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GEAP-4675
AEC Research and
Development Report
September 1965

CFSTI PRICE\$

SOME ELECTRICAL PROPERTIES OF THE PLUTONIUM-URANIUM MIXED OXIDE SYSTEM

H.C. \$ 1.00; MN. 50

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RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

Prepared for the
United States Atomic Energy Commission
Under
Contract No. AT(04-3)-189, Project Agreement No. 10

Printed in U.S.A. Available from the
Clearing House for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia
Price: \$2.00 per copy

ADVANCED PRODUCTS OPERATION
GENERAL ELECTRIC
SAN JOSE, CALIFORNIA

2747-FRFT-26
135-wdh-8/66

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SECTION I

SUMMARY

A study was conducted on the electrical properties of mixed oxides of $(\text{PuO}_2\text{-UO}_2)$ solid solutions to establish a better understanding of this system, with particular attention being given to compositions of interest as fast ceramic reactor fuels.

Both electrical resistivity and thermoelectric power measurements were made across the $\text{PuO}_2\text{-UO}_2$ binary system and on $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_{2+x}$ and UO_{2+x} specimens with oxygen-to-metal ratios between 1.97 and 2.10. Generally the electrical resistivity and thermoelectric measurements varied as a function of solute content. No step changes in properties were observed. Mixed oxide specimens with stoichiometries between 1.97 and 2.01 were found to be defect structures with only a trace of second phase present.

SECTION II

INTRODUCTION

The mixed oxides of PuO_2 and UO_2 form a continuous series of solid solutions with a characteristic fluorite structure. A significant amount of information has been developed on both UO_2 and PuO_2 but less is known about the binary system. Chikalla, Pijanowski, and others^(1, 2, 3) have measured the melting points across the binary system and have reported an anomalous maximum in the melting data at approximately 10 wt % PuO_2 . Recent melting measurements performed under the Fast Ceramic Reactor contract however dispute the presence of this maximum.⁽³⁾ Sintering properties of the PuO_2 - UO_2 system were reported previously for both coprecipitated and physically mixed powders by Chikalla.⁽¹⁾

Much of this early work on mixed oxides, however, is clouded by the fact that means for accurate measurements of the oxygen-to-metal (O:M) ratio were not available, and it was possible to have either an oxygen deficit or excess structure which can influence the property being measured.

Under the Fast Ceramic Reactor Development Program some of the basic physical properties of the mixed-oxide system have been studied with particular attention being given to compositions in the range from 15 to 35 wt % PuO_2 . The electrical properties near room temperature were of particular interest in their potential use for a simple nondestructive method for determination of O:M ratio in mixed U-Pu oxides.

SECTION III

SPECIMEN PREPARATION

The stoichiometric mixed-oxide specimens used in this study ranged in composition from 2.5 to 90 percent plutonium oxide and were prepared by a process employing the following steps:

1. Coprecipitation with ammonia from nitrate solutions containing a total heavy-element concentration of 100 gm/l ;
2. Filtration and drying of the ammonium diuranate - plutonium hydroxide coprecipitate;
3. Reduction in helium - 6 percent hydrogen gas at 750°C;
4. Ball milling and screening of the mixed-oxide powder;
5. Cold pressing without binder to approximately 50 percent of theoretical density; and
6. Sintering 4 hours at 1600°C in helium - 6 percent hydrogen containing about 1 percent water vapor. Finished pellets were approximately 0.220 inch in diameter and weighed 1.8 grams. Sintered densities were 85 to 95 percent of theoretical.

The hypostoichiometric mixed-oxide specimens were prepared in similar manner, except that sintering was in an atmosphere of helium - 6 percent hydrogen which had been dried by desiccant columns.

