ATOMIC OXYGEN EFFECTS ON HST-SA1 METALS

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ABSTRACT

Several metals and alloys are used on the HST solar array panels. The silver plated molybdenum interconnectors between the solar cells and between the solar cells and the busbars are the most well known. Gold plated interconnectors are used on the diodes. These metals and others such as hinge rods will be investigated using scanning electron microscopy to determine the effect of atomic oxygen on the surface of the metals.

Keywords: Silver, Gold, Incoloy, Metals, Oxidation, Atomic Oxygen

1. INTRODUCTION

The history of atomic oxygen on metallic materials is a well documented subject. Starting from the days of the first HST solar array several improvements have occurred in the protection of metals. One of the reasons to replace the HEC solar panels was the presence of unprotected silver interconnects and busbars. When it became known that the risk of flying solar panels with silver interconnectors was to high, the decision was taken to replace them. The silver interconnectors with an out-of-plane stress relief loop were replaced by silver plated molybdenum interconnectors and the ones with in-plane stress relief loops were replaced with gold plated silver interconnectors. The silver busbars were coated with silicone RTV-S 691 to give protection against atomic oxygen. This could not be applied to the interconnectors while the stresses introduced by the silicone adhesive were damaging to the stress relief loops. These replacements were extensively tested for their compatibility with atomic oxygen. The silver plated molybdenum interconnectors were of course attacked by atomic oxygen, but only the silver coating was effected, the attack stopped at the intermediate layer of platinum between the silver coating and the molybdenum core.

The atomic oxygen effect is usually most pronounced on out-of-plane stress relief loops. In this area the manufacturing stresses and the stresses as a result of the temperature excursions are large. Past experience showed that in these areas the oxide layer tend to flake off and a fresh surface is exposed to the atomic oxygen environment. On flat surfaces this effect is less pronounced while there mainly the difference in volume between the oxide and the parent metal is responsible for cracking of the oxide layer.

The gold plated interconnectors were rejected for out-of-plane stress relief loops because it was impossible to apply a gold coating with such properties that it remained intact after forming the stress relief loop. However, sufficient margin was available for the in-plane stress relief loop interconnector. In principle gold coatings are acceptable for the protection of atox susceptible metals. In spite of this the protection is sometimes not reliable. It was seen several times in the past that these gold layers were either cracking (especially in the out-of-plane loop) or contained small pinhole type defects. Through these defects the underlying silver was oxidised. Large holes under the gold plating were created and silver-oxide was found at the surface.

On ground testing with atomic oxygen uses necessarily a large acceleration factor. Acceleration factors between 100 and 1000 are not uncommon. Also thermal cycling is not always included during

atox exposure. This makes the assessment of the results not straightforward. The most reliable results seem to be the ones acquired during space missions.
The HST solar panels contained a large number of silver coated interconnectors and tapping bars and gold plated interconnectors, also incoloy hinge rods were present.

2. MATERIAL

Three types of material are investigated, namely, silver from the silver plated molybdenum interconnects, gold from the gold plated silver interconnects and incoloy from the hinge rods.
The silver plated molybdenum interconnect comes in different versions. The well known one is the interconnector between two cells, the other is the tapping bar perpendicular to the interconnectors. Both are made from 16 µm molybdenum + 0.5 µm platinum at both side and 5 µm of silver at both sides.
The exposed area of the interconnector is usually only the stress relief loop, the main part of the material is either under the cell towards to p-contact or under the coverglass towards the n-contact. Although this area is quite small it is the most vulnerable region of the interconnect. Also of the tapping bars the small stress relief loops are the most vulnerable visible part, but for this connector also large flat part are exposed as can be seen in figure 1.
A busbar is examined which was damaged by a micro-meteorite impact. This impact resulted in a breakage of the busbar and opened some interconnector welds. The oxidation of these exposed welds is examined.
The gold coating on the diode connectors is examined for defects and diffusion of silver through this gold coating. The connector is comprised of a gold coating of 3.5 µm on a silver thickness of 20 µm. The location of this interconnector can be seen in figure 1.
A hinge rod is examined at the small but exposed aprts and compared with the unexposed part of this rod. A view of a hinge rod configuration is given in figure 2.

