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Document Released By:		**Signature and Date**	

CHANGE RECORD

Issue	Date	Section affected	Change Description

APPLICABLE DOCUMENTS

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AD3			

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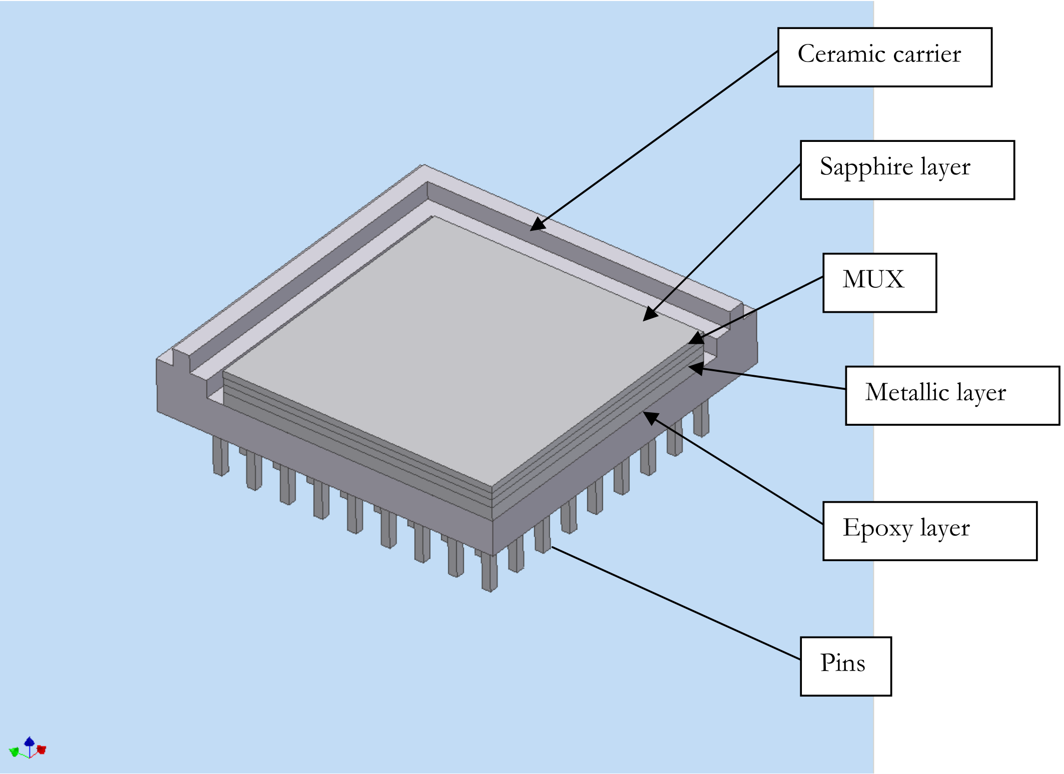
1. INTRODUCTION

This document is meant as a record of analysis carried out on the WFCAM detector/ZIF socket combination in order to investigate possible causes of array failure. FEA analysis was carried out on an assembly which represents the detector arrays. Loads are primarily temperature differentials of the devices, simulated loading and constraints from the ZIF socket. An order of magnitude check is also made on the effect of local heating within the array.

2. DETECTOR GEOMETRY

The detectors have a sandwich construction with layers of various materials and thicknesses bonded together. The exact details are proprietary information and so the geometry and materials are somewhat of an approximation. The solid model from which the FEA model is constructed is shown below.



3. LAYERS AND MATERIALS

The layers and materials used in the model are listed in the table below. The bump bonds and bonding material layers are not modelled.

Item	Dimension	Young's modulus	CTE (300K to 40K)
Pins	0.6mm x 0.6mm x 3mm	Copper, $1.1\text{x}10^{11}$ Pa	$1.2\ \text{x}10^{-5}$
Ceramic carrier	2mm thick	$2.2\text{x}10^{11}$ Pa	$5.0\ \text{x}10^{-6}$

Epoxy layer	0.75mm thick	$3.0\text{x}10^{9}$ Pa	3.9 $\text{x}10^{-5}$
Metallic layer (chosen to minimise Sapphire window stress)	0.45mm thick	$2.1\text{x}10^{11}$ Pa	5.4 $\text{x}10^{-6}$
MUX	0.38mm thick	Silicon $1.3\text{x}10^{11}$ Pa	7.5 $\text{x}10^{-7}$
Sapphire	0.38mm thick	$3.3\text{x}10^{11}$ Pa	4.0 $\text{x}10^{-6}$

CTE's are average values from 300K to 40K

3.1 ZIF SOCKET CONTRACTION

Three different ZIF sockets were measured at room temperature and after immersion in Liquid Nitrogen to determine the CTE and any possible spread between sockets. The results are tabulated below.