Hyperstoichiometric specimens were prepared by controlled oxidation of stoichiometric specimens; i.e., pellets were heated in air at 400°C until a prescribed weight increase had been obtained, and then were soaked in pure argon to ensure a uniform distribution of the excess oxygen. The oxygen-to-metal ratio of representative pellets from each sintering run and each adjustment run was measured by a standard gravimetric method.⁽⁴⁾

The PuO_2 pellets were prepared by precipitating Pu^{+4} oxalate, calcining in air at 350°C, grinding, pressing, and sintering. After sintering in the hydrogen-helium mixture, the plutonia pellets were heated in air to 900°C to constant weight to ensure that stoichiometric PuO_2 was obtained.

Stoichiometric UO_2 pellets were prepared by standard pellet fabrication techniques with sintering in hydrogen. Hypostoichiometric specimens were prepared by heat treating stoichiometric UO_2 specimens at 2000°C for 1 hour in a vacuum of 1×10^{-5} torr. This treatment resulted in specimens with a stoichiometry of 1.98 to 1.99. These specimens exhibited the characteristic UO_{2-x} structure with precipitates of free uranium. Metallographic examinations of stoichiometric, arc-fused UO_2 used in this study did not show the presence of free uranium. Figures 1 and 2 show the microstructure of these specimens.

As Polished

500X

Figure 1. Microstructure of Vacuum Reduced UO_{2-x}
Showing Precipitates of Metallic Uranium

Etched

100X

Figure 2. Microstructure of Stoichiometric, Arc-Fused UO_2

Hyperstoichiometric UO_2 specimens were prepared by steam sintering at 1400°C for 2 hours, and cooling in an argon atmosphere. Sintering under these conditions resulted in O:M ratios of approximately 2.10.

Metallographic examination of the mixed oxide was limited to specimens of composition $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_2$. Figure 3 shows the microstructure of the $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_{1.98}$ specimens. In general, the mixed oxide exhibits very poor etching characteristics, and this photomicrograph represents atypical results. Metallographic studies of 20 wt % PuO_2 -80 wt % UO_2 specimens in the range of 1.98 to 2.04 indicate no systematic change in structure as a function of stoichiometry. Occasionally, second phases are noted, but studies to date show no direct correlation of these structures with stoichiometry.

Etched

500X

Figure 3. Typical Microstructure of 20 Wt % PuO_2 -80 Wt % UO_2

SECTION IV

EXPERIMENTAL TECHNIQUE

A simple holding device (Figure 4) was used and served for the measurement of resistance and microvoltage across the sintered specimens. Resistance measurements were made by inserting Teflon caps over each copper platen, and silver foil probes were used as the electrical contact. The test apparatus was spring loaded to minimize contact resistance. Contact resistance was negligible with respect to the high resistances of the test specimens. Resistance values were measured with a conductivity bridge (range 2.5 to 10^6 ohms) or a megohmmeter (range 10 to 1000 megohms). Excellent reproducibility was found for all resistance measurements and the only anomalous measurement was that shown in Figure 5 for UO_2 . No obvious reason was found for this high reading.

Seebeck measurements were made by heating the upper and lower platens to obtain a controlled Δt of $40^\circ C$. A peak temperature of $80^\circ C$ was used for all measurements. Teflon support rods electrically separated the upper and lower platens and the test apparatus was mounted on a Teflon block to eliminate any stray voltages from the glove box. Stray voltages were present in all emf measurements; the chromel-alumel thermocouples were the prime, but not the only, source of these stray voltages. Because of these stray voltages, all voltages below $800 \mu V$ were eliminated from this study. Microvoltage measurements were made with a precision potentiometer and a null-type galvanometer.

Figure 4. Electrical Property Test Apparatus

SECTION V

EXPERIMENTAL RESULTS

Both x-ray and electrical property measurements were made on selected mixed-oxide specimens to determine the degree of solid solution and to establish the effect of stoichiometry on the electrical carrier type. Electrical properties also were measured on UO_2 specimens of various stoichiometries to establish any similarities between the UO_2 system and the mixed-oxide system $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_2$ with respect to oxygen.