3. INVESTIGATIONS

Visual inspection using a Wild M8 stereozoom is used for the preliminary examination and photography. Selected samples from the silver/molybdenum interconnectors, gold/silver interconnectors and silver/molybdenum tapping bars were cut under the stereozoom using a fresh scalpel blade . These samples were mounted on SEM studs and fixed with conductive carbon cement. The SEM examinations were performed on a Cambridge S360 scanning electron microscope equipped with a four element solid state backscatter detector and a Link AN10000 X-ray analyser with windowless detector.

4. RESULTS AND DISCUSSIONS

Atomic oxygen not only attacks surfaces which are exposed directly to the flux, also surfaces not directly exposed, but in one way or another accessible to the atoms can be oxidised. Figure 4 shows an example of this. After removal of the two cells at both sides of this interconnector the attack on the silver surface, previously under the cell, is visible as a dark layer. The same phenomenum occurs at the rear side of the interconnector especially at the location of the stress relief loop. The amount of attack at these sides accounts for approx. 25-50% of the loss of silver thickness. All investigated interconnectors show this effect.
The total amount of attack on the stress relief loops varies. In some occasions the oxide remained completely on the surface and minor attack is observed. In other occasions total flaking occurred and the complete silver layer is removed.. No particular reason could be given for this phenomenum. In

some instances these two situations were found only halve a millimeter apart as is shown in figure 5. Here we observe two stress relief loops from one tapping bar located between two cells. The right loop shows an attacked surface, but the oxide layer remained in place and protected the underlying material. The left picture shows just the opposite situation. The silver layer is totally destroyed and large amount of flaking is present. These two stress relief loops experienced exactly the same environment, were manufactured in the same operation and are made of the same material. The difference in oxidation behaviour is probably due to minor differences in stress seen during thermal cycling or small amounts of contamination from the silicone adhesive used for bonding the solar cell onto the substrate or the coverglass to the solar cell.

The same situation can occur on flat surfaces. Flat surfaces usually do not show excessive flaking of the oxide layer. The stresses in the material is lower than those in the stress relief loops. The oxide layer on flat surfaces do crack but tend to remain on the surface. The flat surface seen in figure 6 is an example of this. That this is not always the case is illustrated in figure 7. Large flakes and oxidation under these flakes are present. A few tapping bars showed this behaviour. No particular location on the solar array assembly could be attributed to the observed differences.

The examination of a totally clean silver surface exposed to atomic oxygen was possible when a micrometeoroid had impacted and totally penetrated through a busbar. The busbar was locally destroyed and an interconnector tab came loose from the busbar, thus exposing the previous weld area on the rear side of the busbar to atomic oxygen. The difference between a clean silver surface and a contaminated silver surface both now exposed to atomic oxygen is now clearly visible. Due to the large amount of silicone used, the area in the vicinity of the weld is covered with a contamination layer. After the weld separation this contaminated surface as well as the fresh surface were exposed at the same time and seeing the flux. The result is illustrated in figure 8. The fresh silver surface is totally oxidised and the oxide layer is raised out of the plane of the busbar, while the surrounding surface shows only traces of oxide.

The change in gold surfaces after atomic oxygen exposure is in general minor. The changes which are visible on the gold plated silver interconnector can in general be contributed to silveroxide on the gold surface. In some cases the silveroxide can be traced back to small pinholes in the gold surface, through which the silver is oxidised. In other cases no defects under the oxides are detected. Some silver oxidation on gold surfaces can be seen in figure 9. Not all dark discolourations are characteristic of silveroxide., the majority of the discolouration consists of oxidised silicone contaminants. Darkening close to edges is usually associated with silveroxide.

The effect of atomic oxygen exposure on the incoloy hinge rod was absent or at least impossible to measure. The exposed areas are very small and were during their life always in close contact with the solar array blanket. This blanket was protected at both sides with silicone DC93500 and this silicone was always detected on the exposed part of the incoloy hinge rod. The minor discolouration could always be contributed to the presence of this silicone layer.

5. CONCLUSION

The effect of atomic oxygen on silver is well known. For the first time such a large number of interconnectors was received back from space.

A large variation is observed in the oxidation behaviour. Local stresses and the absence or presence of contamination layers are thought to be responsible.

The effect of atomic oxygen on gold plated silver was also expected. During previous examinations small pinholes were found in the gold coating through which the underlying silver was oxidised. The presence of this silveroxide on top of the gold surface is now also confirmed on the HST gold plated silver interconnectors..

