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MIGRATION OF SILVER THROUGH GOLD PLATING ON ELECTRICAL CONTACTS

Stewart B. Tulloch, et al

Army Missile Command
Redstone Arsenal, Alabama

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AD

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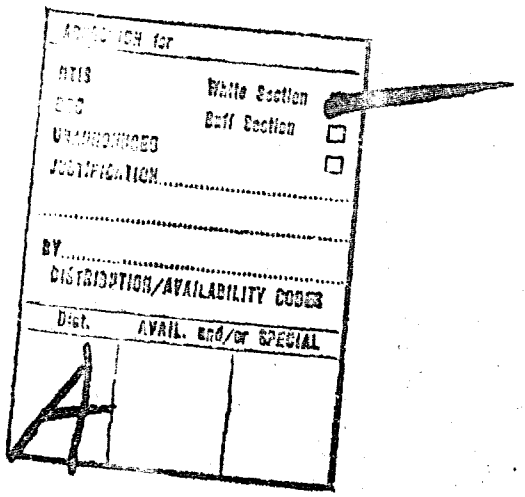

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Comparisons are made between the corroded pins and newly produced nickel flash underplated pins.

Details of illustrations in this document may be better studied on microfiche

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and Engineering Laboratory
US Army Missile Command
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ACKNOWLEDGMENTS

The assistance of Mr. Ray Parker of the Ground Equipment and Materials Directorate in preparation of photographs and the contribution made by Messrs. Robert Clem and Charles Hendrix from the Directorate for Product Assurance in the electron microanalysis of the migrated crystalline materials are gratefully acknowledged.

FOREWORD

This investigation was inaugurated as the result of a problem, presented by the CHAPARRAL FAAR Project Office, regarding badly contaminated electrical angle connector pins. The project office was concerned with the possibility that the use of these connectors would be detrimental to the satisfactory operation of the Forward Area Alerting Radar equipment.

Examination of some 26 connectors containing 18 pins each, and randomly chosen from a stock of approximately 30,000 parts, was conducted using a Spencer 10/15X stereomicroscope, a Bausch and Lomb balphot metallograph and macrocamera, and a Cambridge Stereoscan S-4 scanning electron microscope.

This work demonstrates the inadvisability of using silver as a direct underplate to gold for electrical/electronic contact surfaces.

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1. INTRODUCTION

A prevalent problem with silver underplating of electrical contacts is the tendency of the silver to migrate through the porous gold overplate. Because of this proclivity, the use of silver as an underplate to gold is strongly discouraged as an option in military specifications covering connector pins and printed circuit board contacts.

This inclination of silver to migrate was brought to attention rather forcibly when an angle connector scheduled for use in a radar system was observed to have a black-appearing smut or tarnish on the pins. Whether or not this apparent deteriorated condition would interfere with the utility of the connector was questioned.

A rather extensive examination of the problem was conducted and is documented by this report.

2. DISCUSSION AND RESULTS

A visual examination of the pins in the initially submitted connector indicated a somewhat hairy appearing deposit on all of the pins. Closer scrutiny under a small 14X magnifier revealed the crystalline form of the hairy particles. A more meticulous perusal with a Spencer stereomicroscope showed the individual protrusions in great quantity (Figure 1, macrocamera photograph). When observed under higher magnification, Figure 2, the deposits were seen to range from a massive agglomeration of vitriform nodules at the base of the pins to long whisker-like crystals of presumarly silver and silver salts up the length of the pin, Figure 3. When slightly turned, the pin showed different lengths of crystals, Figure 4.

One of the pins, inspected under higher magnification, gave evidence of the gold plate having flaked off, Figure 5, apparently due to the loss of adhesion because the silver underplate had so completely migrated, leaving a void under the gold.

A companion connector, submitted with the badly tarnished pin connector, appeared, on visual inspection, to be free from tarnish. However, microscopic examination revealed fine whiskers of migrated silver on numerous pins, Figure 6. Higher magnification, Figure 7, confirmed the presence of migrated silver rather than trash contamination of the pin.

It was reported that thousands of these connectors were in depot storage, having been procured per specification MIL-C-55181 prior to 1968, and that a large quantity was in the same tarnished condition as the badly corroded connector submitted to us. There was, however, about one-third of those in stock that appeared to be free of contamination.

Since there was such a profusion of corrosion on the originally submitted item, a request was made to submit more connectors in each condition for a closer and more extensive inspection. Subsequently, a dozen of each type was made available for analysis.

Upon receipt of the two dozen connectors, it was found that practically all the pins in the connectors showing visual contamination were profusely covered with the black deposits on the male (pin) side. Furthermore, many of them had considerable whisker growth on the wire connection side of the pins in the internal areas of the connector. Also, the potting material surfaces had a profusion of bright particles adhering to them, which were evidently crystals that had shattered from the pins. This condition could be quite detrimental to the integrity of the connectors in that they could provide a shorting path between the pins.

A large majority of the pins in connectors that were visually bright and seemingly free of tarnish was found, under microscopic examination, to show definite evidence of silver migration with slight whisker growths. These aristae were apparently just beginning to appear, being widely dispersed with only a few short crystals protruding through the pores of the gold top plate, as shown in Figure 8.

This preliminary examination of the electrical connectors was followed by inquiries about the plating requirements of a large number of military specification connectors and electrical contact devices. It was determined that prior to 1968 most of these specifications did not specify the composition of the underplate. Consequently, large numbers of connector pins were underplated with silver. However, in April 1968, MIL-C-55181 was amended to stipulate that "All contacts shall be gold plated over nickel flash in accordance with MIL-G-45204, type II...," thus eliminating the possible use of silver. There are numerous other connector specifications that specifically prohibit the use of silver as an underplate or require a "flash" or more of nickel, while others call for a double gold plate over a copper flash or directly onto the copper alloy basis metal.

The photographs of aristae, as typified by Figure 9, as well as the forgoing photographs, were developed with a Bausch and Lomb macrocamera at magnifications ranging from 12X to 45X. A more precise examination of individual particles and groups, using the electron microscope, was subsequently pursued.

Photographs (Figures 10 through 29) typical of the migrated crystalline growths were produced at varying magnifications with the Cambridge Stereoscan S-4 scanning electron microscope and are inscribed with self-explanatory captions.

In an attempt to determine the appearance of the gold plate where the crystals began to emerge, an area shown in Figure 30 at 2000X magnification was found. The area to the right in Figure 30 was brought into closer focus at 650X magnification to provide a better look at the hole (Figure 31).

A recommendation was made to acquire new connectors in accordance with the amended MIL-C-55181 specification in order to obtain assurances of long-term workable equipment. The procuring agency contracted for a quantity of such connectors and supplied a dozen for evaluation.

Upon receipt of the new connectors, a microscopic inspection was conducted which indicated that these were acceptable. However, one connector was dissected and a pin examined with the electron microscope, resulting in some peculiar photographs. Figure 32, at 62X, shows the top of a new pin. There appears to be a considerable amount of trash clinging to the sides of the pin (it was not cleaned for fear of removing any crystalling growths that might be present). Also there was a knot on the top and indentations around the upper end, which are apparently machine marks underlying the plating.

