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URANIUM ALLOY DEVELOPMENT

PART VII

URANIUM ALLOYS WITH TWO ATOMIC PER CENT OF SOME RARE AND PRECIOUS METALS

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Metallurgy, all - Uranium

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ABSTRACT

The following 2 atomic per cent uranium alloys were made in 160 g ingots, and the hardness and microstructure investigated after a variety of heat treatments: V, Au, Pd, Os, Ru, Ir, Re, Rh, and Ga. All of the alloys were more or less brittle as quenched from 900° C., except those containing palladium and rhodium, and appear not to warrant further study. The rhodium alloy shows some promise of being a useful high strength uranium alloy, but further work is needed to confirm this.

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URANIUM ALLOYS WITH TWO ATOMIC PER CENT OF SOME RARE AND PRECIOUS METALS

Part VII

In the report of February 15, 1944, (LA - 68) a series of 1 gram alloy melts containing 2 atomic per cent V, Au, Pd, Os, Ru, Ir, Re, Rh, and Ga were briefly described. The microstructures and hardness values in the 900° C. as-quenched condition were given. Because the hardness values in general were quite high, it appeared as though at least some of these compositions might be promising for a high strength uranium alloy. Accordingly, a series of 160 g melts of 2 atomic per cent of each of the metals listed above were prepared in the usual way for further study.

<u>Effect of Heat Treatment on the Hardness of the Alloys</u>

All the castings were first homogenized at 900° C. for at least two hours before subsequent heat treatment and quenching at lower temperatures. The hardness value observed at each temperature level is shown in Table I.

It will be observed that a few alloys were cracked as cast, and most of them were cracked as quenched from 900° C. These groups of alloys can practically be eliminated from further consideration because of excessive brittleness. The rhenium and osmium alloys were especially brittle, and exceedingly difficult to cut. While most of the alloys show possibility of improvement in hardness on heat treatment, none shows a minimum hardness as quenched from higher temperatures, which is generally desirable for a heat treatable alloy; but the minimum hardness occurs at 700° C. or 600° C. Also, most of the alloys show a maximum hardness both at 900° C. and at 400° C.

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Table I. Compositions and Rockwell A Hardness of
Heat Treated 2 Atomic Per Cent Alloys
All Alloys Originally Quenched from 900° C.

Alloy No.	Intended Composition Atomic%	Weight %	Analysis Weight %	As cast	900	800	700	600	500	[illegible]
2406	2 V *	0.45 V	0.465 top 0.384 bottom	59	71	71	60	60	69	[illegible]
2413	2 Au *	1.03 Au	1.40 top 1.18 bottom	63	65	64	56	60	69	[illegible]
2414	2 Pd	0.913 Pd	1.01 top 1.03 bottom	66	70	70	61	57	69	[illegible]
2415	2 Os +*	1.61 Os	--------	61	66	65	63	63	61	[illegible]
2416	2 Ru *	0.87 Ru	--------	66	72	70	69	64	69	[illegible]
2420	2 Ir +*	1.63 Ir	1.40 top 1.24 bottom	72	65	63	63	59	60	[illegible]
2421	2 Re +*	1.57 Re	--------	73	65	65	66	65	65	[illegible]
2422	2 Rh	0.88 Rh	--------	63	73	72	70	63	69	[illegible]
2423	2 Ga *	0.59 Ga	0.30 top 0.74 bottom	63	62	64	61	56	61	[illegible]

+ Cracked as cast
* Cracked as quenched 900° C.

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The rhodium alloy appears to show a slightly greater hardness than the palladium alloy as quenched from 900° C. and as re-heated to 400° C.

Microstructure

Microstructures of all the alloys at every stage of heat treatment are shown in the following Figs., 1-63.

Vanadium Alloy, Figs. 1-7

Most of the structures shown appear to consist of two phases, one of them sometimes rather finely divided.

Gold Alloy, Figs. 8-14

The gold alloy appears to consist of a single phase at 900° C. and possibly at 600° C. Many of the areas show cracks which had formed on the initial 900° C. heat treatment.

Palladium Alloy, Figs. 15-21

The alloy appears to be nearly one phase at 800° C., but at other temperatures seems to consist of two phases. The peculiar nodular structure exhibited at 700° C. is probably caused by growth of a new phase from the old structure. It is possible that the matrix of the structure in Fig. 19 consists of the nodular structure grown completely together.

Osmium Alloy, Figs. 22-28

Most of the structures observed have two phases with the possible exception of the 500° C. and 400° C. heat treated ones. The large dark patch in Fig. 28 is a crack, and all the alloys were cracked from the 900° C. condition.

Ruthenium Alloy, Figs. 29-35

The as cast alloy shows a well defined two phase Muntz metal type

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structure. The 600° C. heated structure seems to be almost a single phase, but there may be a fine precipitate present.

Iridium Alloy, Figs. 36-42

Here again the structures are quite varied, most of them consisting of two phases, with the 500° C. condition possibly showing a single phase structure.

Rhenium Alloy, Figs. 43-49

The structures observed after quenching from 900° C., 600° C., and 500° C. are apparently all essentially single phase ones. It is possible that these structures correspond to gamma, beta, and alpha uranium, but this is only a guess.

Rhodium Alloy, Figs. 50-56

The as cast alloy shows a well defined Muntz metal type two phase structure. Quenching from 900° C. did not retain all of the rhodium in solid solution, and at 800° C. while it is mostly one phase, there is evidence of a finely dispersed second phase. Fig. 53 shows an interesting structure, almost certainly a non-equilibrium one, with a suggestion of three phases present.

At 600° C. there is a copious fine precipitate in a matrix apparently containing most of the rhodium, and at 500° C. the structure appears to consist of a single solid solution. At 400° C. this solution breaks down to form two phases, one of them again a finely divided one, apparently precipitated from the solid solution of Fig. 55.

Gallium Alloy, Figs. 57-63

There seems to be a small amount of a second phase in all the structures, but most of them appear to consist largely of one phase.

It must be emphasized that the micrographs shown in most cases do not correspond to equilibrium structures. While as far as analyses on these alloys

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are available only the gallium showed serious segregation, there is some possibility of segregation in the unanalyzed alloys (Os, Ru, Re) which might give misleading impressions.

The results described are only preliminary, and are intended mostly as a guide to possible future work.