As expected the atomic oxygen effect on incoloy is minimal or even absent.

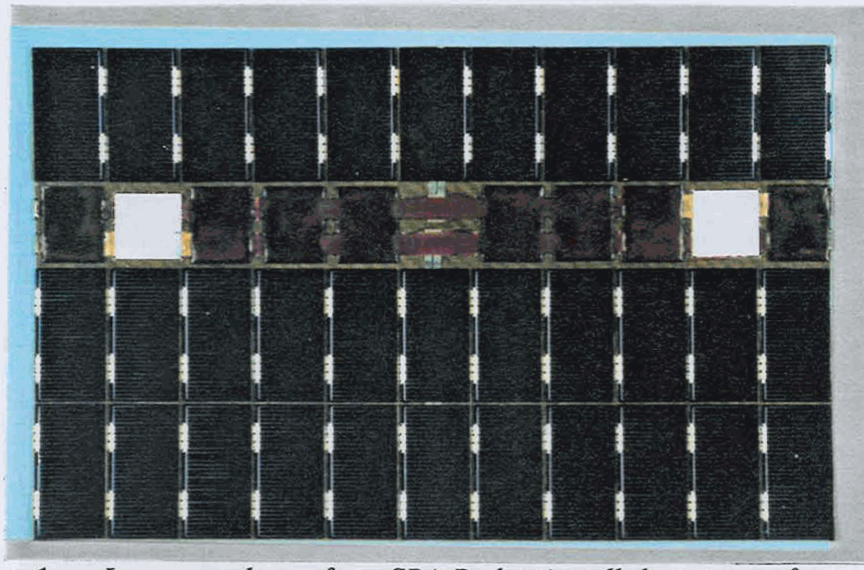

Figure 1. *Large sample cut from SPA D showing all three types of interconnectors. The bright connectors between the solar cells are the well known Ag/Mo interconnects. The tapping bars are located in the middle of this sample perpendicular to the standard interconnectors. The two flat parts can be seen near the top at the position of the RTV coated stiffeners. The gold coated silver interconnectors can be seen at the position of the two diodes.*
Magn. X0.43

