AD/A-005 967

WORK FUNCTION OF THE (100) FACES OF SINGLE CRYSTALS OF REFRACTORY METAL ALLOYS

N. B. Smirnova, et al

Army Foreign Science and Technology Center
Charlottesville, Virginia

6 September 1974

AD A005967

071112

DEPARTMENT OF THE ARMY
U.S. ARMY FOREIGN SCIENCE AND TECHNOLOGY CENTER
220 SEVENTH STREET NE.
CHARLOTTESVILLE, VIRGINIA 22901

TRANSLATION

In Reply Refer to:
FSTC-HT-23-935-74
DIA Task No. T741801

Date: 6 September 1974

ENGLISH TITLE: Work Function of the (100) Faces of Single Crystals of Refractory Metal Alloys

SOURCE: Tashkent. Gosudar. Univer. im Lenina, Nauch.Trudy, No. 393, Fizika, 1971, pp 230-236
CIRC -CSP 73155307

AUTHOR: Smirnova, N. B., Smirnov, B. G., Sytaya, Ye. P.

LANGUAGE: Russian

COUNTRY: USSR

REQUESTOR: GE-Turner

TRANSLATOR: Leo Kanner Associates (DS)

ABSTRACT: Results of measurement of the work functions of the (100) faces of two tungsten-base alloys and one tantalum-base alloy are presented. The crystals studied, of W-Re 5, W-Ta 1 and Ta-Mo 20, were grown by zone equalization and had spontaneous (100) orientation. The work functions of the W-Re 5 and Ta-Mo 20 alloys were close to (100) of pure W and Mo, and they were considerably below the work functions of the (100) faces in W and Ta for W-Ta 1 alloy.

NOTICE

Interest has increased considerably in recent years in alloys of refractory metals, in connection with developing prospects for their use as materials for cathodes of radio tubes and thermionic converters [1-5], since sharp reductions and increases in the work function from those of the components have been discovered in a number of polycrystalline solid solutions and intermetallides. Solid solutions based on these metals are convenient objects for study of the effect of alloying on the emission properties of the pure metals. However, the textures of solution polycrystals can differ from the textures of the pure components, even those deformed in a manner identical with the alloys [6]. Therefore, it is of interest to compare the emission properties of the faces of single crystals of alloys and components, especially if the latter are isomorphic. The emission parameters of the crystal faces of almost all technically important refractory metals have now been measured reliably [7], but data on emission of single crystals of alloys is very limited [6, 8-13], with a considerable part of the work having been carried out on point samples. Large crystals of zone-melted alloys usually are significantly inferior to crystals (zone-melted) of the pure metals, although the requirements for perfection here are tremendously higher than for the pure metals. While crystallographic (and, consequently, emission) non-uniformities of the faces of a pure metal ("spots" on the faces with a different work function) are comparatively easily detected by the thermionic method and are controllable, for example, by surface ionization, in the case of an alloy, it is practically impossible to detect spottiness by the emission method. Crystals with a small impurity content usually are the most nearly perfect [14] and, for polycrystalline solutions with a low alloying metal content, the most interesting temperature and isothermal changes in the work function have been observed and reductions and increases in it have been found which are of practical value [1-5]. Thus, single crystals of solid solutions with a small content of the dissolved element are very interesting, and they are the most accessible objects for study of the effect of alloying on thermal electron emission of pure metals.

Results are presented in this work of measurement of the work functions of the (100) faces of two tungsten-base alloys, W + 5% Re and W + 1% Ta and a tantalum-base alloy, 80% Ta + 20% Mo (weight percent). Rhenium forms a very extensive region of solid solutions in tungsten (up to 30%), i.e., the alloy which we studied is in the region of solution homogeneity (Fig. 1a). The emission properties of polycrystalline solutions of Re and W have been investigated in [3, 15], and the work function of the (100) faces of the two and six percent alloys were determined in work [8], which was published during the time of the present investigation. Within the limits of error, measurements of the work functions of all of these alloys turned out to be close to the work functions of the corresponding tungsten surfaces.

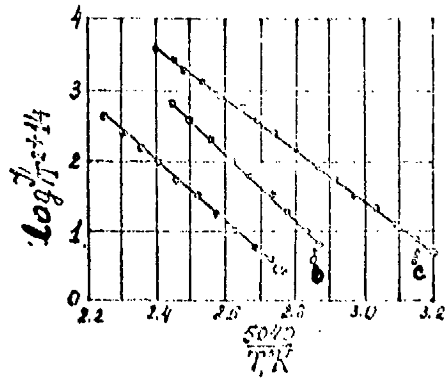

Fig. 1. Richardson lines:
a. TM-20; b. TR-5; c. TT-1.

