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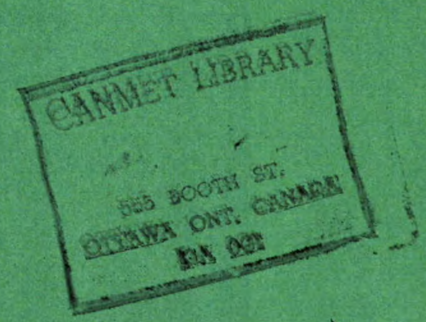
MINES BRANCH INVESTIGATION REPORT IR 58-125

SOLDERING OF COPPER-PLATED ALUMINIUM SHEETS

by

A. COUTURE

PHYSICAL METALLURGY DIVISION



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SOLDERING OF COPPER-PLATED ALUMINIUM SHEETS

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SUMMARY

Soldering tests were carried out on two series of copper-plated aluminium specimens. The tests were performed at 450, 350 and 250°C (840, 660, 480°F) for 1, 5 and 10 minutes. Reasonably good results were obtained after 1 minute at 350°C (660°F) and 1 and 5 minutes at 250°C (480°F). The first series of sheets submitted gave better adhesion than did the second set.

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INTRODUCTION

Three copper-plated aluminium sheet specimens were sent to the Physical Metallurgy Division of the Mines Branch, at Ottawa, by Mr. J.R. Johnson, Development and Promotion Section, Canadian Patents and Development Limited, National Research Building, 100 Sussex Drive, Ottawa 2, Ontario. In a telephone conversation with Mr. J.O. Edwards of the Physical Metallurgy Division, Mr. Johnson stated that difficulties had been experienced during the soldering of the copper-plated sheets and help was requested to overcome this problem.

Five additional copper-plated specimens were later submitted, with a covering letter (file number L44-4-1973) dated February 27, 1958. It was stated that these specimens were believed to be "very good from an adhesion standpoint" and it was requested that specimens of this second series be tested in the same way as were those of the first series.

TESTING PROCEDURE

Soldering tests were carried out on narrow specimens cut out of the copper-plated aluminium sheet panels submitted by Mr. Johnson. One end of these specimens was covered with a thin strip of resin-cored 50-50 solder (50 per cent lead and 50 per cent tin). The specimens were then heated in a furnace for 1, 5, or 10 minutes at a temperature of 450°, 350° and 250°C (840°, 660° and 480°F), and the excess of molten solder was shaken off. The soldered and unsoldered ends of all specimens were bent flat upon themselves (180° bend, zero radius). The specimens were then mounted in bakelite and prepared for metallographic examination. All tests on the first series of specimens submitted were

carried out on the same sheet, whereas, for the second series of tests, duplicate samples were taken from two different sheets.

METALLOGRAPHIC EXAMINATION

Unsoldered Material

Microscopic examination of the copper coatings revealed that the second series of specimens has a more uniform plating than the first series. The thinnest and thickest coatings are found in the first series. However, this appears to be the only visual difference between the two sets of specimens. Figure 1 indicates the appearance of the copper coating on the "as received" sheets. The unsoldered ends of all specimens, examined in the "as received" condition or after heating, had the same general appearance.

Soldering Tests at 450°C (840°F)

After 1 minute at 450°C the soldered copper coating could not withstand the bend test and flaked off badly in the bend area. In that region the base metal is completely bare, as shown by Figure 2. The straight portions of the soldered strips still show apparent adhesion between the copper coating and the base metal in places (Figure 3), although areas similar to that represented in Figure 4 are very common. Figure 5 shows a region where the solder penetrated the copper coating and lifted it off the base metal. An extreme case is shown in Figure 6 where the copper coating has been almost completely dissolved by the solder, leaving only faint traces of the former plating. Where the copper coating has been preserved a dark alloy layer is seen between copper and solder (Figures 3, 4 and 5).

Essentially the same remarks apply to the specimens that were heated at 450°C for 5 minutes, with the exception that solution of the

copper is more advanced and the alloy layer is probably thicker than in the 1 minute specimen. In view of the above results, no tests were carried out at 10 minutes.