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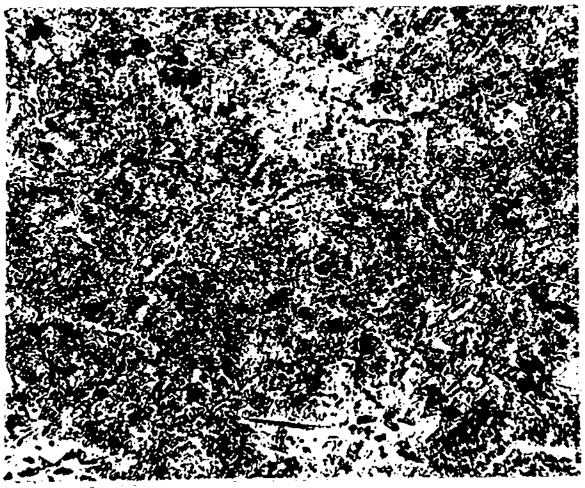

Fig. 1. 2 Atomic Per Cent V-U Alloy
As Cast
Etched in 1:1 Nitric-Acetic Acid

2406-1-1 x 250

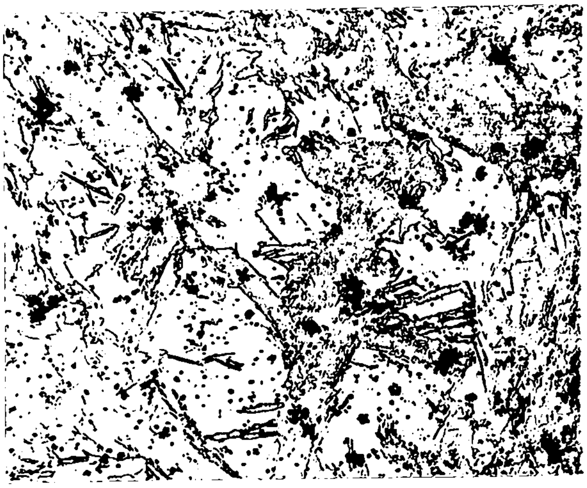

Fig. 2. 2 Atomic Per Cent V-U Alloy
As Quenched 900° C.
Electrolytically etched in 5% Oxalic Acid

2406-2-0 x 250

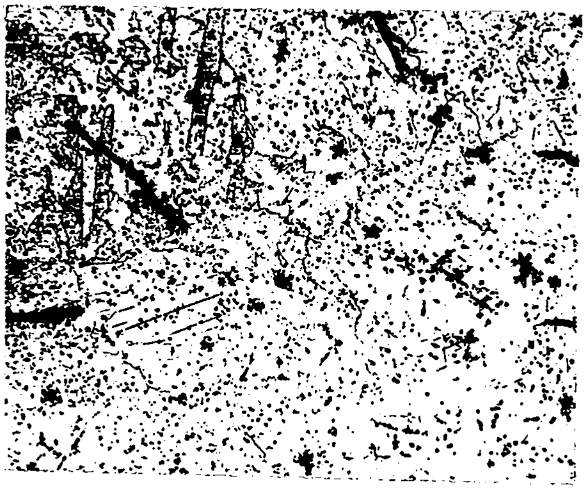

Fig. 3. 2 Atomic Per Cent V-U Alloy
As Quenched 800° C.
Electrolytically etched in 10% Oxalic Acid

2406-3-0 x 250

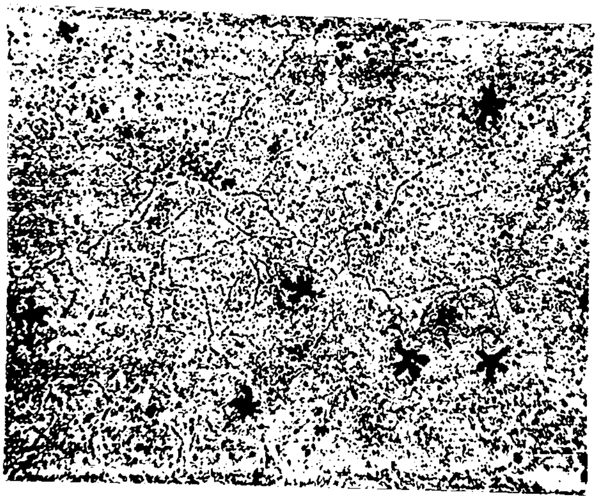

Fig. 4. 2 Atomic Per Cent V-U Alloy
As Quenched 700° C.
Etched in 1:1 Nitric-Acetic Acid

2406-4-0 x 250

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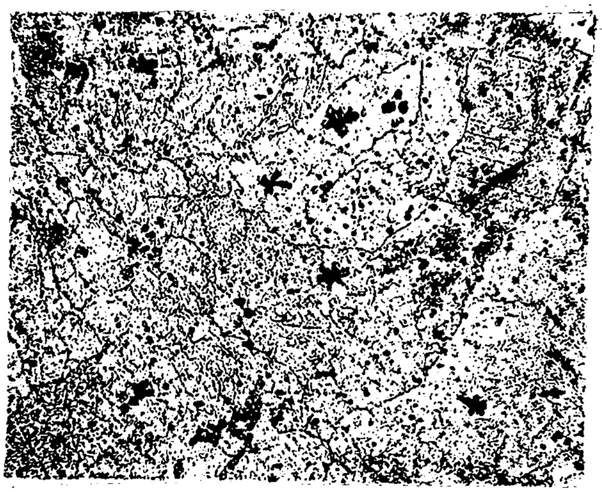

Fig. 5. 2 Atomic Per Cent V-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic Acid

2406-5-0 x 250

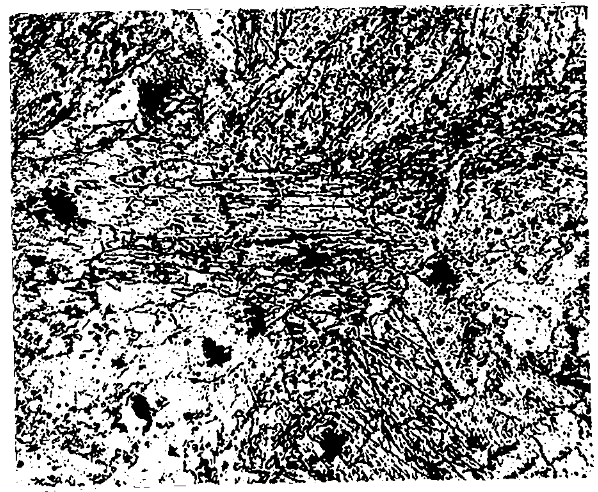

Fig. 6. 2 Atomic Per Cent V-U Alloy
As Quenched 500° C.
Electrolytically etched in 2% Oxalic Acid