Item	Warm	Cold	CTE (average 300-77K) /K
19 Pin ZIF#1	63.8	63.48	2.3 $\text{x}10^{-5}$
19 Pin ZIF#2 (cover)	62.4	62.15	1.8 $\text{x}10^{-5}$
21 Pin ZIF on PCB	69	68.75	1.8 $\text{x}10^{-5}$
21 Pin ZIF unsoldered	69	68.72	1.8 $\text{x}10^{-5}$

The highest figure was used in the modelling

3.1.1 Contact with the manufacturer

Yamaichi have been contacted directly to determine if there was a known change in the material used in the manufacture of the ZIFs or if the material varies between sizes of socket. The PEI material is available in a number of grades. The communications and links to data sent are in the section "Yamaichi comms".

The result of the communications is that there are no intentional or known variations in the material and hence the CTE. The measured results may be due to variations in the material.

4. FEA MODEL

The model is a quarter model of the detector.

4.1 THERMAL CONTRACTIONS

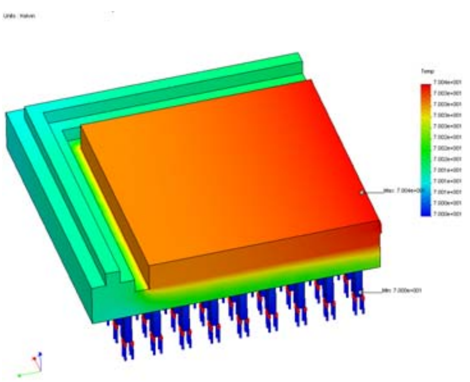
The initial condition is 300K with no strain and a uniform temperature of 40K is imposed on all the parts. The ZIF socket is represented by imposed displacements on the ends of the pins consistent with the measured contraction rate of the ZIF.

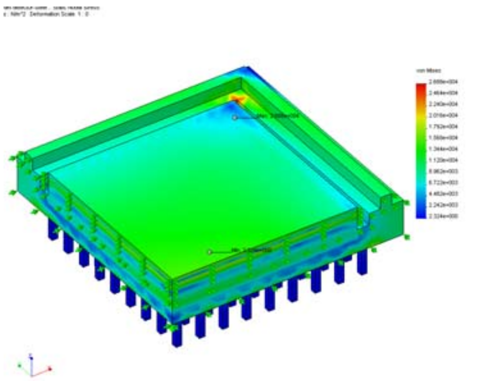
The top cover of the ZIF socket has an array of holes through which the pins go. These holes have been measured at 0.7mm, with the pin diameters measured at 0.4mm. This clearance is just sufficient to allow the cover to contract without imposing strain on the pins.

The pins are held in clips within the ZIF body. These are assumed to contract in towards the centre. The outer pins are approximately 20mm and have forced displacements of 0.1mm. The next row has forced displacements of 0.9 and so on. This is worst case because the pin sockets and ZIF will have some compliance. The highest figure of $2.3x10^{-5}$ was used.

4.2 EFFECTS OF LOCAL HEAT GENERATION

A load case was considered where heat is generated locally within the MUX layer. A transient analysis was carried out with 5 milli-Watts generated on the exposed face of the MUX layer. The temperature gradients and resultant stresses after a few minutes were calculated as shown below.

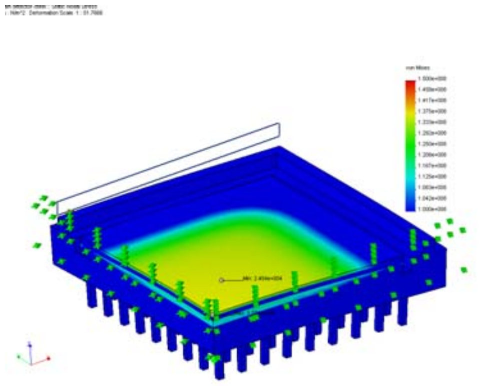


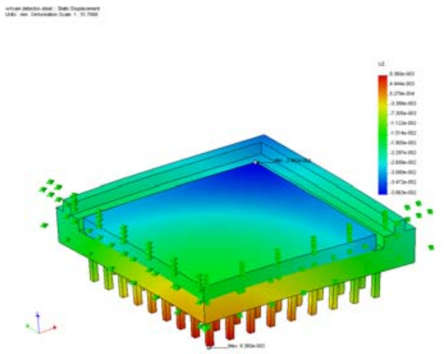


This thermal distribution was input into a static analysis to determine the resultant stress level.