A higher magnification (250X) gives a closer look at the knot, Figure 33. It also shows a small projection on this bump and what seems to be a crack in the plating down the middle of the photograph.

Raising the magnification to 625X, Figure 34, the edge of the knot is brought into better focus, and what appears to be a hole at the base can be observed.

The protrusion on the top of the knot is enlarged also, and could be a bit of trash. However, higher magnification at 2400X, Figure 35, makes it appear to be an intimate part of the pin. Figure 36, from a different angle at 6000X apparently verifies it. However, focusing on the base of the protrusion at 6000X, Figure 37, confirms definitely that it is indeed firmly adhered to the pin.

Pursuing the possibility of a hole in the plating between the knot and the pin, a little more light thrown on the area at 625X magnification, Figure 38, reveals that it is only a depression.

What appeared to be a crack in the plating is shown to be only an overlayer of the plating, as observed by Figure 39 at 625X magnification.

Figure 40, 1230X magnification, shows what ostensibly is a gouge in the gold plate, probably caused when the pin was being removed from the connector and indicates how easily the gold plating can be damaged.

In order to define the plating layers of the two differently plated pins, i.e., silver and nickel underplates, both were sectioned and mounted. However, problems arose when attempting to polish the mount. The gold layer, being soft, tended to smear so that a clear picture of the underplate could not be obtained. Subsequently, in order to anchor the plate, the pins were overplated with electroless nickel. But this procedure did not help the situation with the badly corroded pins because apparently the silver layer had almost completely migrated, leaving the gold layer as a shell very loosely adhered to the brass core. The electroless nickel plating caused a complete detachment of the gold, as illustrated by Figure 41, wherein the cross-hatched center is the pin. The broken dark pieces are gold plate, and the light area surrounding it all is electroless nickel plate that has filled in the voided area and overcoated the gold pieces.

A pin from an original specification connector that had just begun to show silver migration was copper overplated and mounted. This effort was rewarded by providing Figure 42 (280X magnification on the Balphot metallograph). The large area at the bottom is the brass pin. The next layer is the silver plate, which has mostly disappeared in the center, apparently due to migration through the next layer, which is the gold plate. This gold layer appears to be somewhat porous. The wide, broken layer is the copper overplate.

Pins from the new connectors with nickel flash underplating the gold, and electroless nickel overplated, when examined with the metallograph, gave results as seen in the next two picutres. Figure 43, 1000X magnification, from left to right shows the dark portion as the brass pin, the faint thin next layer as the flash nickel plate, the light wide band as the gold plate, the band next to it, defined by the dark line, as the electroless nickel outer plate, and the wide light-streaked portion in the picture as the mounting plastic. Figure 44, 1000X magnification, defines the electroless nickel layer somewhat more clearly.

An analysis with the electron microscope of the migrated crystals, Figure 45, revealed that they are composed mostly of silver and silver sulfide with possibly some silver oxide. Figure 46 shows an integrated plot versus energy of crystals and the gold background of a pin. The dots in the photograph are produced by the gold. The short barred peak is the sulfur and the tall barred peak represents the silver and silver salts.

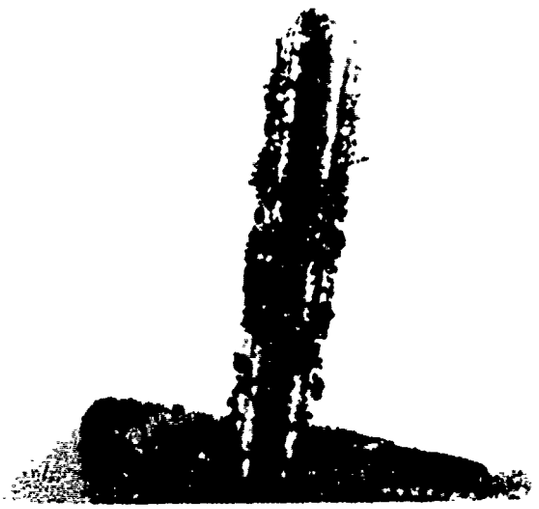
Figure 47 is a density plot at the gold energy level. The bare area is devoid of gold or blanked out by another substance. Figure 48 is a density plot of the same area at the silver energy level, such that the denser dotted area shows the amount of excess silver. These figures and analyses confirm the original supposition that the black metallic deposits on the pins are the result of corrosive/galvanic migration of the silver underplate through the porous gold top plate.

3. CONCLUSIONS

This exercise is proof positive that silver should be scrupulously avoided as direct underplate to gold on electrical/electronic equipment.

Although a majority of the connectors were originally packaged in the Marvelseal 1312 envelopes per MIL-B-131E, class II, in September 1968 and resealed in the same type packages in April 1970, apparently this packaging did not prevent silver migration from developing.

It is further indicated that these conditions could contribute to faulty operation of equipment by the shattering of the corrosion products from the gold surfaces or the flaking of the gold plate from the pins to form bridges between pins or contacts, thus causing shorting and/or poor electrical contacts.



FIGUHE 1. PHOTOMACROGRAPH OF A CONTAMINATED CONNECTOR PIN SHOWING THE GREAT QUANTITY OF PROTRUSIONS AT 12X MAGNIFICATION.

FIGURE 2. PHOTOMACROGRAPH OF A CONTAMINATED CONNECTOR PIN DEMONSTRATING THE MASSIVE AGGLOMERATION OF VITRIFORM NODULES AT BASE OF PIN. MAGNIFICATION 40X.

FIGURE 3. PHOTOMACROGRAPH OF A PIN DEPICTING THE LONG WHISKER-LIKE CRYSTALS UP ITS ENTIRE LENGTH. MAGNIFICATION 40X.

FIGURE 4. PHOTOMACROGRAPH OF THE ABOVE PIN SLIGHTLY TURNED TO SHOW THE DIFFERENT CONFIGURATIONS OF THE CRYSTALS. MAGNIFICATION 40X.

FIGURE 5. PHOTOMACROGRAPH TAKEN NEAR BASE OF PIN INDICATING AN AREA WHERE GOLD PLATE HAS FLAKED FROM IT. MAGNIFICATION 45X.

FIGURE 6. PHOTOMACROGRAPH OF LEAST CONTAMINATED PIN EVIDENCING FINE WHISKER GROWTH, INDICATING THE BEGINNING OF SILVER MIGRATION. MAGNIFICATION 12X.

FIGURE 7. PHOTOMACROGRAPH CLOSE-UP OF FINE WHISKERS SHOWN IN FIGURE 6. MAGNIFICATION 35X.

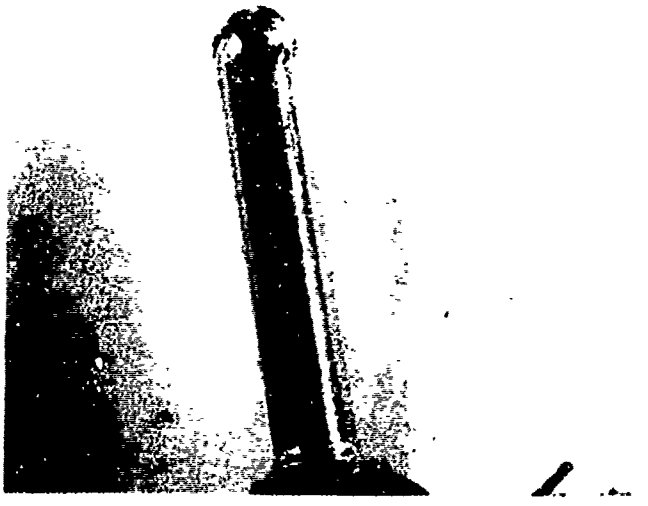


FIGURE 8. PHOTOMACROGRAPH OF VISUALLY BRIGHT PIN DISPLAYING ARISTAE JUST BEGINNING TO APPEAR ON THE TIP. MAGNIFICATION 12X.