2406-6-1 x 250

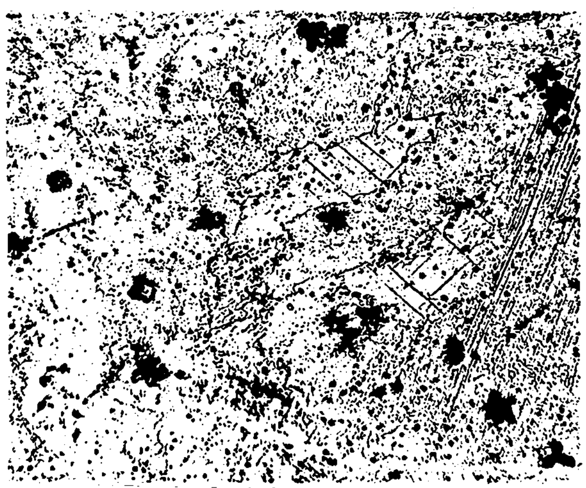

Fig. 7. 2 Atomic Per Cent V-U Alloy
As Quenched 400° C.
Electrolytically etched in 2% Oxalic Acid

2406-7-0 x 250

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Fig. 8. 2 Atomic Per Cent Au-U Alloy
As Cast
Electrolytically etched in 2% Oxalic Acid

2413-1-0 x 250

Fig. 9. 2 Atomic Per Cent Au-U Alloy
As Quenched 900° C.
Electrolytically etched in 2% Oxalic Acid

2413-2-0 x 250

Fig. 10. 2 Atomic Per Cent Au-U Alloy
As Quenched 800° C.
Electrolytically etched in 2% Oxalic Acid

2413-3-1 x 250

Fig. 11. 2 Atomic Per Cent Au-U Alloy
As Quenched 700° C.
Electrolytically etched in 2% Oxalic Acid

2413-4-0 [redacted]50

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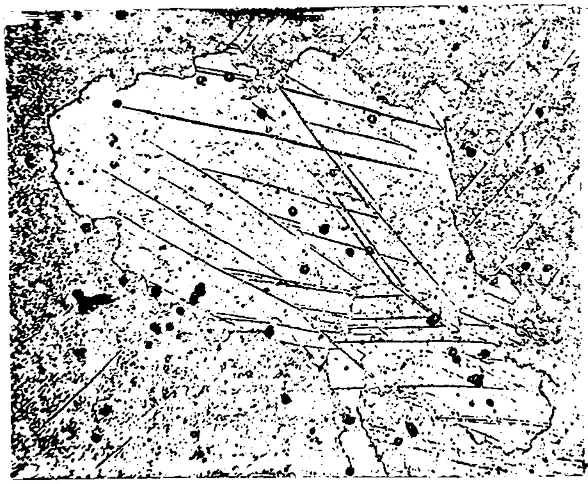

Fig. 12. 2 Atomic Per Cent Au-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic Acid

2413-5-0 x 250

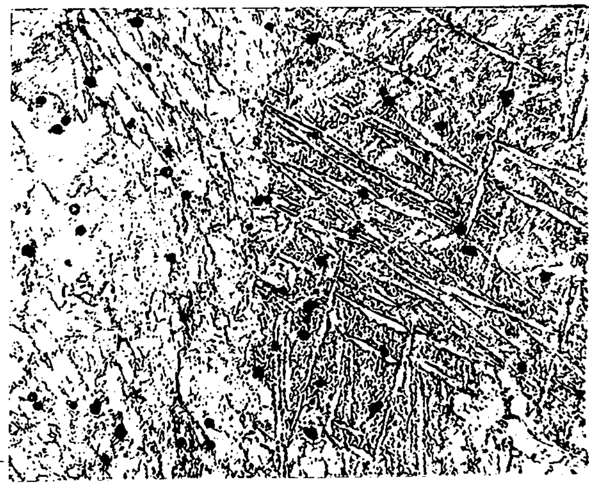

Fig. 13. 2 Atomic Per Cent Au-U Alloy
As Quenched 500° C.
Electrolytically etched in 2% Oxalic Acid

2413-6-0 x 250

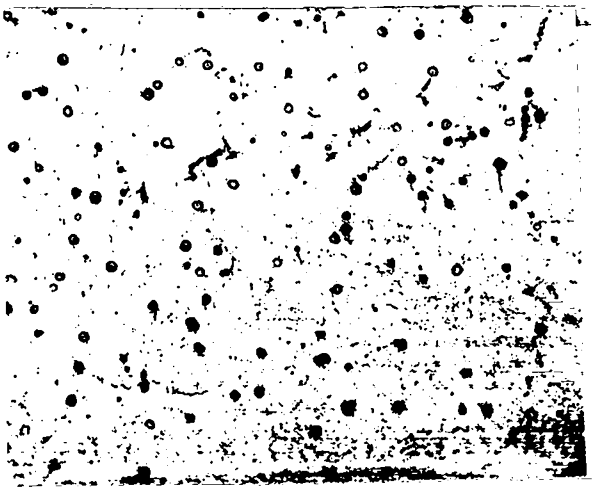

Fig. 14. 2 Atomic Per Cent Au-U Alloy
As Quenched 400° C.
Electrolytically etched in 5% Oxalic Acid

2413-7-0 x 250

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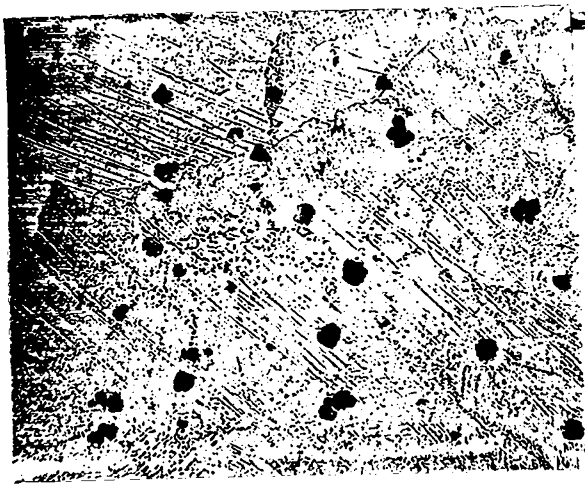

Fig. 15. 2 Atomic Per Cent Pd-U Alloy
As Cast
Electrolytically etched while polishing.

