current after bonding (usually, when a post-bonding
problem occurs it results in the current increasing by a factor 5-10).



A set of series and pre-series baby detectors were mounted onto a ceramic base and current measurements taken before and after both gluing and wirebonding. No significant increase in detector current was noted and any differences were removed by baking the detectors after wirebonding.

SeriesBaby Detectors

Currents at 150V

	1420	*1421*	*1446*	*1447*	*1448*	*1522*	*1524*	*1598*	*1599*	*1600*
Hamamatsu	*3*	*3*	*3*	*152*	*4*	*3*	*3*	*3*	*3*	*3*
After Glueing	*6*	*8*	*10*	*130*	*9*	*7*	*12*	*8*	*6*	*7*
After Bonding	*8*	*12*	*40*	*30*	*20*	*9*	*500*	*108*	*10*	*7*
After Bake	*5*	*5*	*6*	*110*	*6*	*4*	*26*	*8*	*5*	*6*

Currents at 350V

Hamamatsu	*4*	*4*	*4*	*452*	*6*	*4*	*4*	*5*	*5*	*5*
After Glueing	*10*	*15*	*20*	*320*	*16*	*14*	*170(*)*	*16*	*11*	*14*
After Bonding	*16*	*20*	*72*	*67*	*33*	*18*	*1000*	*230*	*20*	*19*
After Bake	*15*	*9*	*9*	*150*	*9*	*7*	*57*	*16*	*9*	*9*

(*) Breakdown at 340V

PreSeries Baby Detectors

I. Currents at 150V

	0001	*0002*	*0006*	*0007*	*0015*	*0134*	*0135*	*0137*	*0138*	*0139*
Hamamatsu										
After Glueing	*5*	*5*	*5*	*4*	*4*	*4*	*4*	*4*	*4*	*5*
After Bonding	*12*	*11*	*10*	*6*	*5*	*5*	*5*	*5*	*5*	*5*
After Bake	*4*	*4*	*5*	*4*	*4*	*4*	*4*	*4*	*4*	*4*

II. Currents at 350V

Hamamatsu										
After Glueing	*9*	*9*	*9*	*8*	*8*	*8*	*9*	*8*	*9*	*9*
After Bonding	*22*	*27*	*18*	*12*	*9*	*9*	*10*	*9*	*9*	*9*
After Bake	*8*	*8*	*9*	*7*	*8*	*7*	*8*	*6*	*7*	*7*

Conclusions.

Reduction of Initial Bond Force has been tried and has found to give an improved quality of bond. It would appear that successful wire bonding on K&S 1470 with 22gram initial bond force setting is possible and results in a much smaller bond foot deformation which is the same size as that bonded on 120KHz machines. Given that the wire in both cases is 1% Si, 25um Aluminium wire then there must be the same force exerted during the bonding period to cause the same deformation.

This work suggests that, combined with good pull strength results, the bonding parameters, when bonding 25um wire on ATLAS SCT detectors, should be set to achieve a bond foot profile of 35um width. This should also help in reducing the possibility of shorting channels when bonding to the finer pitch, unpassivated, second row of the hybrid pitch adapters.

There is now a need for more statistics and a program of work should be established to show that all wirebonding establishment machines are capable of producing the required bond foot on 25um wire. Further proof of this bonding optimisation should result from future detector bonding and associated detector current measurements.