The W-Ta and Ta-Mo systems are characterized by continuous mutual solubility, as a consequence of isomorphism of metal lattices (Fig. 1b). We do not know the emission properties of Ta-Mo system alloys. W-Ta system alloys were investigated in detail in [4], and the curve of concentration vs. work function φ (c) obtained in this work, similar to the φ (θ) curve for a normal film system, has a sharply expressed minimum in the region of low tantalum concentrations and a "shelf" in the region of high ones. This type of φ (c) curve was obtained by the authors of [3, 4], for a number of systems with unlimited solubility, and the minimum in the curve always corresponded to the region of low concentrations of the lower-melting component. The work function at the minimum is considerably below the work function of both components (up to 3.8 eV in the W + 3% Ta alloy), if the characteristic work function of the impurity is less than that of the matrix metal. If the work function of the impurity is higher than the work function of the matrix, its values for an alloy may exceed both values [16]. In a qualitative explanation of this effect, the authors of [1-5, 16] consider absorption of atoms of the low-melting component in the alloy as a process which reduces the alloy cathode to a film. The absence of noticeable change in the work function in slightly alloyed tungsten-rhenium alloys is explained in [3], by insufficient difference in the heats of the component atoms to cause strong absorption in rhenium at the emission measurement temperatures.

Experiment and Results

Crystals of the alloys were grown by zone equalization [14], and they had a spontaneous (100) orientation. Metallographic and X-ray structural indexing of the crystal faces was carried out. Unit disorientation was negligible for the W-Re 5 and the W-Ta 1 alloys, and it was 5-6 degrees for Ta-Mo 20 alloys. Flat specimens heated by electron bombardment were used. The measurements were carried out in a vacuum of at least $1\text{-}5 \cdot 10^{-8}$ torr. The emission parameters were calculated from the Richardson curves (Fig. 2) and the resulting data are presented in the table.

TABLE

a Сплав	φ_R, эв b	A_R, c а/см²град²
W-Re5	4.52	II
Ta-Mo20	4.38	43
W-TaI	3.50	I 3

Key: A -- Alloy
B -- eV
C -- $A/cm^2 \cdot degree^2$

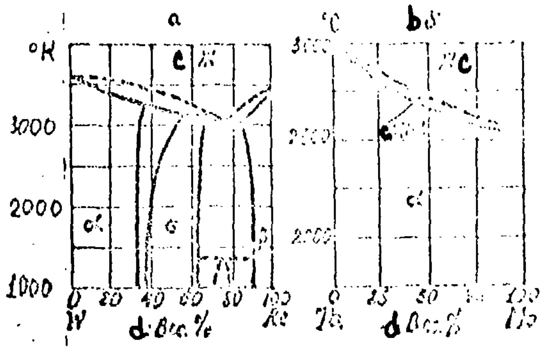

Fig. 2. Phase diagrams of W-Re and Ta-Mo alloys.

Key: C -- Liquid
D -- Weight %

The values of the work function for W-Re5 and Ta-Mo 20 alloys proved to be close to φ (100) of pure W and Mo and, for W-Ta 1 alloy, considerably below the work function of the (100) face in W and Ta. The results obtained for all three alloys can be explained within the framework of the film hypothesis [3, 4], although it should be noted here that, for the (111) face of certain alloys, we observed considerable increase in work function, instead of the expected reduction [17].

The authors thank R. N. Alimov for carrying out certain X-ray structural studies and A.K. Zhdanova for performing chemical analysis of the samples.

Bibliography

1. B. Ch. Dyubua, A.I. Pekarev, B.N. Popov, M.A. Tylkina, Radiotekhnika i elektronika 7 (1962) 1568.
2. B. Ch. Dyubua, O.K. Kultashev, Ibid. 9 (1964) 1725.
3. B. Ch. Dyubua, O.K. Kultashev, FMM 21 (1966) 396.
4. B. Ch. Dyubua, O.K. Kultashev, L.V. Gorshkova, FTT 6 (1966) 1105.
5. B. Ch. Dyubua, O.K. Kultashev, in the collection Poverkhnostnyye yavleniya v rasplavakh i voznikayushchikh iz nikh tverdykh fazakh (Surface Phenomena in Melts and Solid Phases Formed in Them), Nal'chik, 1965, p. 430.
6. N.D. Konovalov, V.A. Kuznetsov, B.M. Tsarev, ZhTF 39 (1969) 1110.
7. G.N. Shuppe, Izv. AN SSSR, seriya fiz., 30 (1966) 1935.
8. A. Ye. Aveu, J. Appl. Phys. 39 (1968) 120.
9. N.B. Smirnova, B.G. Smirnov, S.M. Mikhaylov, Ye. P. Sytaya, FTT 11 (1969) 962.
10. N.B. Smirnova, B.G. Smirnov, S.M. Mikhaylov, G.N. Shuppe, FTT 12 (1970) 1277.
11. N.B. Smirnov, G.B. Smirnov, S.M. Mikhaylov, Report to XIV All-Union Conference on Emission Electronics, Tashkent, 1970.