FIGURE 9. PHOTOMACROGRAPH OF LONG ARISTAE PROTRUDING FROM THE UPPER HALF OF A PIN. MAGNIFICATION 40X.

FIGURE 10. ELECTRON MICROGRAPH OF A SILVER MIGRATION CONTAMINATED CONNECTOR PIN DISCLOSING THE HAIRY APPEARANCE OF THE PROTRUSIONS. MAGNIFICATION 200X.

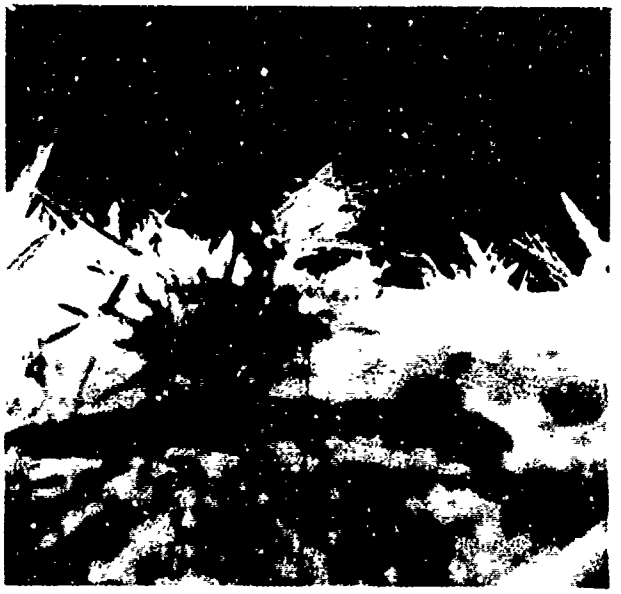


FIGURE 11. ELECTRON MICROGRAPH OF A PIN'S SURFACE DISCLOSING A PROFUSION OF SILVER/SILVER SALT CRYSTALLINE SHAPES. MAGNIFICATION 325X.

FIGURE 12. ELECTRON MICROGRAPH REVEALING THE INTRICATE SHAPE OF THE CENTRAL GROWTH IN FIGURE 11 AT A MAGNIFICATION OF 650X.

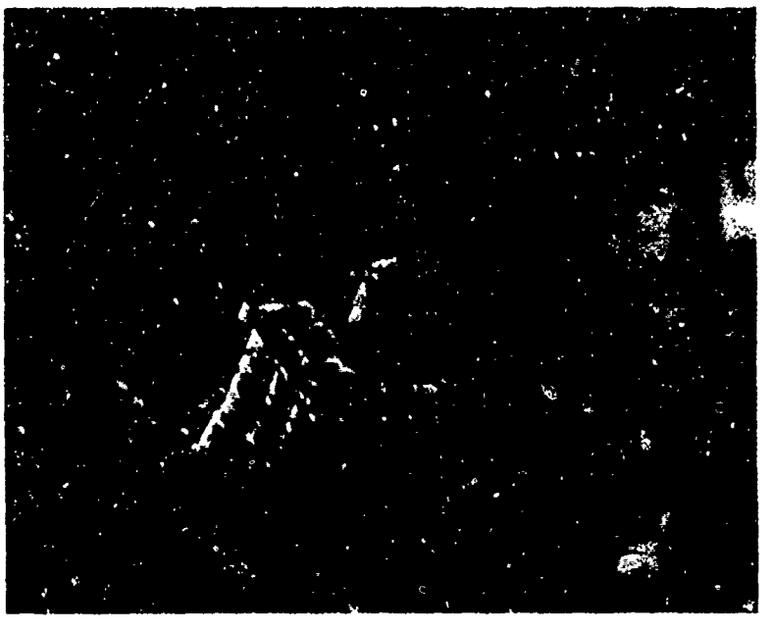


FIGURE 13. ELECTRON MICROGRAPH DISPLAYING THE ELABORATE CONVOLUTION OF CRYSTALLINE GROWTH. MAGNIFICATION 1300X.

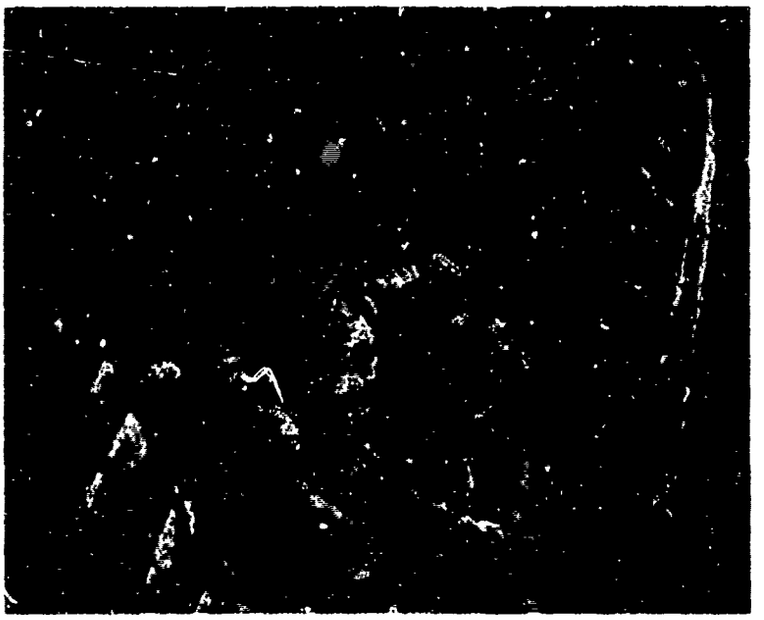


FIGURE 14. ELECTRON MICROGRAPH DISPLAYING INTIMATE DETAILS OF THE CRYSTAL ARRANGEMENTS OF ARISTAE UNDER A MAGNIFICATION OF 3600X.

FIGURE 15. ELECTRON MICROGRAPH. DISPLAYS A CHRYSANTHEMUM-LIKE GROWTH WITH THE WIDE SHARP POINTED PETALS. MAGNIFICATION 200X.

FIGURE 16. ELECTRON MICROGRAPH. A MORE INTIMATE LOOK AT THE CHRYSANTHEMUM GROWTH REVEALING DEWDROP ON THE PETALS. MAGNIFICATION 500X.

FIGURE 17. ELECTRON MICROGRAPH. A CLOSE-UP LOOK AT THE TIP OF THE FLOWER PRESENTS THE FAN-LIKE SHAPE OF THE END CRYSTAL. MAGNIFICATION 500X.

FIGURE 18. ELECTRON MICROGRAPH OF THE SPIKE-LIKE CRYSTALS IN A FERN FOREST. MAGNIFICATION 250X.