4.3 RESULTS

The plots below show stresses and deformations for typical load cases considered





The results are tabulated below

Load case	Bowing deformation of sapphire surface	Stress in sapphire (MPa)	Sapphire UTS (MPa)
NO ZIF	12 microns	34 average, 109 max	270-400 Mpa
Include ZIF represented as forced displacements on pins	18 microns	51 average, 114max	
Include ZIF cover represented as forced displacements on pins and constraints on pins in Z	8 microns	39 average, 116 max	

Thermal distribution only	0.00026 microns	0.003Mpa	

4.3.1 Forces on the pins

From the fully constrained model the reaction forces on selected individual pins were obtained and are in the table below.

From centre to edge Force (N)	From centre to corner Force (N)
-17.8	-17.8
-11.6	-5.5
-11.0	-4.0
-10.4	-2.2
-9.0	0.13
-9.3	0.12
-7.4	4.7
-4.9	10.4
-2.0	17.0

As can be seen the forces are large compared with the weight of the device. Slippage of pins in the ZIF may explain why creep out of the socket has been observed on thermal cycling.

4.3.2 Effects of metallic layer CTE

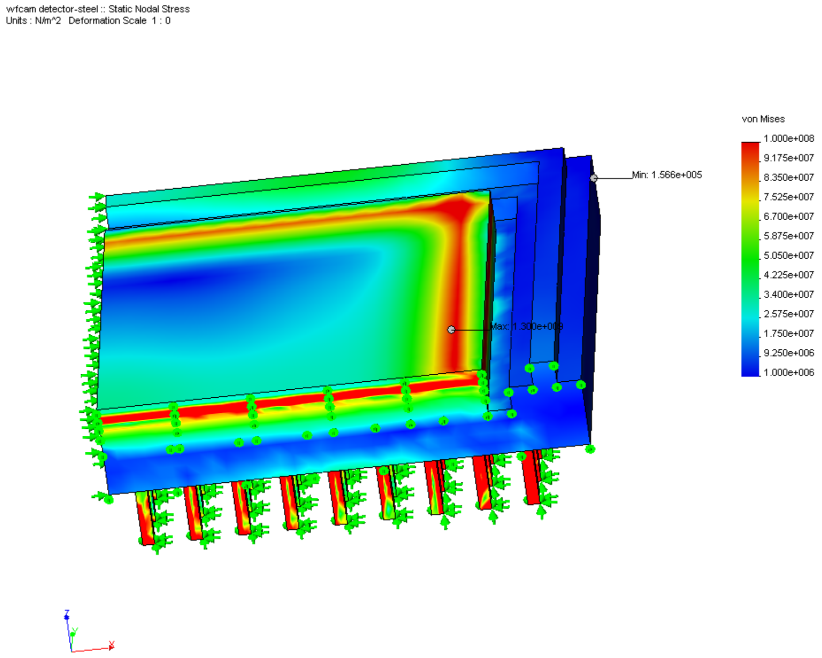
The material and CTE for the metallic layer is not known. However, it assumed that the CTE would be optimised to give the minimum stress on the Sapphire window. A set of analysis was carried out to investigate this and determine what the layer might be. This leads to a choice of material that is used in the rest of the analysis. The results are tabulated below.

Averaged CTE (/K)	Nearest material with this average CTE (within 10%)	Average stress over window surface (MPa)	Detector surface bow middle to edge (Microns)
9x10^{-6}	Iron	101	11
7.2x10^{-6}	Bearing steel 440C	55	11
5.4x10^{-6}	Ti	34	12
3.6x10^{-6}	Tungsten	70	13
1.8x10^{-6}	Invar	113	13

From this it is assumed that the metallic layer has an averaged CTE between 300K and 70K of 5.4x10^{-6}

4.4 STRESSES IN THE OTHER LAYERS

The plot below shows the stresses through the layers for the case with the highest stress.
As can be seen the highest stresses are in the Sapphire window and Silicon layer but this is very dependent on the layer properties and we have insufficient data to lend this result much credibility.