A typical difference between the first and second series of copper-plated specimens is that solution of the copper plating is definitely not as pronounced in the second series as it is in the first series. Although the reason for this is unknown, this difference is probably due to a variation in the chemical analysis or in the structure of the copper coatings.

Soldering Tests at 350°C (660°F)

Heating for 1 minute at 350°C produces very good results in the first series of specimens submitted. The copper coating still adheres to the base metal over the whole soldered surface. In the bend area, however, the copper plating is broken up but the broken pieces of plating are covered with solder and still adhere to the base metal (Figure 7). This shows good adhesion between base metal and copper. In the second series, however, the soldered copper coating flaked off in the bend area, although it appears to be satisfactory in the straight portions of the specimens.

After 5 minutes at 350°C the copper coating was partially dissolved in places in the specimen from the first series, as shown in Figure 8. Specimens of the second series did not show solution of the copper coating. Copper apparently adheres to the base metal in the straight parts of the specimens (Figure 9) but it flaked off badly during bending (Figure 10). Essentially the same remarks apply to the 10 minute specimens.

It has been found in these tests that the thickness of the

alloy layer at the copper-solder interface increases with increasing time at temperature. Long needles, presumably of a copper-tin intermetallic compound of the same nature as the alloy layer, have grown into the solder as shown in Figure 11. Smaller crystals can also be seen in the specimens that were heated for 5 minutes at 450 or 350°C. In Figure 11 an alloy layer can be seen on both sides of the copper coating, indicating that the solder got under the copper plating. In this particular area there is no adhesion at all between the copper plating and the base metal.

Soldering Tests at 250°C (480°F)

Specimens of the first series that were heated for 1 or 5 minutes at 250°C gave essentially the same results as those treated at 350°C for 1 minute. After 10 minutes at 250°C the adhesion is still generally good (Figure 12). In the bend area the soldered copper coating tended to come off the base metal, although broken pieces of copper still adhere to the base metal and are covered with solder.

Specimens from the second series behaved differently. One of the two specimens heated at 250°C for 1 minute showed reasonably good adhesion in the bend area, while in the other the copper coating came off completely in the bend area. Specimens heated for 5 and 10 minutes did not show any adhesion in the bend area. The base metal is completely bare. One of the 10-minute specimens shows a considerable amount of solder between the copper coating and the base metal.

The 10-minute specimens show a few fine crystals which are apparently of the same type as presented in Figure 11.

Bend Tests on Unsoldered Ends

All the unsoldered ends of the specimens, soldered as detailed above, successfully withstood the bend test. There was some cracking of the copper coating, but it adhered to the underlying aluminium.

DISCUSSION

From the soldering tests described in this report, it appears that there exists for soldering copper-plated aluminium sheets a maximum temperature and soaking time above which the copper coating is likely to flake off during a subsequent bending operation. A soldering temperature of 450°C is obviously too high to produce satisfactory results, even if the soaking time is as short as 1 minute. At 350°C, reasonably good results were obtained on the first series of samples submitted by Mr. Johnson, when the soaking time was of the order of 1 minute. The length of time at 250°C could be increased to 5 minutes in the first series with satisfactory results. However, a treatment of 10 minutes was already unsafe. Diffusion of the soldering alloy is obviously taking place through the copper cladding. Optimum results are obtained when solder diffuses only enough to produce good adhesion between solder and copper coating. If the solder diffuses as far as the interface between cladding and base metal, adhesion is destroyed. In extreme cases solder will get under the copper coating and lift it off the base metal. This may be by penetration of the plate or by seepage under the edges.

The first series of sheets sent to this Division was better than the second one for adhesion after the bend test. In the second series only one specimen, heated one minute at 250°C, gave satisfactory results after the bend tests. The soldered copper cladding flaked off badly in all the other specimens. Another difference between these two series of specimens is that, although their claddings are essentially of the same thickness, the copper coatings of the first series have a greater tendency to be dissolved by the solder than have the coatings

of the second series.