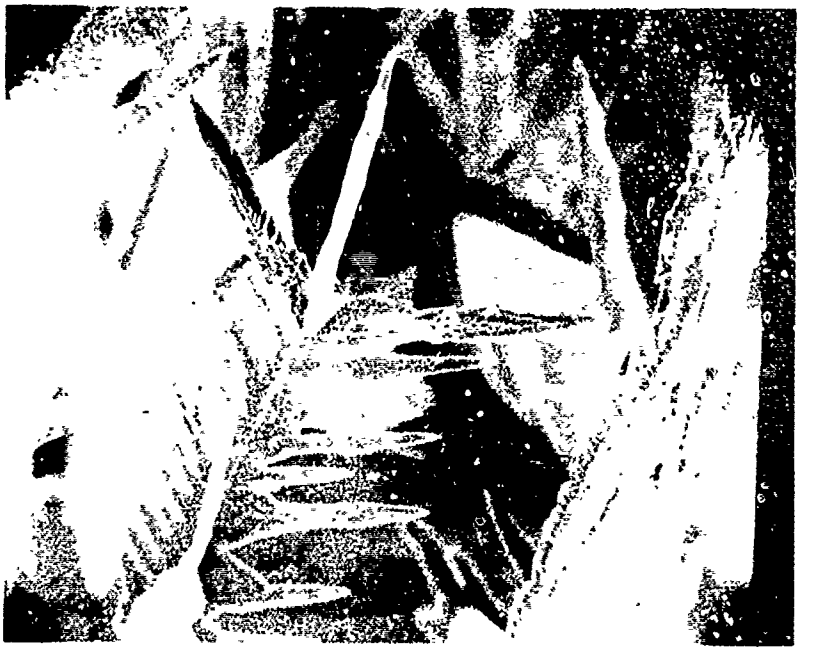


FIGURE 19. ELECTRON MICROGRAPH. DELINEATES THE UNEVEN DEVELOPMENT OF FERN FRONDS. MAGNIFICATION 1900X.

FIGURE 20. ELECTRON MICROGRAPH. EXHIBITS A CORAL-LIKE STRUCTURE OF SILVER/SILVER SALT CRYSTALS. MAGNIFICATION 1300X.

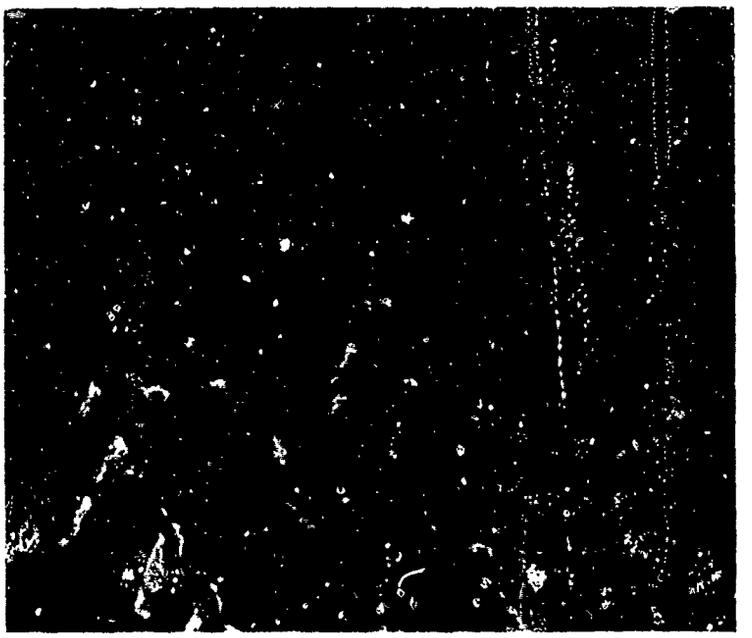


FIGURE 21. ELECTRON MICROGRAPH. THIS IS THE SAME GROWTH AS FIGURE 20, AT HIGHER MAGNIFICATION – 2600X.

FIGURE 22. ELECTRON MICROGRAPH. DEPICTS THE PROFUSION OF NEEDLE-LIKE APPEARING CRYSTALS SEEN UP THE SIDES OF A PIN. MAGNIFICATION 200X.

FIGURE 23. ELECTRON MICROGRAPH. PORTRAYS THE BRANCHING AT THE TIP OF A NEEDLE-LIKE CRYSTALLINE PROTRUSION. MAGNIFICATION 500X.

FIGURE 24. ELECTRON MICROGRAPH. SHOWS A PROFUSION OF SHAPES EMERGING FROM A FERN FOREST. MAGNIFICATION 200X.

FIGURE 25. ELECTRON MICROGRAPH. OUT OF THE FERN FOREST EMERGES A CHRISTMAS-TREE-LIKE GROWTH IN THE BACKGROUND AND A SPIRE PROTRUDES IN THE FOREGROUND. MAGNIFICATION 200X.

FIGURE 26. ELECTRON MICROGRAPH. SHOWS THE TOP OF THE CHRISTMAS TREE (FIG. 25) WITH BEAD DECORATION AND FLOWER JUST BELOW THE TIP. MAGNIFICATION 500X.

FIGURE 27. ELECTRON MICROGRAPH. THE CHRISTMAS TREE (FIG. 25) EXHIBITS THE BEADED AREA LOOKING MORE LIKE ROUGH DIAMONDS WITH THE FLOWER AT THE TOP AN ORCHID. MAGNIFICATION 1000X.

FIGURE 28. ELECTRON MICROGRAPH. A DIFFERENT ANGLE MAKES THE CHRISTMAS TREE APPEAR TO BE JUST A FERN FROND WITH GRAINS OF SAND. MAGNIFICATION 800X.

FIGURE 29. ELECTRON MICROGRAPH. DELINEATES THE CENTER OF THE SPIRE FROM FIGURE 25, SHOWING THE UNIQUE COMPLEXITY OF CRYSTALS MAKING UP THE CRYSTALLINE PROTRUSION. MAGNIFICATION 1000X.

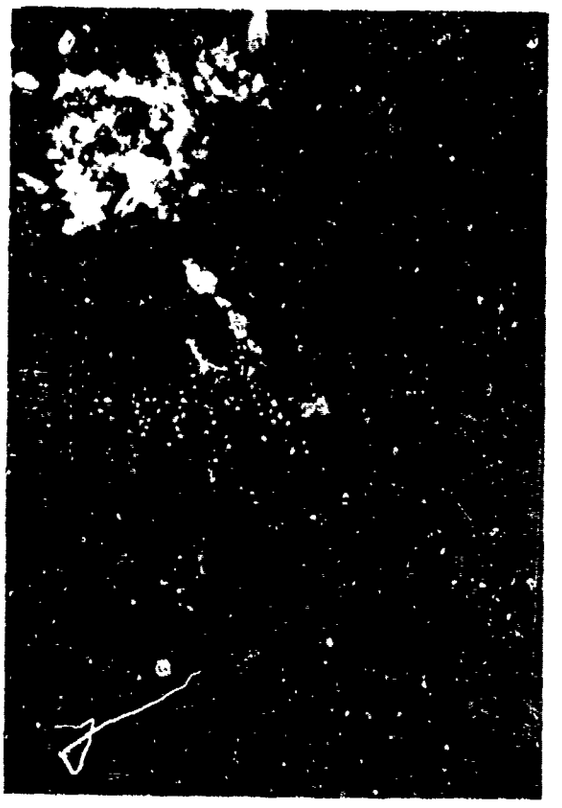


FIGURE 30. ELECTRON MICROGRAPH. AN AREA OF GOLD PLATE WITH CRACK AND EMERGING SILVER/SILVER SALTS. MAGNIFICATION 2000X.