2414-1-0 x 250

Fig. 16. 2 Atomic Per Cent Pd-U Alloy
As Quenched 900° C.
Electrolytically etched in 5% Oxalic Acid

2414-2-0 x 250

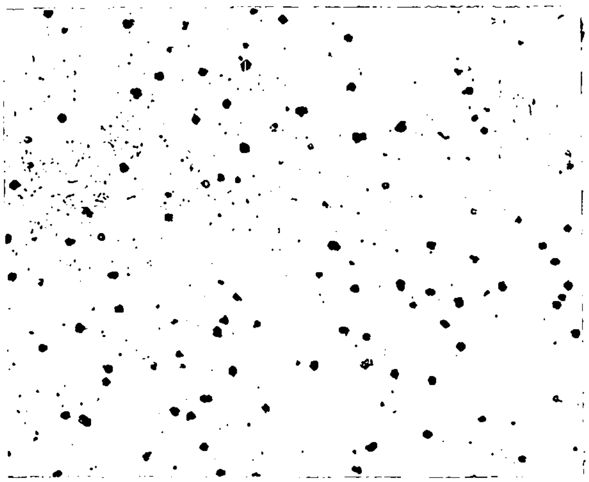

Fig. 17. 2 Atomic Per Cent Pd-U Alloy
As Quenched 800° C.
Etched in 1:1 Nitric-Acetic Acid

2414-3-0 x 250

Fig. 18. 2 Atomic Per Cent Pd-U Alloy
As Quenched 700° C.
Electrolytically etched in 5% Oxalic Acid

2414-4-0 x 250

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Fig. 19. 2 Atomic Per Cent Pd-U Alloy
As Quenched 600° C.
Electrolytically etched in 5% Oxalic Acid

2414-5-0 x 250

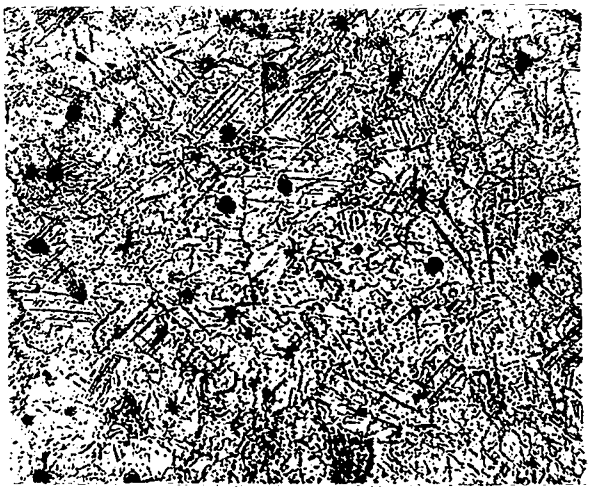

Fig. 20. 2 Atomic Per Cent Pd-U Alloy
As Quenched 500° C.
Electrolytically etched in 5% Oxalic Acid

2414-6-0 x 250

Fig. 21. 2 Atomic Per Cent Pd-U Alloy
As Quenched 400° C.
Electrolytically etched in 5% Oxalic Acid

2414-7-0 x 250

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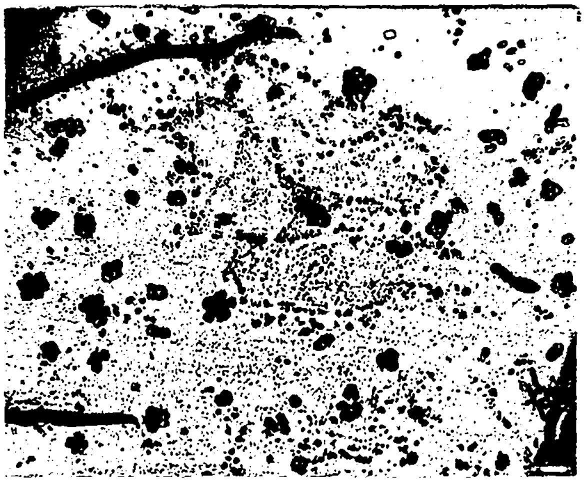

Fig. 22. 2 Atomic Per Cent Os-U Alloy
As Cast
Electrolytically etched in 5% Oxalic
Acid

2415-1-0 x 250

Fig. 23. 2 Atomic Per Cent Os-U Alloy
As Quenched 900° C.
Electrolytically etched in 5% Oxalic
Acid

2415-2-0 x 250

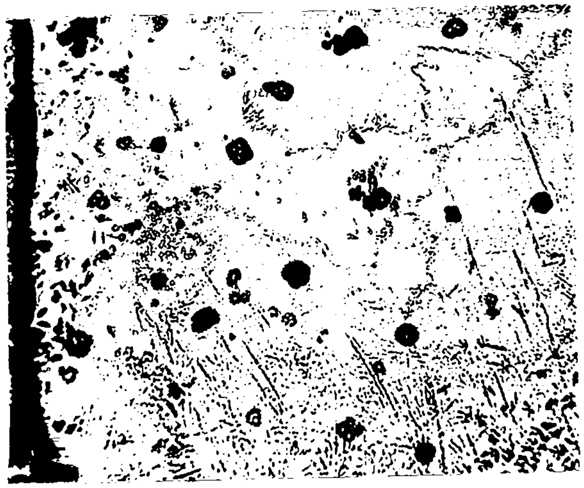

Fig. 24. 2 Atomic Per Cent Os-U Alloy
As Quenched 800° C.
Electrolytically etched in 5% Oxalic
Acid

2415-3-0 x 250

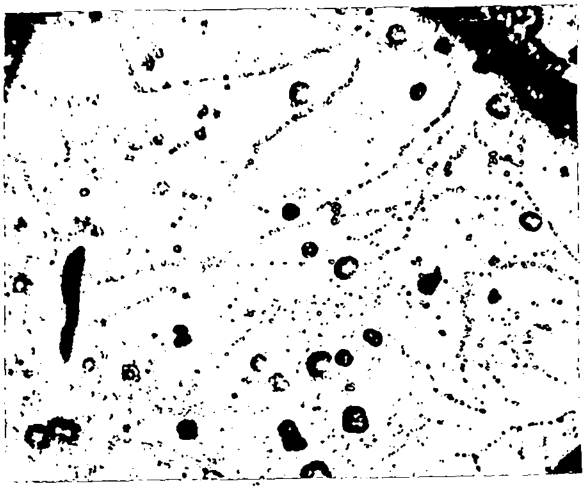

Fig. 25. 2 Atomic Per Cent Os-U Alloy
As Quenched 700° C.
Electrolytically etched in 5% Oxalic
Acid