There is formation of an alloy layer at the interface between copper and solder, and the thickness of that layer increases with increasing soaking time. In the specimens heated for 10 minutes at 350°C, large needles have grown through the solder layer. The size and occurrence of these crystals increase with temperature and length of time at a given temperature.

In general, no difficulty was experienced in "tinning" the copper plating with the solder, but it will be seen from the above that the adhesion of the copper plate to the aluminium sheet was somewhat variable even under optimum conditions.

CONCLUSIONS

From the tests carried out in this experimental work, it appears that:

a) Soldering at 350°C (660°F) with the solder in the molten state for 1 minute, and at 250°C (480°F) for 1 to 5 minutes, produced reasonably good results.

b) In general, the first series of copper-plated sheets submitted gave better adhesion than did the second set.

c) It is apparent from the above that while it should be possible to make such soldered joints as electrical connections, strong mechanical joints to resist flexure, bending or vibration may not be so satisfactory.

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(Figures 1 to 12 follow, on pages 7 to 10.)

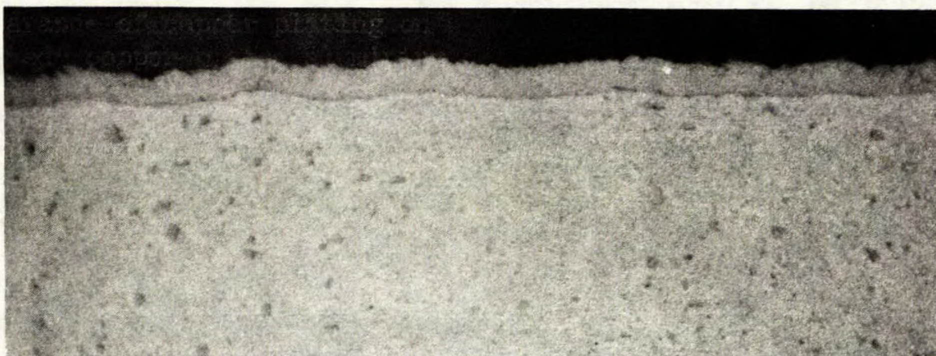

Fig. 1. - Appearance of copper plating on "as received" copper-plated aluminium sheets.

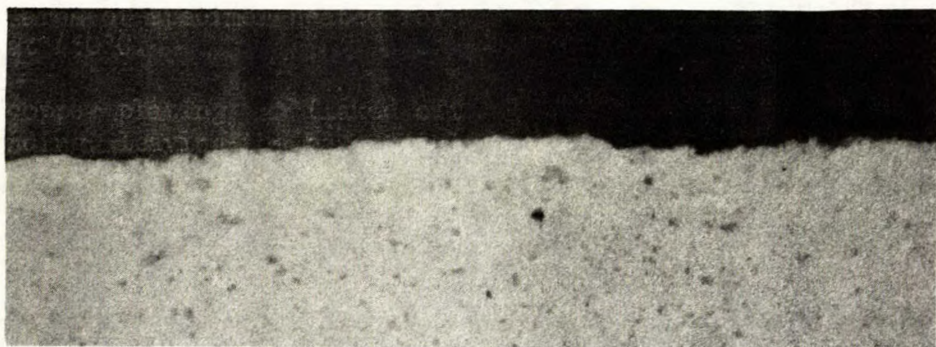

Fig. 2. - Bend area of specimen heated for 1 minute at 450°C.

The copper plating has flaked off during bending, leaving the base metal bare.