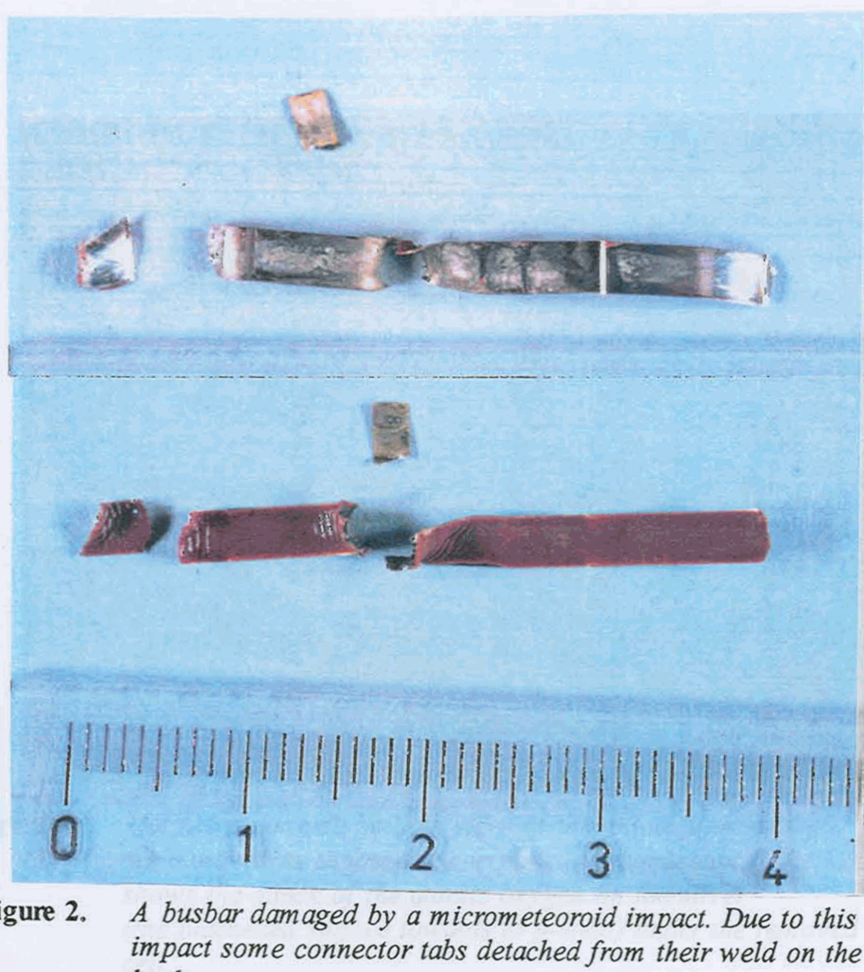

Figure 2. *A busbar damaged by a micrometeoroid impact. Due to this impact some connector tabs detached from their weld on the busbar.*
The bottom picture shows the RTV side of the busbar, while the top picture shows the silver side of the busbar.
Magn. X2.3

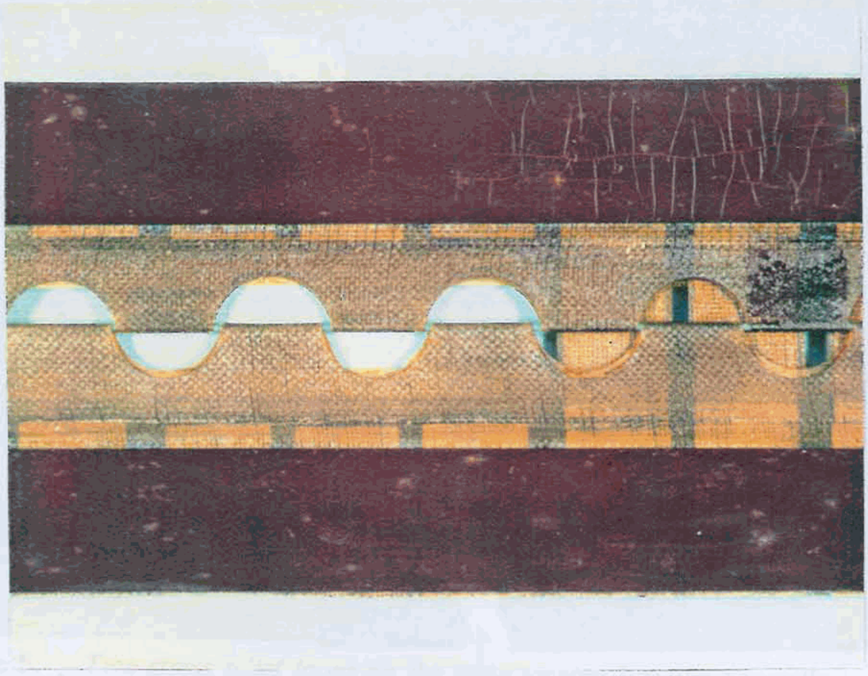

Figure 3. *Detail of hinge rod/bridge piece between SPA D and SPA E. The exposed parts of the hinge rod is just visible between the blanket folds.*
Magn. X1.35