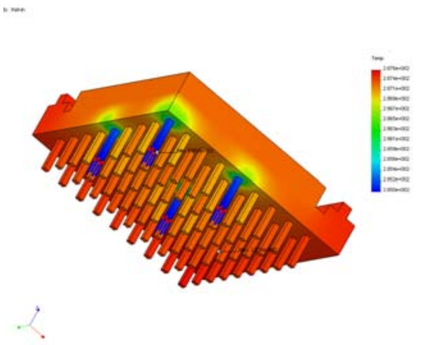


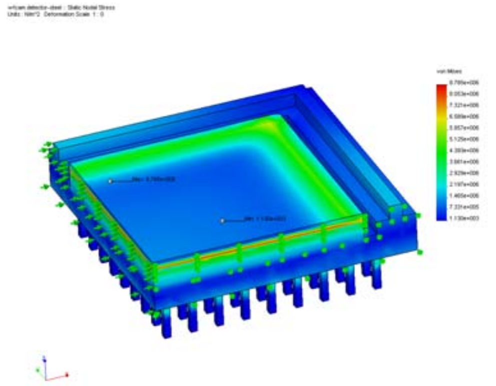
The UTS of the silicon may be as low as 200Mpa or as high as 450 MPa(one reference on the web)

5. EFFECT OF LOCAL COOLING ON PINS

The devices are cooled by connecting copper wicks to discrete pin positions. To investigate this effect a transient analysis was done cooling four pins from 300 to 80K with a gradient of 0.5 degrees/min.

The largest temperature differentials between the ceramic at the cooling pins and the corner of the sapphire window were after half an hour at about 2.4 degrees.
The plot below shows the temperatures predicted. Using this temperature distribution, the predicted stresses are shown for the device free of the ZIF carrier.

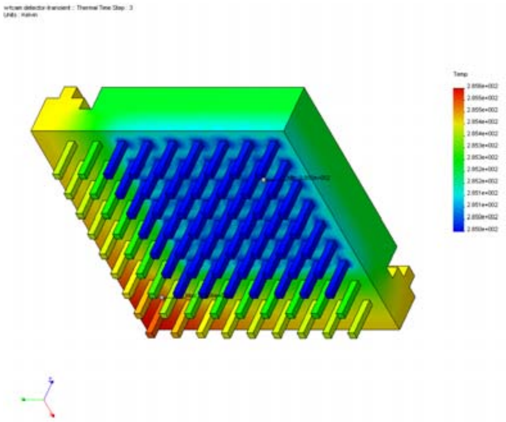


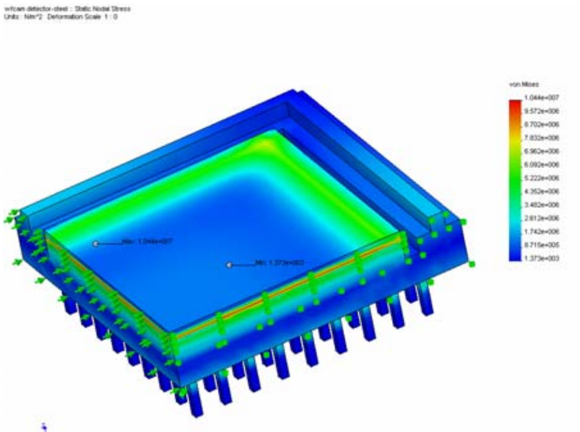


As can be seen, the stresses are low and not localised at the cooling points being dominated by the bulk lowering in temperature.

5.1 EFFECT OF CONNECTING MORE PINS

An alternate cooling scheme was modelled where all of the cooling pins are connected. The predicted temperatures and resultant stresses are shown below.