2415-4-0 x 250

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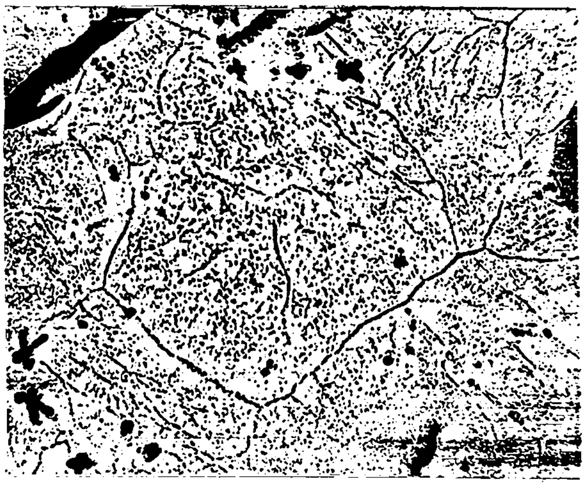

Fig. 26. 2 Atomic Per Cent Os-U Alloy
As Quenched 600° C.
Electrolytically etched in 5% Oxalic Acid

2415-5-0 x 250

Fig. 27. 2 Atomic Per Cent Os-U Alloy
As Quenched 500° C.
Electrolytically etched in 5% Oxalic Acid

2415-6-0 x 250

Fig. 28. 2 Atomic Per Cent Os-U Alloy
As Quenched 400° C.
Electrolytically etched in 2% Oxalic Acid

2415-7-0 x 250

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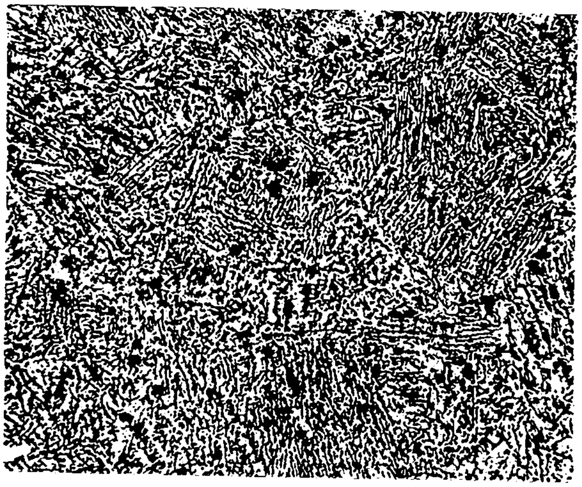

Fig. 29. 2 Atomic Per Cent Ru-U Alloy
As Cast
Etched in 1:1 Nitric-Acetic Acid

2416-1-0 x 250

Fig. 30. 2 Atomic Per Cent Ru-U Alloy
As Quenched 900° C.
Electrolytically etched in 2% Oxalic Acid

2416-2-0 x 250

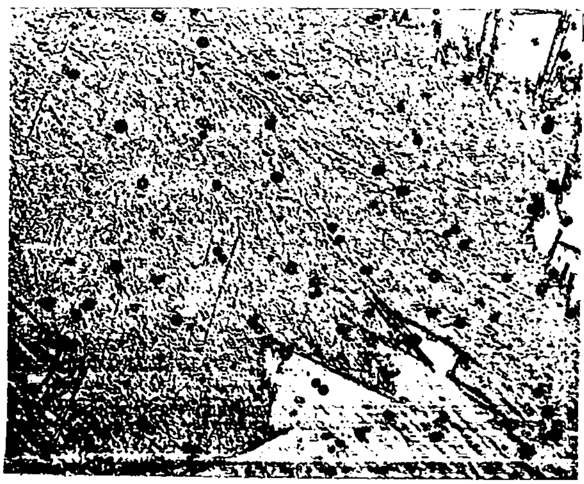

Fig. 31. 2 Atomic Per Cent Ru-U Alloy
As Quenched 800° C.
Electrolytically etched in 5% Oxalic Acid

2416-3-0 x 250

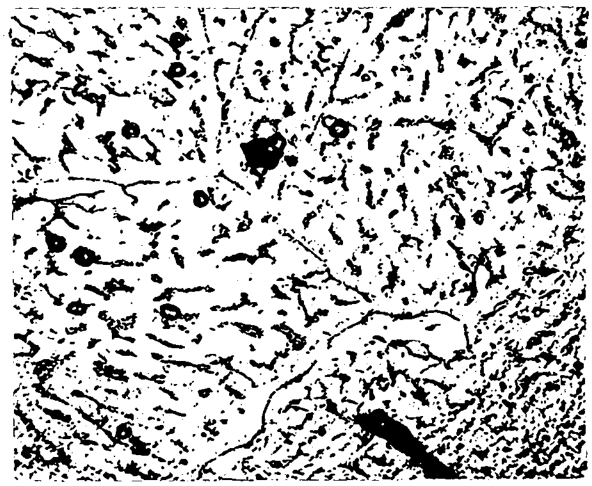

Fig. 32. 2 Atomic Per Cent Ru-U Alloy
As Quenched 700° C.
Etched in 1:1 Nitric-Acetic Acid

2416-4-0 x 250

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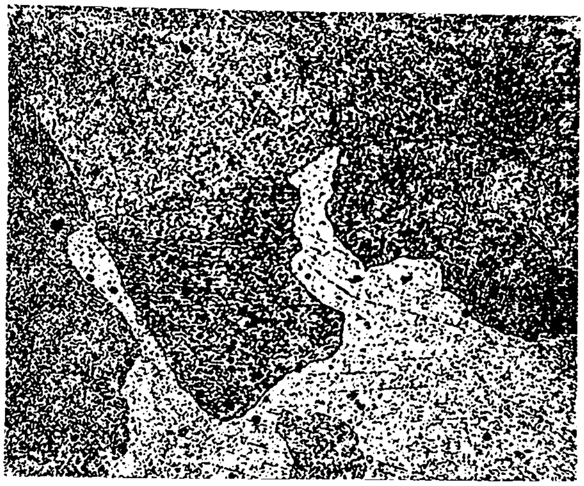

Fig. 33. 2 Atomic Per Cent Ru-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic Acid

2416-5-0 x 250

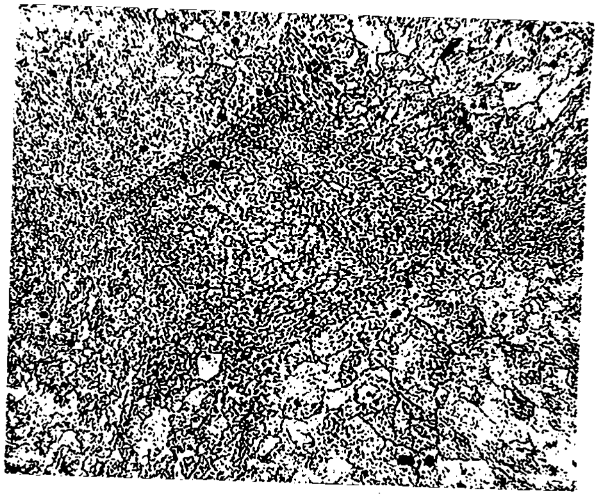

Fig. 34. 2 Atomic Per Cent Ru-U Alloy
As Quenched 500° C.
Electrolytically etched in 2% Oxalic Acid