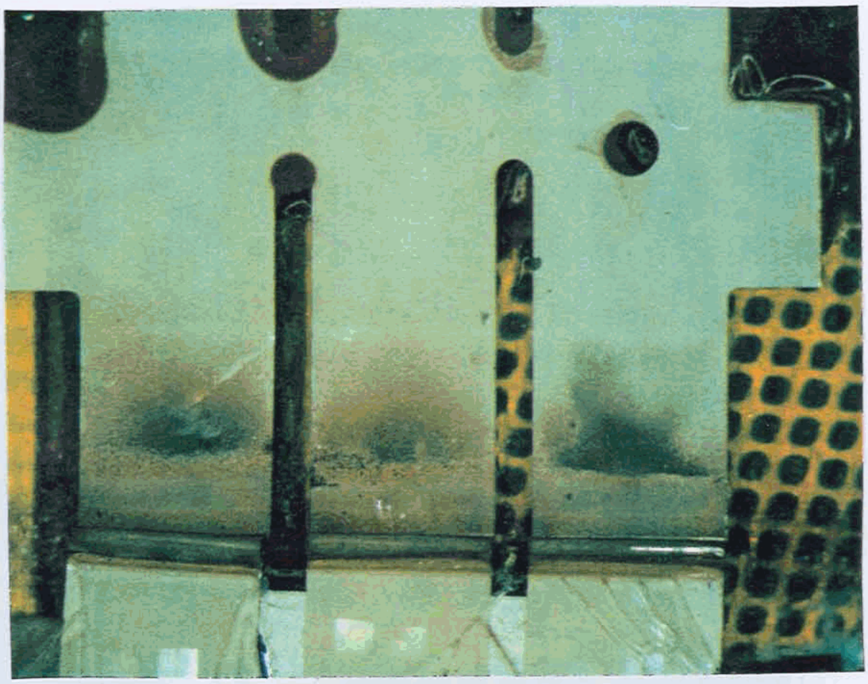

Figure 4. *The two solar cells at both sides of this interconnector are removed to expose the complete interconnector. It shows the attack of the atomic oxygen on the silver (the blackened surface towards to p-weld) under the removed cell.*
Magn. X12

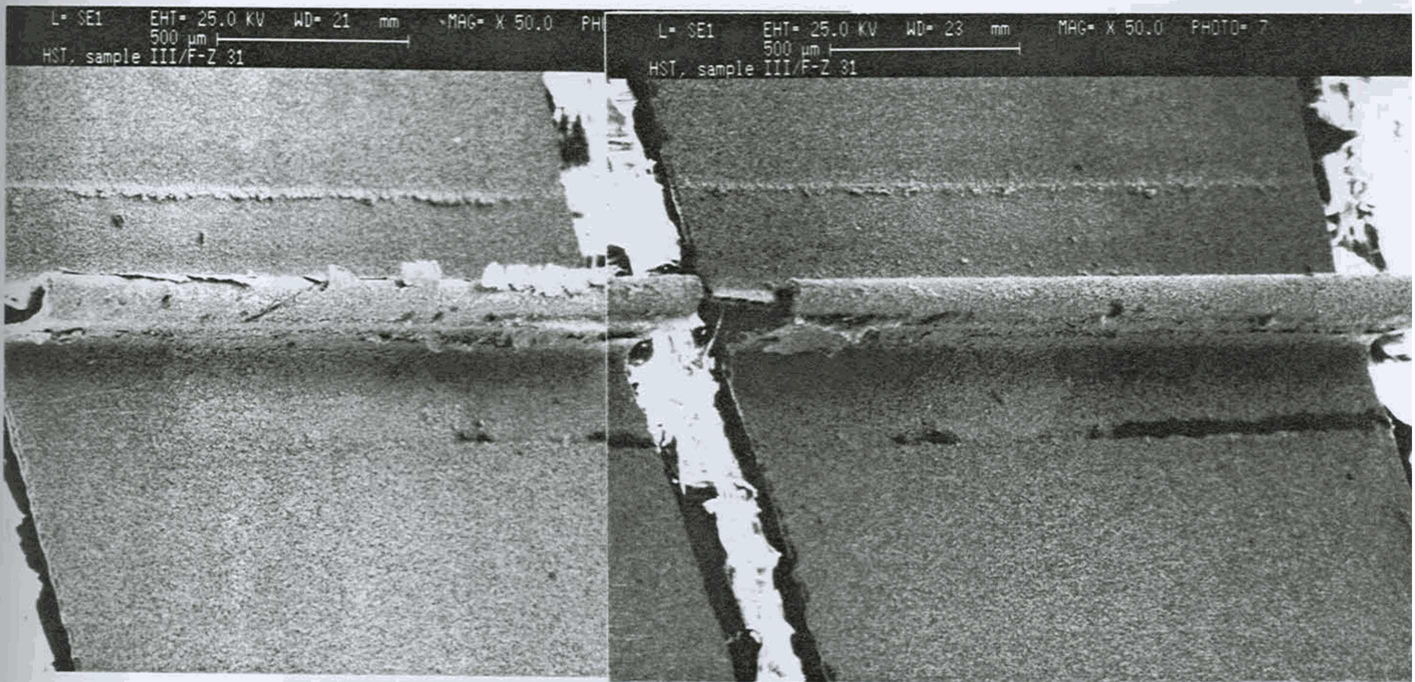

Figure 5. *Two stress relief loops on the same tapping bar (the two cells at both sides of these loops were removed). The left stress relief loop shows heavy flaking and in some places the silver is totally removed. The right one shows no flaking but an intact oxidised surface. The complete silver thickness (partially changed to oxide) is still present.*
Magn. X50