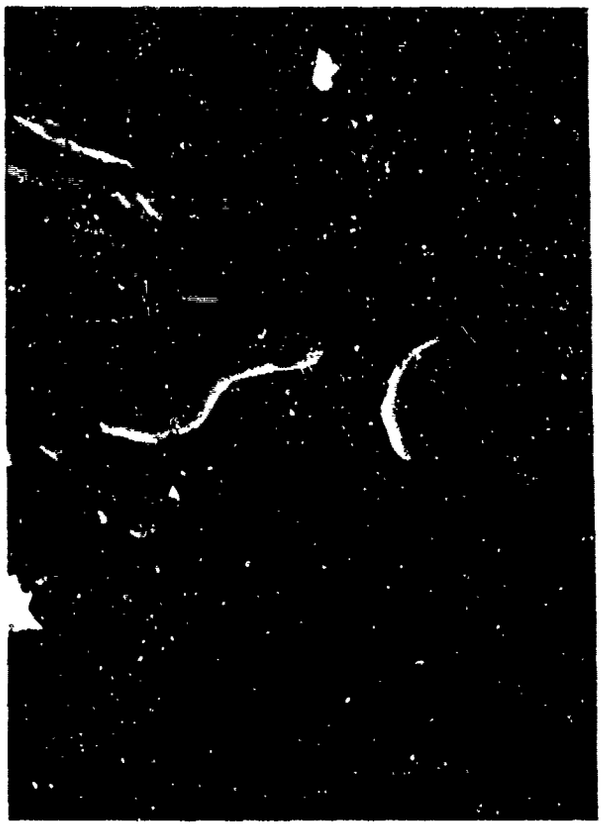


FIGURE 31. ELECTRON MICROGRAPH. A CLOSER FOCUS ON THE AREA SHOWN IN FIGURE 30 PROVIDES A PICTURE OF THE HOLE THROUGH WHICH SILVER MIGRATES. MAGNIFICATION 650X.

FIGURE 32. ELECTRON MICROGRAPH. DEPICTS THE TIP OF A NEW CONNECTOR PIN WITH TRASH CLINGING TO IT. MAGNIFICATION 62X.

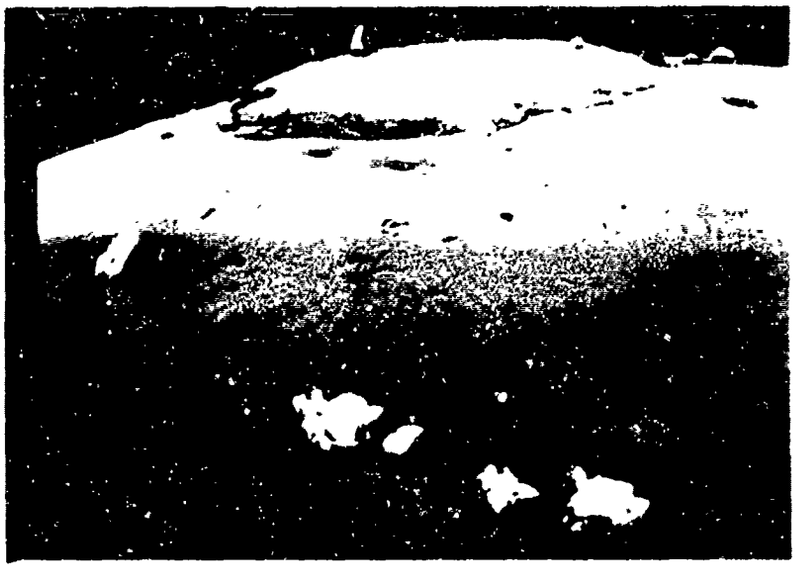


FIGURE 33. ELECTRON MICROGRAPH. DISPLAYS THE TOP OF A NEW PIN SHOWING THE SMALL KNOT ON THE TIP AND A SMALL PROTRUSION ON THE KNOT, AS WELL AS A CRACK DOWN FROM IT. MAGNIFICATION 250X.

FIGURE 34. ELECTRON MICROGRAPH. A HIGHER MAGNIFICATION OF THE KNOT ON THE PIN SHOWING AN APPARENT HOLE AT ITS BASE AND AN ENLARGEMENT OF THE POSSIBLE BIT OF TRASH. MAGNIFICATION 625X.

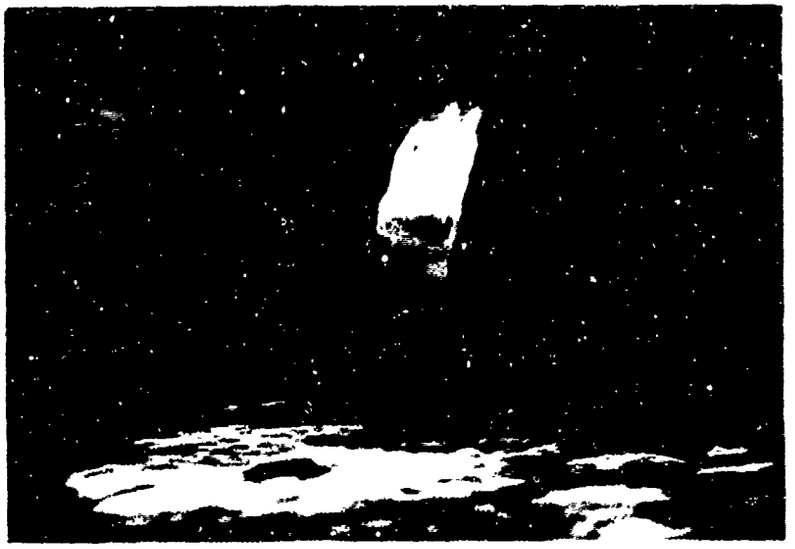


FIGURE 35. ELECTRON MICROGRAPH. AT HIGHER MAGNIFICATION THE POSSIBLE PIECE OF TRASH LOOKS MORE LIKE AN INTEGRAL PART OF THE PIN. MAGNIFICATION 2400X.

FIGURE 36. ELECTRON MICROGRAPH. AT STILL HIGHER MAGNIFICATION AND A SLIGHTLY DIFFERENT ANGLE THE BIT ON THE TIP APPEARS MORE LIKE AN INTIMATE PART OF THE PIN. MAGNIFICATION 6000X.

FIGURE 37. ELECTRON MICROGRAPH. CLOSE-UP OF THE PROTRUSION'S BASE DEFINITELY CONFIRMS THAT IT IS FIRMLY ADHERED TO THE PIN. MAGNIFICATION 6000X.

FIGURE 38. ELECTRON MICROGRAPH. A CLOSE LOOK AT BASE OF THE KNOT INDICATES THE POSSIBLE HOLE IS ONLY A DEPRESSION. MAGNIFICATION 625X.