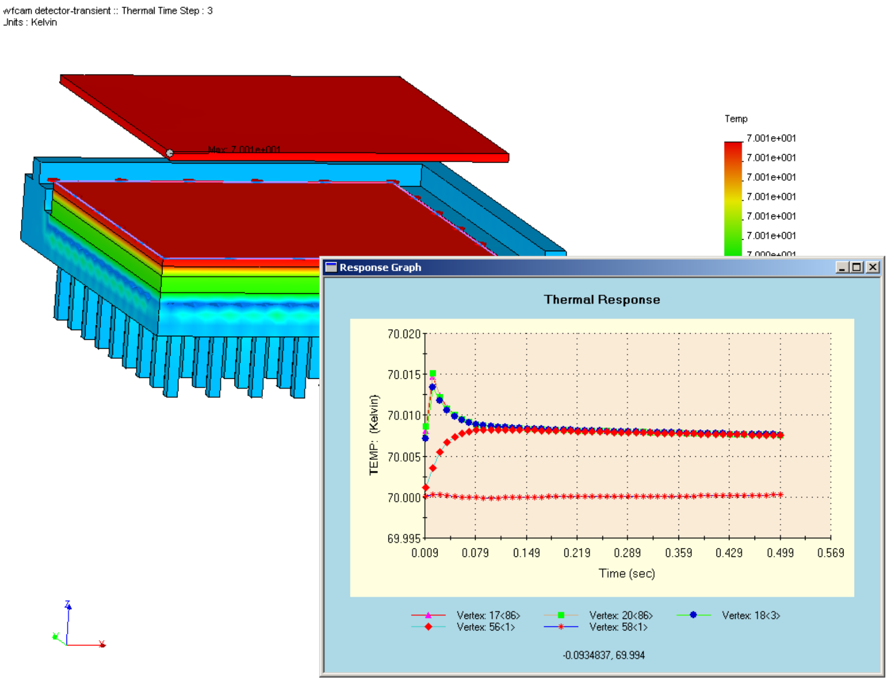




As expected the cooling is much more even. The stresses are higher with more pins connected but this can be attributed to the lower bulk temperature as it is cooling about 20% faster.

6. EFFECT OF TRANSIENT HEATING ON POWER UP

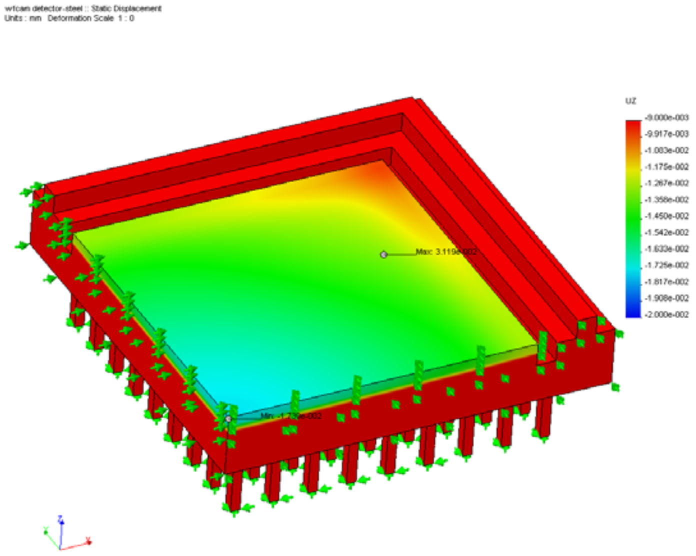
On power up, it has been determined by experiment that there may be as much as 800mW dissipated in the MUX layer over a time of 20ms (this value applied one quarter of the array). This loading was input and transient temperature curves obtained to investigate the resultant temperature distributions. The results are shown below. For the centre of the device, vertexes are on successive layers;



As can be seen from the plots the temperature rises and differences are very small and resultant stresses would be negligible.

7. ANALYSIS OF A MUX

Tests were carried out on MUX devices using a scanner and the co-planarity device. A model was carried out with the Sapphire and metallic layer removed in order to compare the model with measured deformation of the MUX surface. The results are shown below.



As can be seen from the plot the bowing is estimated to be 5 microns at the edge, 8 microns at the diagonal corner. This compares well with 5-6 microns measured in the test setup.

8. CONCLUSIONS

The largest stresses are due to the CTE mismatch in the layered construction of the device. This is however very dependent on the materials and thicknesses used in its construction. We have insufficient data for an accurate model.
For the construction modelled and constraints assumed, the ZIF socket contractions and restraints are significant in terms of the stresses they produce. If correct, the stresses imposed are quite high for a brittle material.

There is some evidence that the CTE's of the ZIF sockets can vary by a factor of 1.3. This could modulate the stresses and deformations caused by the ZIF by the same ratio. This could be a contributory factor and explain why some devices have failed and not others. We should search for a correlation between the ZIFs used and failures. It is noted that the devices which have undegone successful previous cool-downs with the same socket.

The stresses are acceptable in terms of factors of safety on the UTS but the failure mechanism is almost certainly brittle fracture. In which case, case crack propagation from a flaw will greatly reduce the apparent factor of safety.

Thermal stresses caused by localised heating are not significant assuming 5 milliwatt levels.