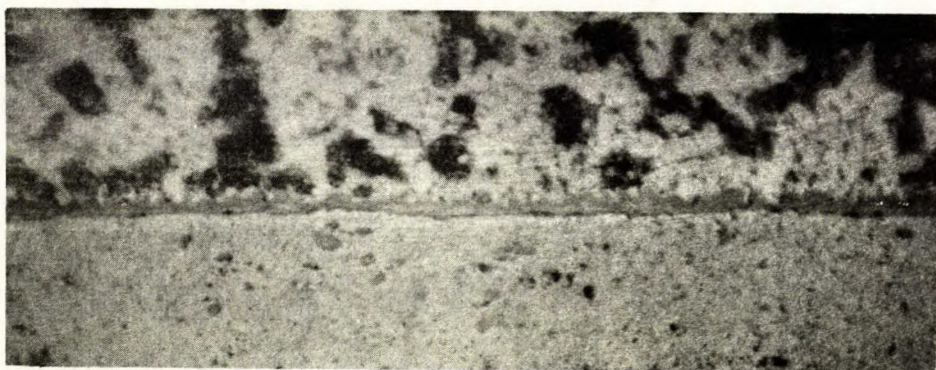

Fig. 3. - Straight portion of specimen heated for 1 minute at 450°C.

The soldered copper plating (upper part of picture) apparently adheres to base metal. Note dark alloy layer in top part of plating.

(All at X750, unetched)

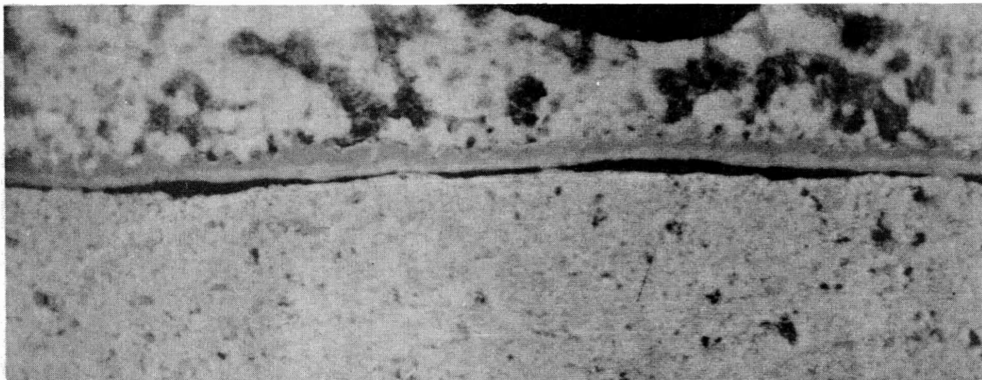

Fig. 4. - Specimen heated for 1 minute at 450°C.

This shows lack of adhesion between soldered copper plating and base metal.

Fig. 5. - Specimen heated for 1 minute at 450°C.

In this area some solder penetrated the copper plating and lifted it off the base metal.

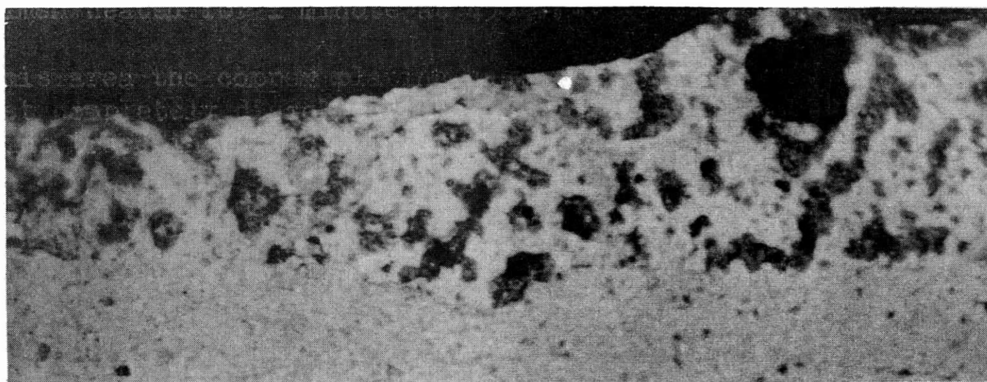

Fig. 6. - Specimen heated for 1 minute at 450°C.

In this area the copper plating has been almost completely dissolved, leaving a very faint trace in the solder layer.