2416-6-0 x 250

Fig. 35. 2 Atomic Per Cent Ru-U Alloy
As Quenched 400° C.
Electrolytically etched in 2% Oxalic Acid

2416-7-0 x 250

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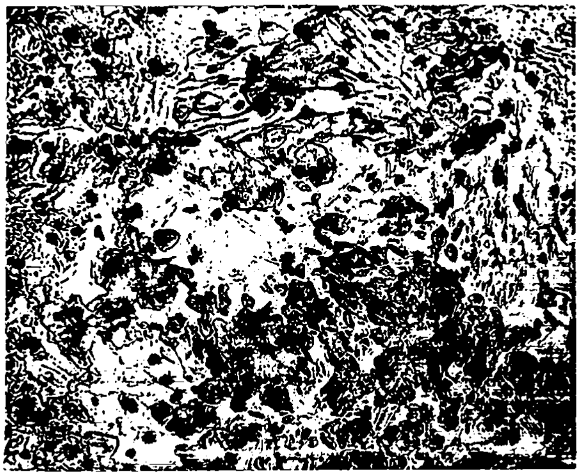

Fig. 36. 2 Atomic Per Cent Ir-U Alloy
As Cast
Electrolytically etched in 10% Chromic Acid

2420-1-0 x 250

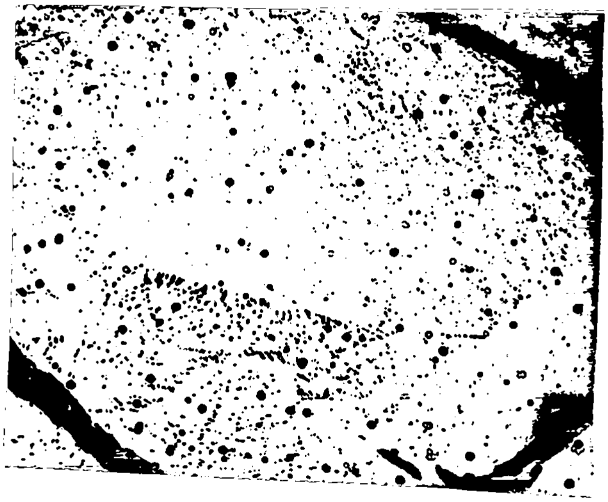

Fig. 37. 2 Atomic Per Cent Ir-U Alloy
As Quenched 900° C.
Electrolytically etched in 2% Oxalic Acid

2420-2-0 x 250

Fig. 38. 2 Atomic Per Cent Ir-U Alloy
As Quenched 800° C.
Electrolytically etched in 2% Oxalic Acid

2420-3-0 x 250

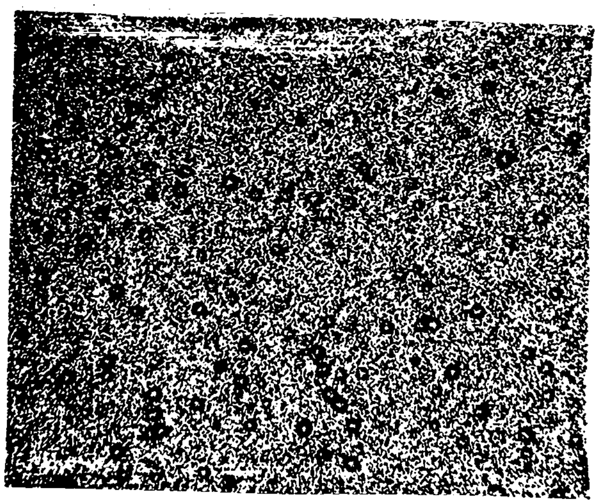

Fig. 39. 2 Atomic Per Cent Ir-U Alloy
As Quenched 700° C.
Electrolytically etched in 10% Chromic Acid

2420-4-0 x 250

[redacted]

[redacted]

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Fig. 40. 2 Atomic Per Cent Ir-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic Acid

2420-5-0 x 250

Fig. 41. 2 Atomic Per Cent Ir-U Alloy
As Quenched 500° C.
Electrolytically etched in 5% Oxalic Acid

2420-6-1 x 250

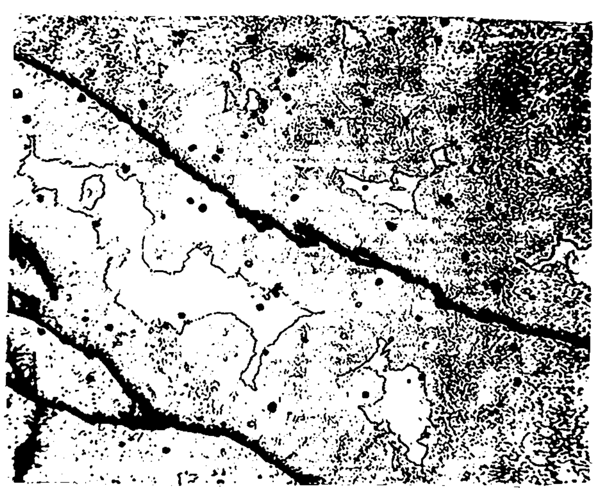

Fig. 42. 2 Atomic Per Cent Ir-U Alloy
As Quenched 400° C.
Electrolytically etched in 2% Oxalic Acid

2420-7-1 x 250

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Fig. 43. 2 Atomic Per Cent Re-U Alloy
As Cast
Electrolytically etched in 2% Oxalic Acid

2421-1-0 x 250

Fig. 44. 2 Atomic Per Cent Re-U Alloy
As Quenched 900° C.
Electrolytically etched in 5% Oxalic Acid

2421-2-0 x 250

Fig. 45. 2 Atomic Per Cent Re-U Alloy
As Quenched 800° C.
Electrolytically etched in 5% Oxalic Acid

2421-3-0 x 250

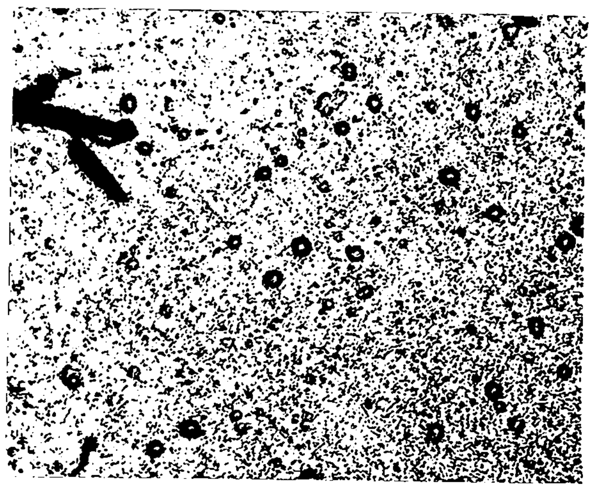

Fig. 46. 2 Atomic Per Cent Re-U Alloy
As Quenched 700° C.
Electrolytically etched in 5% Oxalic Acid