The electrical property measurements are summarized in Figures 5, 6, 7, and 8. Thermoelectric power measurements were based on an average Δt of approximately 45°C , with a peak specimen temperature of 80°C . All electrical resistivity measurements were made at room temperature.

Figure 5 shows the electrical resistivity measurements of the PuO_2 - UO_2 system at 2.00 stoichiometry. For comparison purposes the earlier French⁽⁵⁾ data are noted. The NUMEC electrical resistivity data for the PuO_2 - UO_2 system were somewhat discontinuous and the investigators suggested that stoichiometry control was possibly at fault.⁽⁶⁾

Resistivity of both UO_2 and PuO_2 are summarized in Table 1. All of the measured UO_2 data agree reasonably well, with resistivities varying between 0.5×10^3 and 7.0×10^3 ohm-cm.

TABLE 1
RESISTIVITY OF STOICHIOMETRIC PuO_2 AND UO_2 at ROOM TEMPERATURE

$\text{UO}_{2.00}$		PuO_2	
Resistivity, ohm-cm	Investigator	Resistivity, ohm-cm	Investigator
1.7×10^3	This study	1×10^9	This study
7.0×10^3	Ref. 5	3×10^8	Ref. 5
0.5×10^3	Ref. 6	2×10^5	Ref. 6
0.9×10^3	Ref. 8	1×10^8	Ref. 7
3.5×10^3	Ref. 9		
1.0×10^3	Ref. 10		

Resistivity data for stoichiometric PuO_2 exhibited a very high value which agreed very well with all but one of the other investigators. It is possible that this low value could have been caused by oxygen-deficient PuO_2 which according to McNeilly, could seriously decrease the resistivity.⁽⁷⁾

Figure 5. Resistivity of (Pu_{0.2}U_{0.8})O₂ and UO₂ as a Function of Stoichiometry

Figure 6. Electrical Resistivity of Stoichiometric $\text{PuO}_2\text{-UO}_2$ Solid Solutions

Figure 7. Seebeck Coefficient Versus Percent PuO_2

Figure 8. Effect of Stoichiometry on Seebeck Coefficient of Both UO_2 and Mixed Oxide

Figure 7 shows the Seebeck coefficient of stoichiometric mixed oxide across the PuO_2 - UO_2 system. A gradual decrease in the thermoelectric power of the mixed oxide was noted with increasing PuO_2 content. At approximately 70 wt % PuO_2 a shift from p- to n-type conduction was noted. No reading was obtained for the stoichiometric PuO_2 sample because of the extremely high resistivity (1×10^9 ohm-cm). (Seebeck coefficients for specimens with resistivities greater than 1×10^6 ohm-cm were not measured in this study because there was insufficient current for galvanometer displacement.)

An extrapolation of the mixed-oxide data indicates that the stoichiometric PuO_2 would exhibit metal-excess, n-type conduction.

Both the resistivity and the Seebeck coefficient were found to be extremely dependent on the stoichiometry. Figures 7 and 8 show these results. A similar behavior was noted for both UO_2 and the mixed oxide as a function of stoichiometry. (As with the PuO_2 specimen no Seebeck measurements were obtained on the 1.99 O:M specimens because of their extremely high resistances.)

SECTION VI

DISCUSSION OF RESULTS

In the $\text{PuO}_2\text{-UO}_2$ system a continuous series of solid solutions are formed which have a fluorite-type lattice and are single phase at room temperature. This is verified by room-temperature x-ray diffraction results noted in Figure 9 which show a nearly linear relationship between lattice parameter and composition per Vegards law.⁽¹¹⁾

Figure 9. Variation of Lattice Parameter with Composition in the $\text{UO}_2\text{-PuO}_2$ System