(All at X750, unetched)

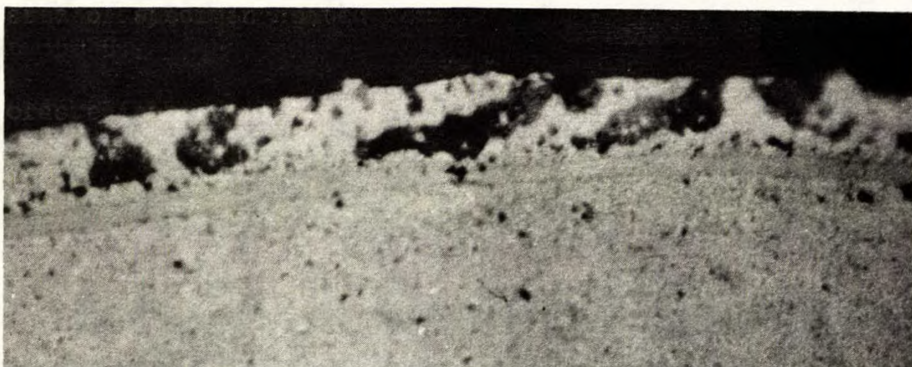

Fig. 7. - Bend area of specimen heated for 1 minute at 350°C.

The soldered copper plating still adheres to the base metal.

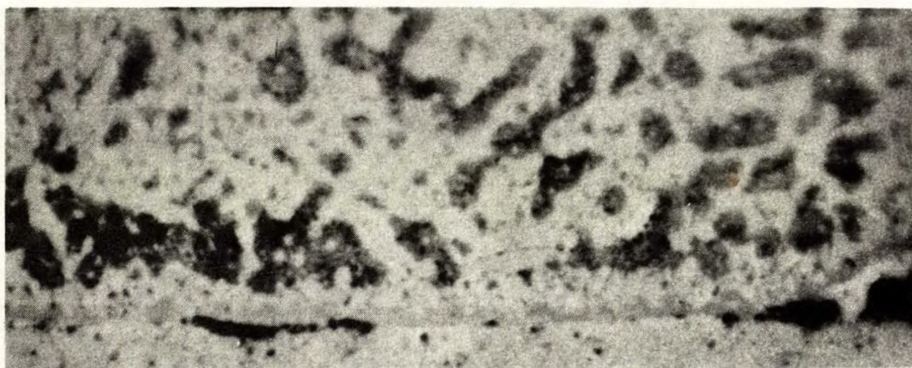

Fig. 8. - Specimen heated for 5 minutes at 350°C.

The copper plating has been almost all dissolved in places.

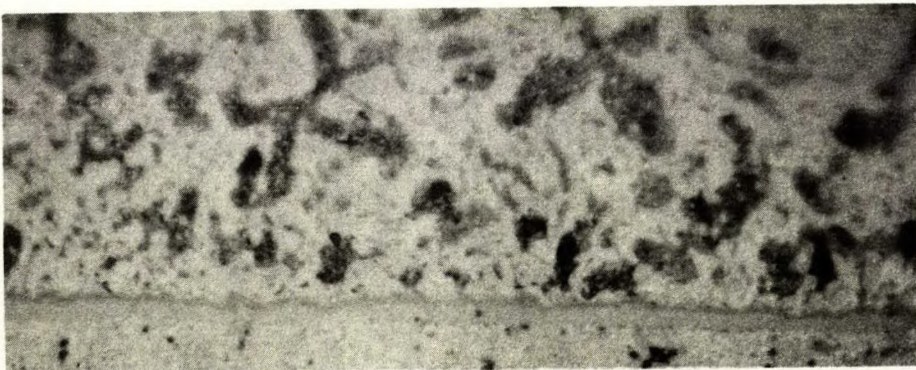

Fig. 9. - Specimen heated for 5 minutes at 350°C.

In some areas the soldered copper plating apparently adheres to the base metal.