2421-4-0 x 250

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Fig. 47. Atomic Per Cent Re-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic Acid

2421-5-0 x 250

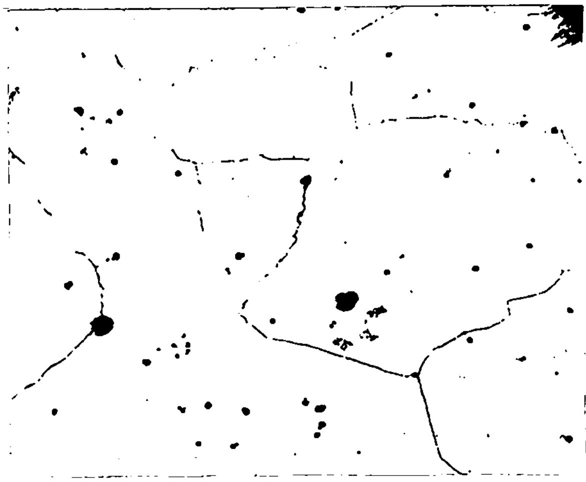

Fig. 48. 2 Atomic Per Cent Re-U Alloy
As Quenched 500° C.
Electrolytically etched in 2% Oxalic Acid

2421-6-0 x 250

Fig. 49. 2 Atomic Per Cent Re-U Alloy
As Quenched 400° C.
Electrolytically etched in 5% Oxalic Acid

2421-7-0 x 250

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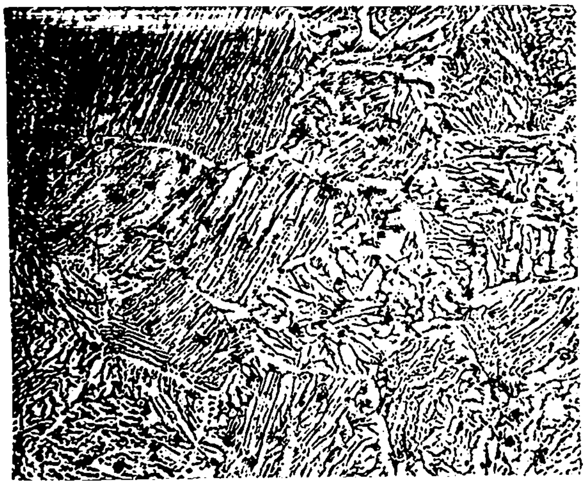

Fig. 50. 2 Atomic Per Cent Rh-U Alloy
As Cast
Electrolytically etched while polishing.

2422-1-0 x 250

Fig. 51. 2 Atomic Per Cent Rh-U Alloy
As Quenched 900° C.
Electrolytically etched in 10% Chromic Acid

2422-2-0 x 250

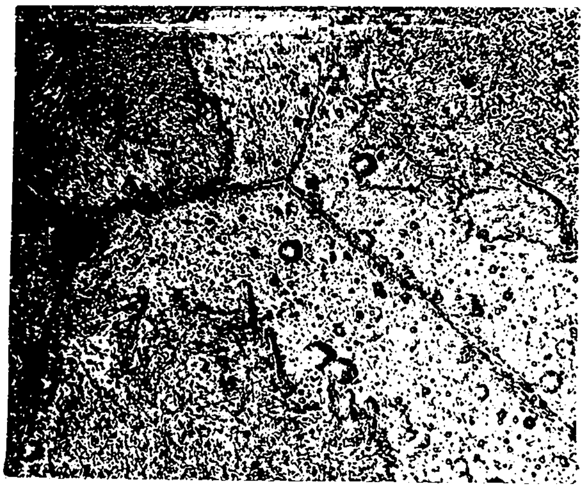

Fig. 52. 2 Atomic Per Cent Rh-U Alloy
As Quenched 800° C.
Electrolytically etched in 10% Chromic Acid

2422-3-0 x 250

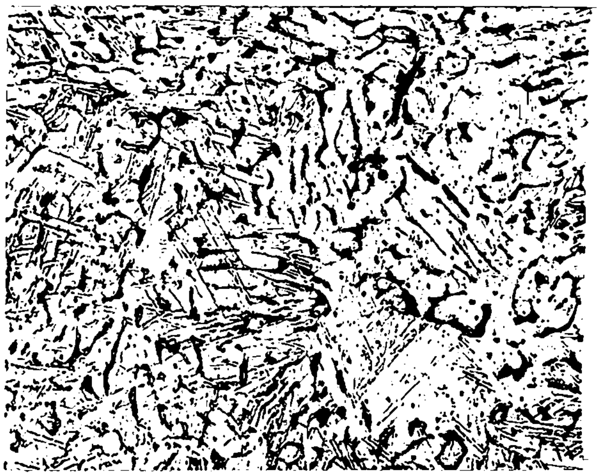

Fig. 53. 2 Atomic Per Cent Rh-U Alloy
As Quenched 700° C.
Electrolytically etched in 10% Chromic Acid

2422-4-1 x 250

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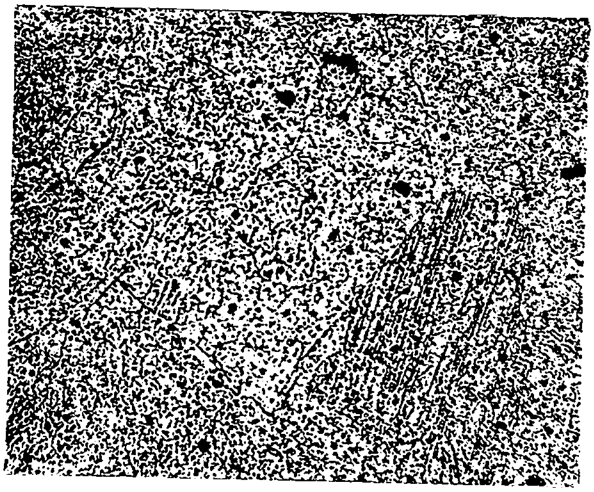

Fig. 54. 2 Atomic Per Cent Rh-U Alloy
As Quenched 600° C.
Electrolytically etched in 10% Chromic
Acid

