Tracker Bias Circuit Bonding Update

6/26/04

Symptoms and Causes

Large scale delamination of the kapton bias circuit from the tray was initially seen in thermal-vacuum testing of the laminated tray as documented in NCR/FM/INFN/RM2/1 & 2. The test was being done at 85^0C and subsequent to the observation of the large scale delamination, the procedure was changed to reduce the temperature of the thermal-vacuum test to 55^0C. Subsequent tests of laminated trays at 55^0C showed that some delamination persists even at reduced temperature.

The lamination failure could be caused by shear failure of the epoxy at elevated temperature, or by adhesive failure of the epoxy at either the tungsten or kapton surface. The failure at 85^0C showed global failure of the epoxy. While not conclusively proven, the continued failures in the lower temperature test are consistent with the assumption of adhesive failure of the epoxy, primarily at the tungsten surface.

The bonding failure has three symptoms: Small (<2cm) mostly round bubbles, elongated narrow bubbles, and large scale ripples.

The working assumption is currently that we are dealing with adhesive failure, primarily at the tungsten surface because when large scale delaminations have occurred, it is observed that the tungsten surfaces are clean without visible epoxy on them, while the kapton surface is still covered by the epoxy. Also, since the 85^0C test was discontinued, the pattern of bubbles has been random around the surface.

There are currently two working criterion for success in the lamination process:

1. The bubbles that are generated during the thermal-vacuum test (55^0C for 24 hours) must have a height less than 100 microns and must be less than 1cm in diameter if they are round and less than 4 cm long if they are long and narrow.
2. When the tray is thermal-vacuum cycled a second time, (55^0C for 24 hours), the existing bubbles do not change an no new bubbles are formed.

It is agreed that any bubbles present at any stage in the bonding process will result in an NCR for the tray.

Path Forward

With the working assumption that we are dealing with adhesive failure primarily at the tungsten surface, we are working to improve the surface preparation process to ensure better adhesion. The experts at Goddard have been engaged in the issues. The following steps have been or are being taken:

1. The preparation on the tungsten surface has been improved by bead blasting the tungsten to a depth of 1 micron. This has been tested and yields a much more uniform abrasion (compared with the previous process of hand sanding). Test coupons show more uniform wetting of the tungsten with epoxy in this process and the adhesion of the bias circuit to the tungsten is improved a factor of 2 in this process as measured in coupon tests. The coupon tests show a much narrower distribution of measurements indicating a more uniform and controlled process. There is clear evidence of epoxy adhesion to both the tungsten and the kapton.
    a. The bonding of the bias circuit to the tungsten has been tested with one tray and bubbles persist. However they are small (vertical height less than 100 microns) and in the second thermal-vacuum test they do not move and no additional bubbles were formed.
2. The preparation of the kapton surface will be improved. In the implementation being strongly considered, the surface of the kapton will be abraded prior to lamination. In addition, both the kapton and the tungsten will be cleaned with isopropyl alcohol immediately before bonding

If bonding problems persist, four other measures have been mentioned as possible mitigations.

3. If the problem continues to be with the tungsten surface, an acid etch of the tungsten could be considered. Concern has been expressed that this would remove too much material and impact the physics capability of the tracker. This is a subject that could be investigated but early thinking is that removal of up to 5% of the tungsten in each layer would not have a significant impact on the physics capability of the instrument.
4. Again if the problem of adhesion to the tungsten surface continues, another alternative would be to coat the tungsten with a primer that could then ensure good adhesion to the Scotch-Weld 2216 epoxy being used.
5. One could consider further studies of alternate epoxies for the bond. There has been no investigation into the wetting properties of different epoxies on tungsten so it may be possible to improve adhesion. This would also be an essential line of investigation if the working assumption that we are dealing with a surface adhesion problem proves to be incorrect and we needed to find an epoxy with greater shear strength at elevated temperature.
6. Finally we can explore the necessity of the 55^0C test and see if lower test temperatures might be acceptable.

Additional Studies

In addition to the bonding studies mentioned above using flight trays and flight bias circuits, two supporting analyses are being done.

1. The first analysis compares differences in the stress distribution with and without the SSD ladders. If the stresses are significantly reduced when the silicon is added, the tendency for the bias circuit to delaminate could go away in which case the current test may be over stressing the system.
2. The second analysis resets the zero-stress-state to a temperature higher than 23C by modeling a higher-than-room-temperature cure. The idea is to see if the stresses in the bias circuit—tungsten bond can be significantly reduced with a higher temperature cure. Effectively one is reducing the temperature delta at the hot temperatures, where the adhesive strength seems to break down. The downside to this is the increased stress at the cold temperature. Although the adhesive strength increases, there may be added risk to the silicon getting loaded up. Also it is not at all clear that a higher temperature cure is feasible in production.

Tracker Bias Circuit Bonding Update II

8/10/04

Delamination Issues

Large scale delamination of the kapton bias circuit from the tray was initially seen in thermal-vacuum testing of the laminated tray as documented in NCR/FM/INFN/RM2/1 & 2. The test was being done at 85^0C and subsequent to the observation of the large scale delamination, the procedure was changed to reduce the temperature of the thermal-vacuum test to 55^0C and the surface preparation of the kapton and the tungsten were changed. Subsequent tests of laminated trays at 55^0C showed that some delamination persists. Furthermore, the process used to lance the bubbles that appeared in the thermal-vacuum testing was found to cause shorts between the HV and ground, causing trays to be rejected.

The working assumption was made that we are dealing with adhesive failure primarily at the tungsten surface. The following steps were taken:

1. The preparation on the tungsten surface was been improved by bead blasting the tungsten to a depth of 1 micron.

2. The preparation of the kapton surface was improved.

While the new surface procedures increased the glue adhesion, the yield is still too low. One reason suggested is that it is very difficult to increase the W roughness: the thin W layers are not perfectly flat and they are even worst after 1um blasting. An alternative strategy that has been suggested to improve the adhesion to the W plates is to paint the W plates on both sides with a primer. This operation is fast, clean, and easy to test.

At this point the lack of a successful process for the bias circuit bonding has stopped tracker production.

Paths Forward

I would like to suggest that the tracker team proceed in parallel with three investigations:

1. We need to answer the question: “Over what temperature range do we have a working design? Are the failures (delaminations, bubbles) occurring at 35^0C? 50^0C? “ What flexibility exists in the qualification temperature for the design?
2. We need to engage as much expertise as possible to develop a process that eliminates the development of bubbles in the T/V testing process. We should be producing laminations with no bubbles at all.
3. We need objective criteria to determine what size of bubble can be ignored.

For all of these investigations, we need:

- A step by step plan of action
- Analysis to support the plan where appropriate
- A timeline to completion of the plan
- A process to validate the qualification scheme.

The project management and PI are moving to set up a tiger team in consultation with the tracker management that will be charged to develop the plan needed to resolve the technical issues. They hope to have the tiger team in place within a few days and the team would plan to come to PISA in the last week of August.