Thermal stresses caused by transient cooling locally applied at a few pins are not significant

9. YAMAICHI COMMS

9.1 E-MAIL

Hi David:

Our sockets are only rated at -40 degrees C to 170 degrees C. Attached are the material specs.

Regards, Safa

Safa Aliabadi
Inside Sales
2235 Zanker Road
San Jose, CA 95131
Direct: 408-473-9129
Main: 408-456-0797
Fax: 408-456-0799
Email: Safa.a@yeu.com
www.yeu.com

-----Original Message-----
From: David Montgomery [mailto:dm@roe.ac.uk]
Sent: Thursday, March 18, 2004 12:55 AM
To: 'Safa Aliabadi'
Subject: RE: Information Request Form

Safa,

Thank you for your promt reply.

Perhaps I can explain further regarding the temperature effects;

We are using 19 and 21 pin Yamaichi ZIF sockets to mount Infra red detector devices on PCB's as part of astronomical instrumentation. This is recommended practice by the device manufacturer Rockwell. The devices are cooled to 77K. We have made measurements that indicate there may be a 30% variation in the contraction between individual ZIF sockets when cooled to this temperature. This could affect the operation of the devices.

Perhaps this is a random variation in the material used for the ZIF but I thought there may be a systematic effect caused by changes you have made to the material over time or between sizes of socket (19/21pin). The sort of thing that would do this would be variations in the glass content of the PEI material used for the ZIF. Such a change may not be significant in terms of the materials mechanical properties.

Regards,

David

> -----Original Message-----
> From: Safa Aliabadi [mailto:Safa.a@yeu.com]
> Sent: Wednesday, March 17, 2004 17:40
> To: 'dm@roe.ac.uk'
> Cc: Bassam Asfoor; Safa Aliabadi
> Subject: RE: Information Request Form
>
>
> Hi David:
> My name is Safa and I am the inside sales rep supporting your

```
> area and Bassam Asfoor is the area sales manager.
> In regards to your questions below:
> 1. The material used for the bodies of the 19 and 21 pin ZIF
> sockets are the same.
> 2.  I do not understand your second question about the
> temperature ranges. Please explain.
>
> I look forward to hearing from you.
>
> Best regards, Safa
>
>
>
> Yamaichi Electronics
> Safa Aliabadi
> Inside Sales
> 2235 Zanker Road
> San Jose, CA 95131
> Direct: 408-473-9129
> Main: 408-456-0797
> Fax: 408-456-0799
> Email: Safa.a@yeu.com
> www.yeu.com
>
>
> -----Original Message-----
> From: anonymous@mail-da-1.dns-solutions.net
> [mailto:anonymous@mail-da-1.dns-solutions.net]
> Sent: Wednesday, March 17, 2004 1:26 AM
> To: info@yamaichi.us
> Subject: Information Request Form
>
>
> Below is the result of your feedback form.  It was submitted by
>  () on Wednesday, March 17, 2004 at 02:25:47
> --------------------------------------------------------------
> -------------
>
> Name: David Montgomery
>
> Company: United Kingdon Astronomy Technology Center
>
> Address: Royal Observatory Edinburgh
>
> City: Edinburgh
>
> State: AZ
>
> ZIP: 85748
>
> Country: USA
>
> e-mail: dm@roe.ac.uk
>
> Comments:       Can you please tell me if the materials used
> for the bodies
> of the 19 and 21 pin ZIF sockets are different? Part numbers:
>
> NP89-44111
```

```
> NP89-36105
>
> We are particularly interested in CTE differences over the
> temperature ranges from 300K to 77K. We have measured
> differences which indicate a
> change or variation in the material between the two sockets.
>
> -------------------------------------------------------------
> -------------
>
> HTTP_USER_AGENT: Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)
>
```

9.2 DATA SHEETS

Data sheets were sent for copper pins and the ZIF body material, these are in PDF format in projects\ukirt\wfcam\dmm\word docs

9.2.1 Dimensional stability of the ZIF socket

From the data sheet, the ZIF socket material absorbs moisture and this can lead to dimensional changes by as much as 0.15% at equilibrium for 68% relative humidity 21°C. This represents a displacement of 0.03mm of the pins farthest from the centre which is 30% of the contraction at 70K.

It is not known how this level of moisture absorption effects the CTE to 70K but the CTE used in the analysis is consistent with values measured by experiment. The parts were open to normal lab conditions for extended periods prior to the measurements.