2422-5-0 x 250

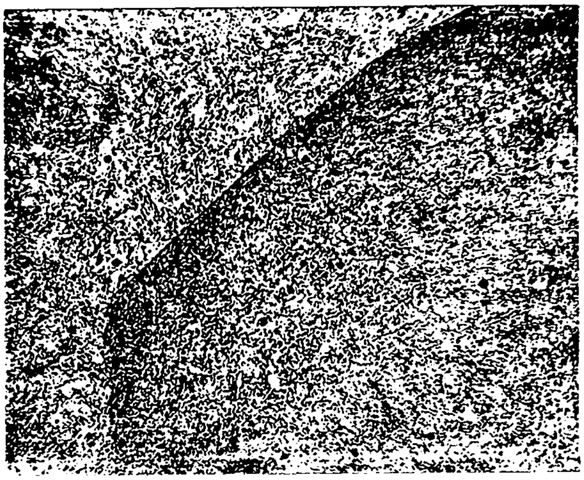

Fig. 55. 2 Atomic Per Cent Rh-U Alloy
As Quenched 500° C.
Electrolytically etched in 10% Chromic
Acid

2422-6-0 x 250

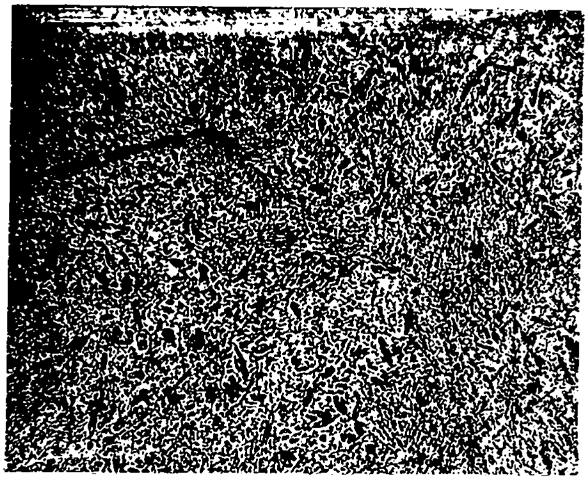

Fig. 56. 2 Atomic Per Cent Rh-U Alloy
As Quenched 400° C.
Electrolytically etched in 10% Chromic
Acid

2422-7-0 x 250

[redacted]

[redacted]

[redacted]

Fig. 57. 2 Atomic Per Cent Ga-U Alloy
As Cast
Electrolytically etched in 10% Chromic Acid

2423-1-0 x 250

Fig. 58. 2 Atomic Per Cent Ga-U Alloy
As Quenched 900° C.
Electrolytically etched in 2% Oxalic Acid

2423-2-0 x 250

Fig. 59. 2 Atomic Per Cent Ga-U Alloy
As Quenched 800° C.
Electrolytically etched in 10% Oxalic Acid

2423-3-0 x 250

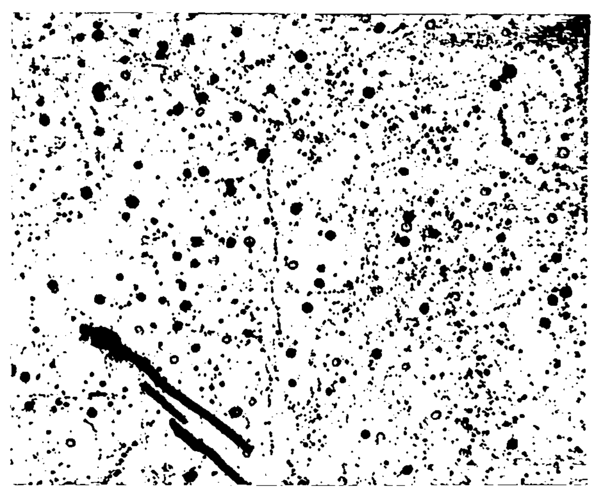

Fig. 60. 2 Atomic Per Cent Ga-U Alloy
As Quenched 700° C.
Electrolytically etched in 10% Chromic Acid

2423-4-0 x 250

[redacted]

APPROVED FOR PUBLIC RELEASE [redacted]

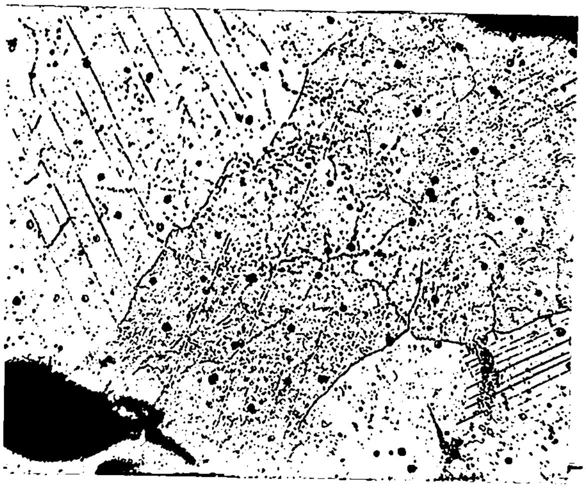

Fig. 61. 2 Atomic Per Cent Ga-U Alloy
As Quenched 600° C.
Electrolytically etched in 2% Oxalic
Acid

2423-5-0 x 250

Fig. 62. 2 Atomic Per Cent Ga-U Alloy
As Quenched 500° C.
Electrolytically etched in 10% Chromic
Acid

2423-6-0 x 250

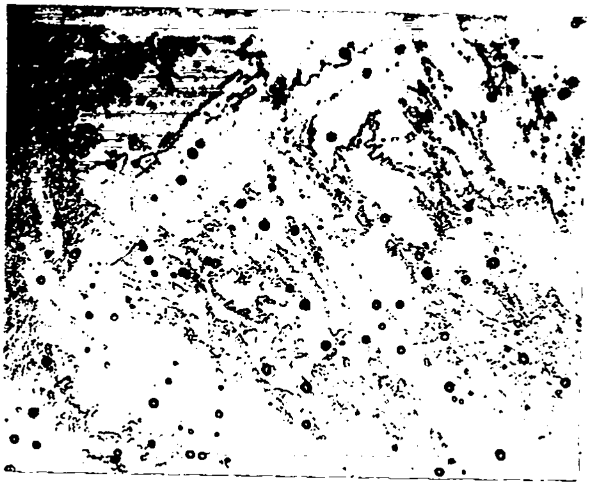

Fig. 63. 2 Atomic Per Cent Ga-U Alloy
As Quenched 400° C.
Electrolytically etched in 2% Oxalic
Acid

2423-7-0 x 250