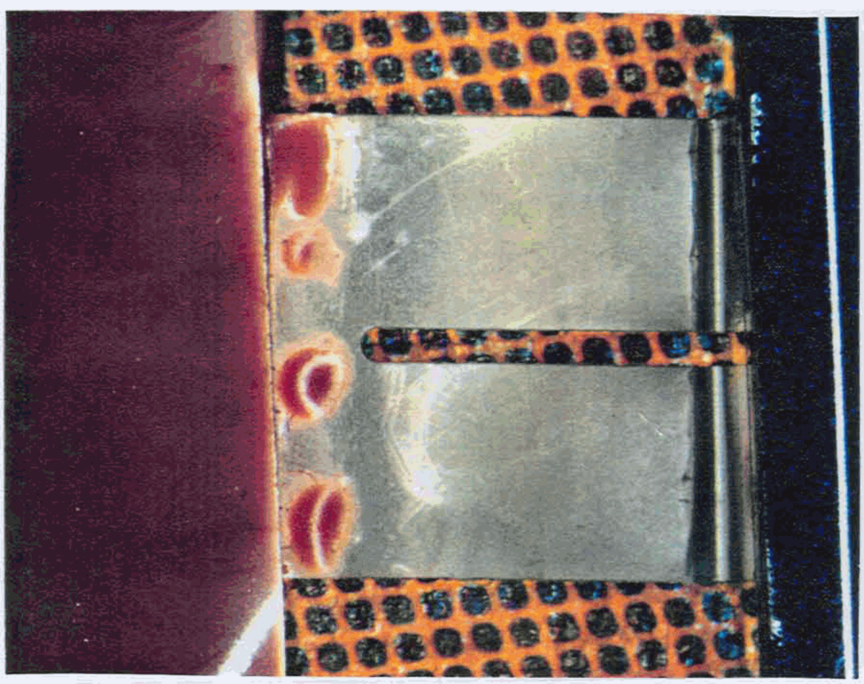

Figure 6. *Front side of tapping bar between solar cell and stiffener. The silver surface is slightly oxidised and no flaking is present.*
Magn. X12

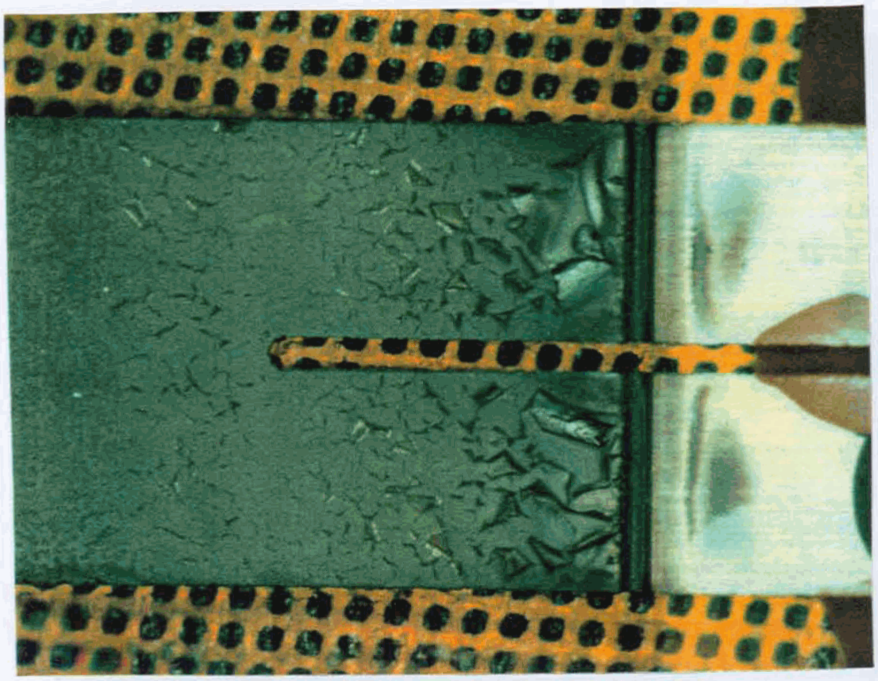

Figure 7. *Front side of tapping bar showing heavy oxidation with large flakes of silveroxide. The heaviest flaking has occurred close to the stress relief loop, further away the flakes are transformed to surface cracks.*
Magn. X12