(All at X750, unetched)

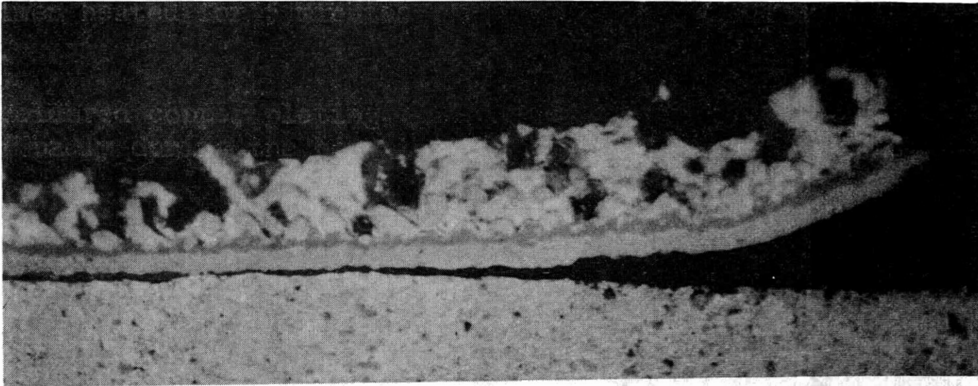

Fig. 10. - Specimen heated for 5 minutes at 350°C.

The soldered copper plating flaked off badly during the bend test.

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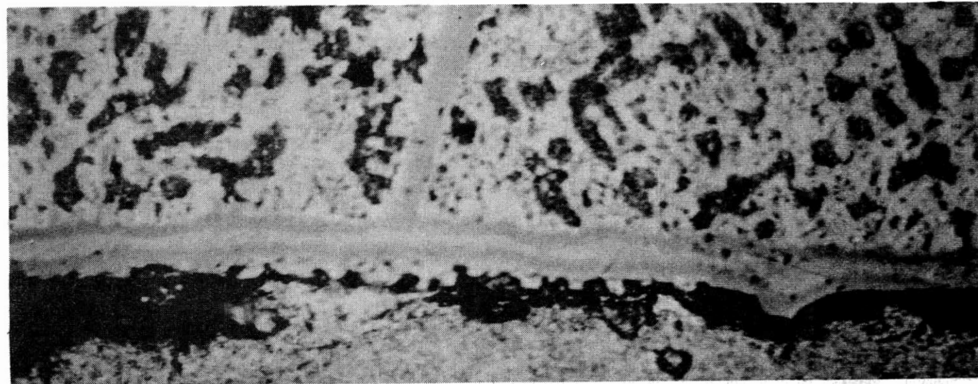

Fig. 11. - Specimen heated for 10 minutes at 350°C.

The alloy layer is thicker than in Fig. 10. Note alloy layer on both sides of the copper plating. Huge crystals have grown into the solder layer.

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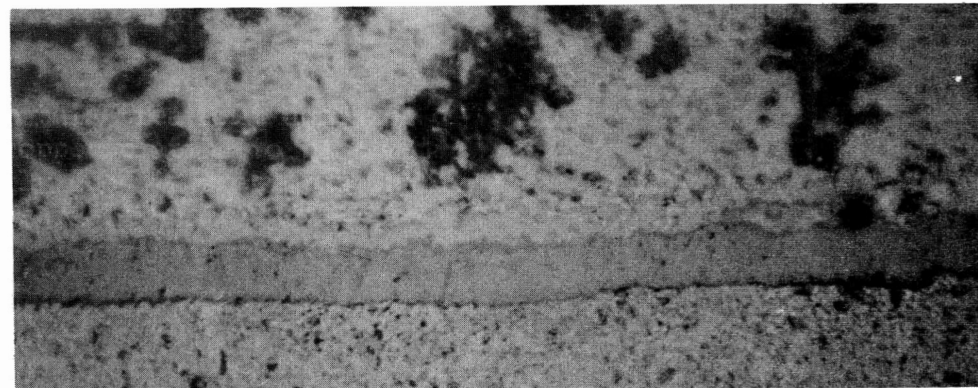

Fig. 12. - Specimen heated for 10 minutes at 250°C.

After this treatment adhesion of soldered copper plating to base metal is generally good in specimens from the first series.

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(All at X750, unetched)

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