FIGURE 39. ELECTRON MICROGRAPH. FOCUSING ON THAT POSSIBLE CRACK SHOWS THAT IT IS APPARENTLY AN OVERLAYER OF PLATING. MAGNIFICATION 625X.

FIGURE 40. ELECTRON MICROGRAPH. A SCAR ON THE PIN TOP SHOWS HOW EASILY THE GOLD CAN BE DAMAGED. MAGNIFICATION 1230X.

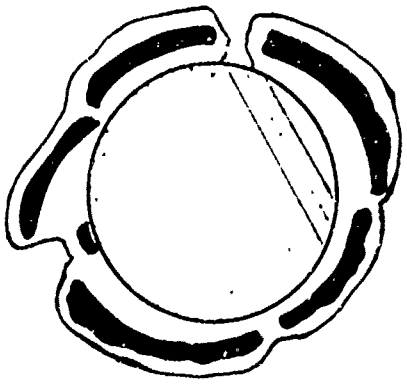


FIGURE 41. PHOTOGRAPHED SKETCH. AN ILLUSTRATION OF A BADLY SILVER MIGRATED PIN ELECTROLESS NICKEL PLATED TO CAPTURE THE LOOSELY ADHERED GOLD PLATING. CENTER: PIN, DARK PARTICLES: GOLD PLATE; OUTLINED SURROUNDING LIGHT AREA: ELECTROLESS NICKEL PLATE.

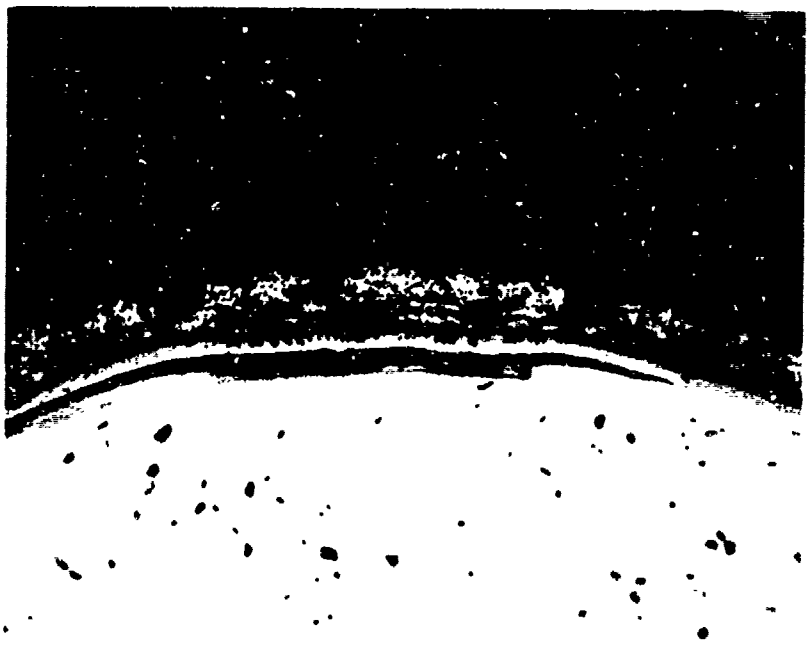


FIGURE 42. PHOTOMACROGRAPH. PIN DEVOID OF SILVER PLATE UNDER THE GOLD. TOP LAYER IS COPPER HOLDING OVER PLATE; NEXT, THE UNDERLAYER IS GOLD PLATE; THIRD UNDERLAYER IS SILVER PLATE; THE BOTTOM AREA IS BRASS PIN. MAGNIFICATION 280X.

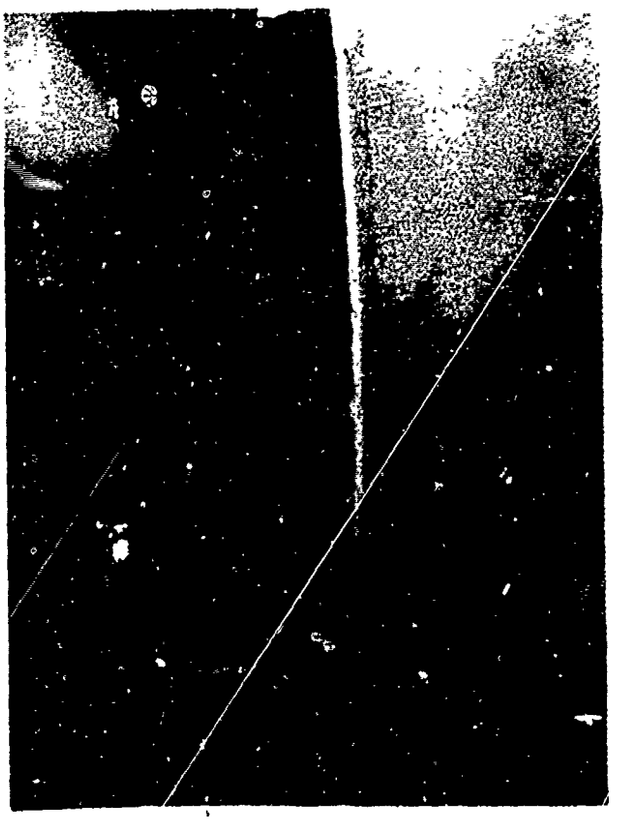


FIGURE 43. PHOTOMACROGRAPH. NEW PIN SHOWING THE PLATING LAYERS. FROM LEFT TO RIGHT: BRASS PIN; FAINT THIN NEXT LAYER IS FLASH NICKEL UNDERPLATE; LIGHT WIDE BAND IS GOLD PLATE; NEXT LAYER OUTLINED BY THE DARK LINE IS ELECTROLESS NICKEL OVERPLATE; WIDE LAYER TO THE RIGHT IS MOUNTING PLASTIC. MAGNIFICATION 1000X.

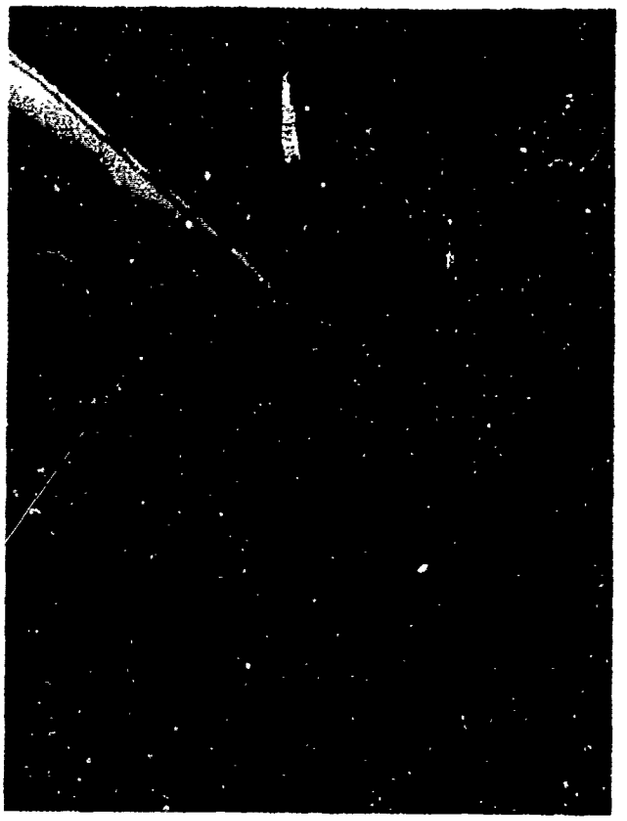


FIGURE 44. PHOTOMACROGRAPH. NEW PIN SHOWING THE VARIOUS LAYERS OF PIN, NICKEL FLASH, GOLD PLATE, ELECTROLESS NICKEL OVERPLATE, AND PLASTIC MOUNTING, FROM LEFT TO RIGHT. MAGNIFICATION 1000X.