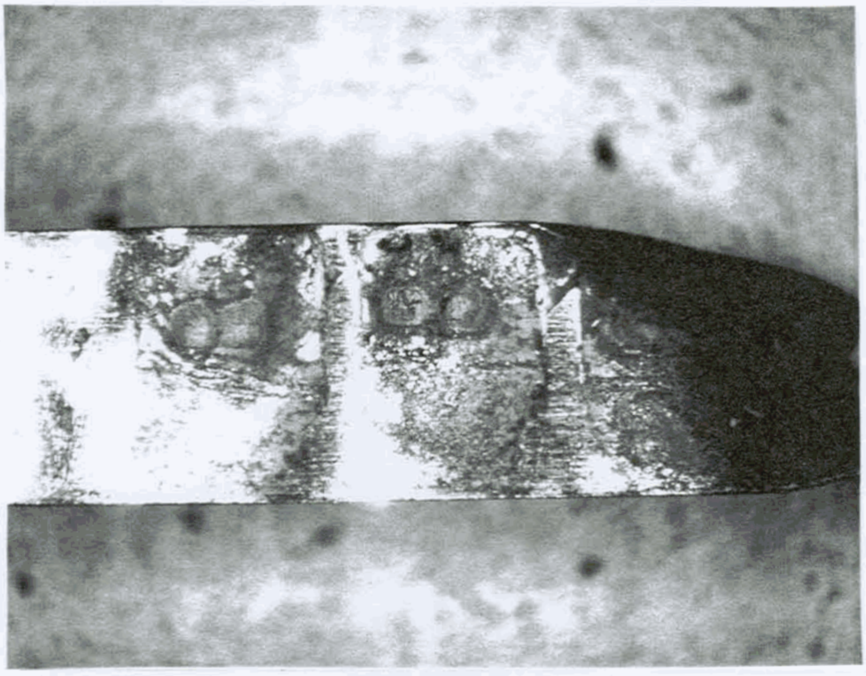

Figure 8. *Rear side of busbar after micrometeorite had impacted and lifted the busbar and detached a weld tab. Fresh silver surface from the previous weld is completely oxidised, while the surrounding area shows much less oxidation due to the presence of a silicone contaminant on the surface.*
Magn. X12

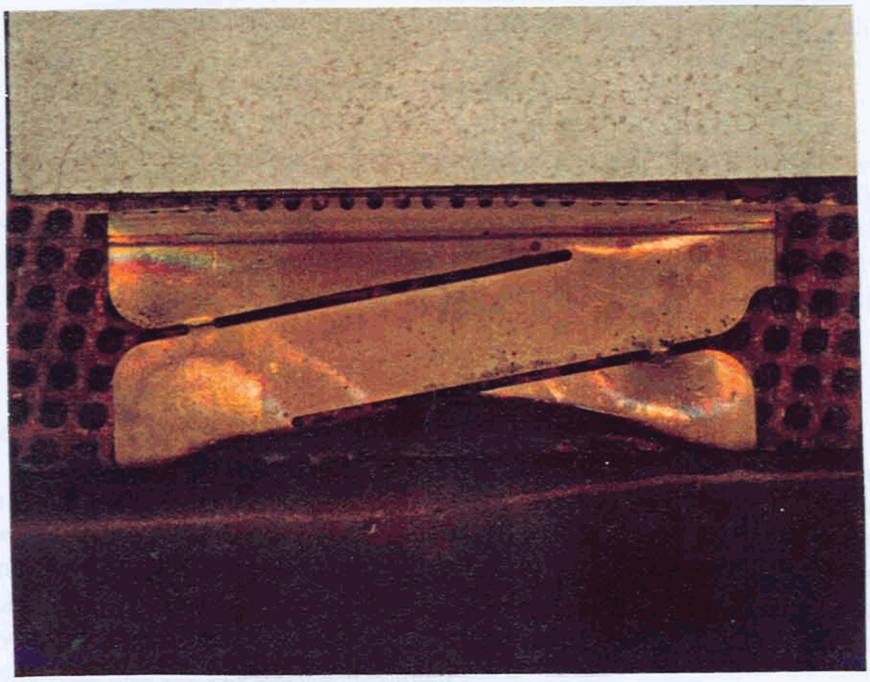

Figure 9. *Gold plated silver interconnects from diode. The gold surface shows some pit-like attack on the edges. The dots are associated with silveroxide from the bulk of the connector. Other stains originate from the presence of silicone on the surface. Magn. x12*