FIGURE 45. ELECTRON MICROGRAPH. A PATCH OF MIGRATED SILVER CRYSTALS ON THE GOLD SURFACE OF A CONNECTOR PIN. MAGNIFICATION 750X.

FIGURE 46. X-RAY ENERGY ANALYZER OF ELECTRON MICROSCOPE PHOTOGRAPH. THE DOTTED PEAK OUTLINE IS PRODUCED BY THE GOLD. THE SHORT, BARRED PEAK INDICATES THE SULFUR AND THE TALL, BARRED PEAK REPRESENTS THE SILVER AND SILVER SALTS PRESENT.

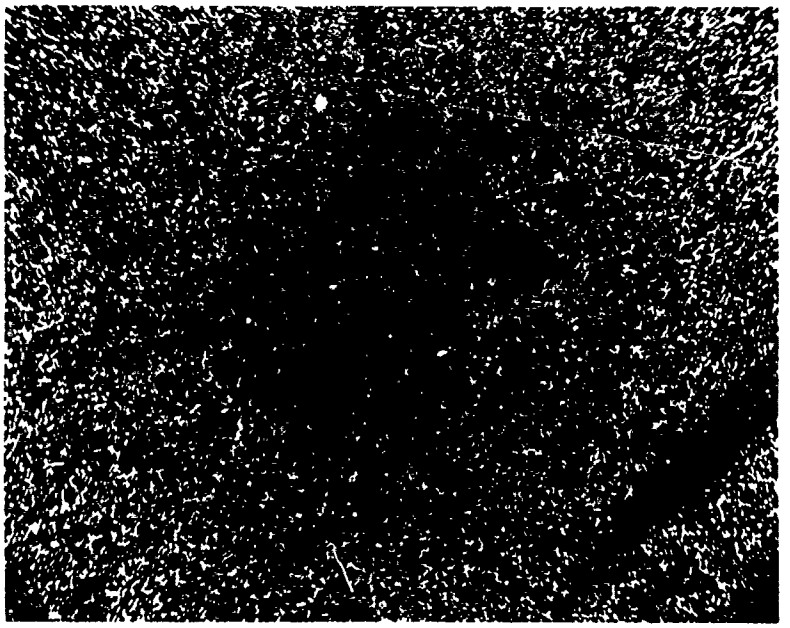


FIGURE 47. X-RAY ENERGY ANALYZER/ELECTRON MICROSCOPE PHOTOGRAPH. A DENSITY PLOT AT THE GOLD ENERGY LEVEL. THE MORE OR LESS BARE AREA IN CENTER IS SURROUNDED BY A FIELD OF GOLD. THE BARE AREA IS MASKED OUT BY ANOTHER ELEMENT. MAGNIFICATION 750X.

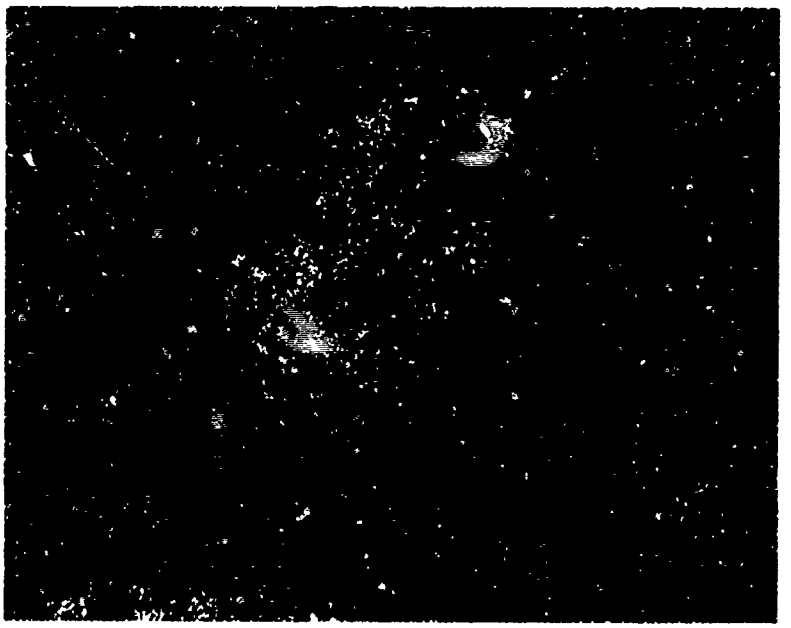


FIGURE 48. X-RAY ENERGY ANALYZER/ELECTRON MICROSCOPE PHOTOGRAPH. THE MORE CONCENTRATED DOTTED PORTION IS THE SAME AREA AS THE BLANK SPOT IN FIGURE 47, BUT AT THE SILVER ENERGY LEVEL, SHOWING THE EXCESSIVE AMOUNT OF SILVER. MAGNIFICATION 750X.

ADDENDUM

An additional set of electron micrographs was subsequently developed to enhance the original information.

Another connector from the severely contaminated set of 12 was disassembled and a pin severed from the mounting. This pin was not as badly contaminated as the ones originally examined. Figure 49 depicts various crystalline protrusions of migrated silver. The caterpillar-like projection on the right side of the pin was enlarged to 350X magnification to show a flower-like appearance, Figure 50.

This flower-like mass was examined with the electron microscope x-ray analyzer at the silver energy level to develop Figure 51, showing the growth to consist primarily of silver. The same flower, when exposed at the sulfur energy level, provided Figure 52, indicating that there is some sulfide present. At the gold energy level, Figure 53, only a minute amount of gold can be detected in the crystalline growth area, but the pin displays a good coating of that element.

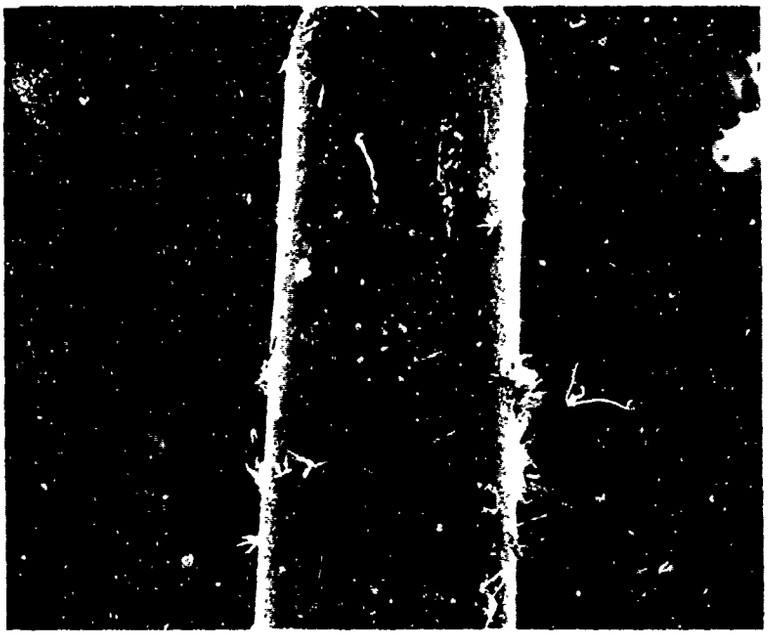


FIGURE 49. ELECTRON MICROGRAPH. CONTAMINATED CONNECTOR PIN SHOWING THE SCATTERED MIGRATED CRYSTALS OF SILVER/SILVER SALTS, ESPECIALLY THE CATERPILLAR-LIKE PROTRUSION ON THE RIGHT SIDE. MAGNIFICATION 32X.

FIGURE 50. ELECTRON MICROGRAPH. THE CATERPILLAR-LIKE GROWTH HAS TURNED INTO A FLOWER, WHEN MAGNIFIED TO 350X.

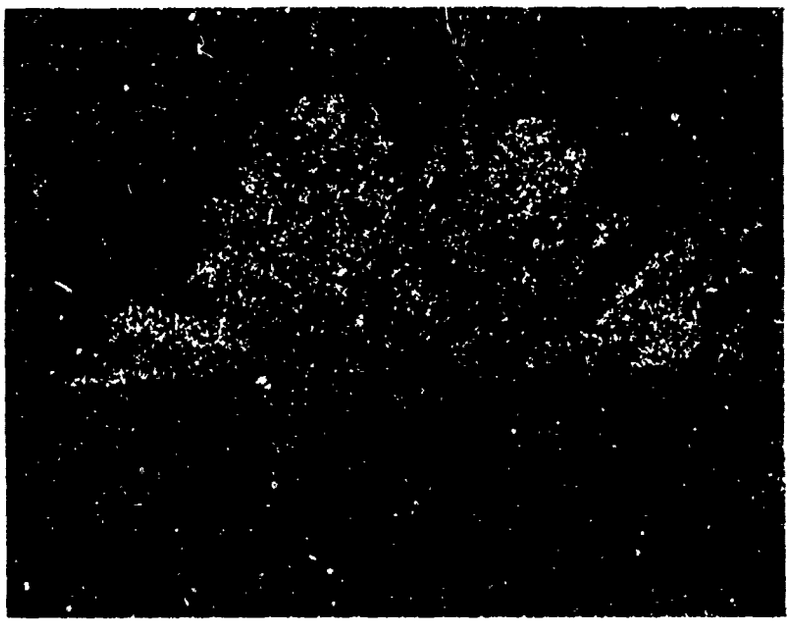


FIGURE 51. X-RAY ENERGY ANALYZER OF ELECTRON MICROSCOPE. SILVER ENERGY LEVEL PHOTOGRAPH OF THE FLOWER-LIKE GROWTH SHOWING THE PROFUSION OF SILVER/SILVER SALTS. MAGNIFICATION 350X.

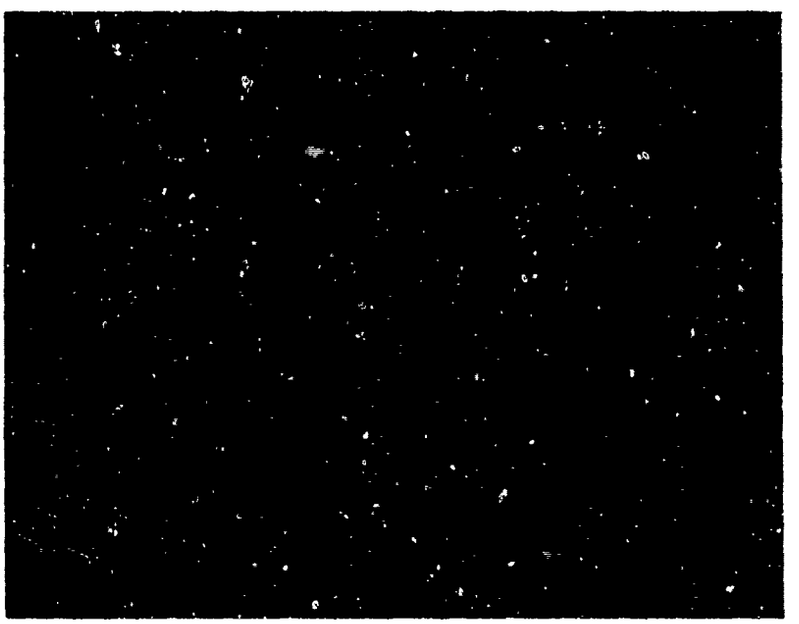


FIGURE 52. X-RAY ENERGY ANALYZER OF ELECTRON MICROSCOPE. SULFUR ENERGY LEVEL PHOTOGRAPH OF THE FLOWER-LIKE GROWTH INDICATING THE PRESENCE OF SULFIDE. MAGNIFICATION 350X.

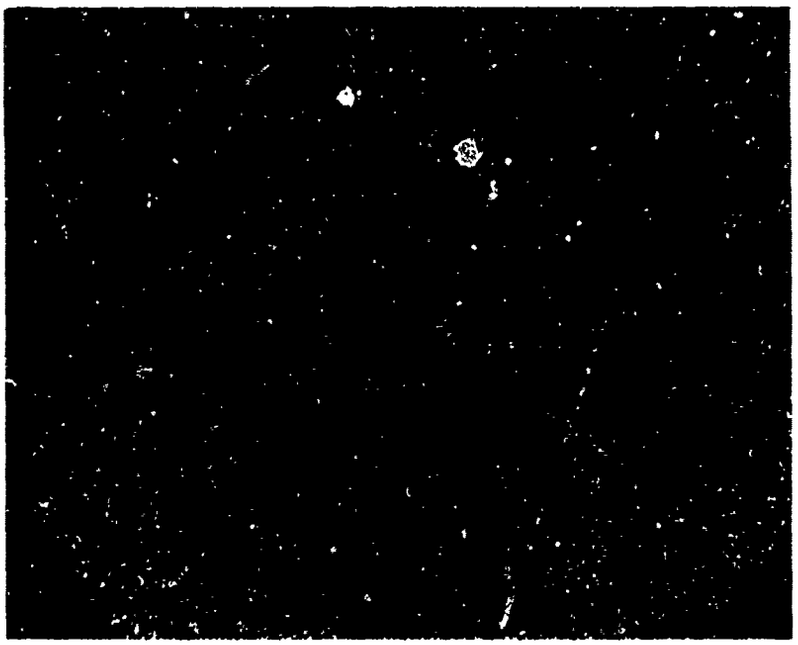


FIGURE 53. X-RAY ENERGY ANALYZER OF ELECTRON MICROSCOPE. GOLD ENERGY LEVEL PHOTOGRAPH OF THE FLOWER-LIKE GROWTH DELINEATING A LACK OF GOLD IN THE CRYSTALS BUT A LARGE AMOUNT ON THE PIN SURFACE. MAGNIFICATION 350X.