The data shown in Figure 7 indicates an almost linear decrease in the Seebeck coefficient as a function of PuO_2 in a manner similar to the x-ray data. A change in slope of the electrical resistivity was noted at approximately 20 wt % PuO_2 . Detailed x-ray diffraction studies at this composition have been made which indicate no unique second phases at this composition. (Traces of $\alpha\text{-Pu}_2\text{O}_3$ are occasionally found at other compositions and no step change in $\alpha\text{-Pu}_2\text{O}_3$ as a function

of composition or stoichiometry has been noted.) The inversion from p- to n-type conduction at approximately 70 wt % PuO_2 is inconsistent with McNeilly's data which suggest that stoichiometric PuO_2 should exhibit p-type conduction at room temperature.⁽⁷⁾ Because $\alpha\text{-Pu}_2\text{O}_3$ is more n-type than $\text{PuO}_{2.00}$, it is possible that a discontinuity exists between 80 wt % PuO_2 and pure $\text{PuO}_{2.0}$ where there exist more electrons than holes. A second possible reason for this disagreement is that PuO_2 usually exhibits a very small p-type Seebeck coefficient at room temperature and any impurities in the PuO_2 could convert it to a metal-excess type where there is a higher mobility for electrons than holes.

The addition of oxygen to a $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_2$ unit cell results in a gradual linear contraction of the cell size in a manner similar to that of the UO_2 unit cell. This is shown in Figure 10 and Table 2. This linear decrease in cell size shows that a defect single-phase structure exists within 1.97 and 2.01 stoichiometry. These compositions are not necessarily the solubility limits but represent the range studied in this investigation. The type and magnitude of these oxygen vacancies or interstitials should be determined readily by electrical property measurements. Such a relationship was found, as noted in Figures 7 and 8. No change from p- to n-type conduction was observed with decreasing oxygen content in the mixed-oxide system as was previously reported for the UO_2 to UO_{2-x} system. Since the UO_{2-x} system is characteristically metal excess (see Figure 1) and the $(\text{Pu}_{0.2}\text{U}_{0.8})\text{O}_{2-x}$ is not, this difference is as expected. The increase in electrical conductivity with increasing holes in both the UO_2 and the mixed-oxide systems is consistent with theory.

TABLE 2

CHANGE IN LATTICE PARAMETERS AND SECOND PHASES IN MIXED OXIDE
WITH VARYING OXYGEN CONTENT

O:M (Chemical Analysis)	PuO_2 Content (Chemical Analysis), Wt %	Pu/Pu+U (X-Ray Analysis), Wt %	Lattice Parameter of Solid Solutions Phase, Å	Trace Phases	Relative Amount of Trace Phases
2.010	20.0	20.37	$5.455 \pm .001$	Alpha- Pu_2O_3 *	weak minor
2.000	20.0	20.36	$5.4567 \pm .0002$	Alpha- Pu_2O_3	weak minor
1.989	20 (nominal)	18.73	$5.4577 \pm .0002$	Alpha- Pu_2O_3	very weak
1.976	20.0	20.16	$5.460 \pm .007$	Alpha- Pu_2O_3	weak

* $\text{Pu}_2\text{O}_3\text{-Pu}_4\text{O}_7$ - Identity of these phases is based on a measured lattice parameter of the second phase at 11.03 to 11.01 Å. The structure of alpha- Pu_2O_3 was indexed by Zachariasen and was shown to be a defect structure that can contain additional oxygen atoms in the range Pu_2O_3 to Pu_4O_7 .^(12, 13) Ellinger, in a separate study, found that the lattice parameter of alpha- Pu_2O_3 could vary between 11.00 ± 0.02 and 11.04 ± 0.02 Å for oxygen-rich and oxygen-deficient structures, respectively.⁽¹⁴⁾

The highest resistance measured for mixed oxides and UO_2 was found at stoichiometries of 1.975 and 1.99, respectively. Since the maximum resistivity normally would be expected to occur at the stoichiometric composition, it is interesting that the electrically neutral structure may occur at or near 1.975 for the mixed oxide and at 1.99 for UO_2 . This is apparently in agreement with Duncan and Ferrari's data which showed that the minimum charge carrier concentration for UO_2 was 1.99.⁽¹⁰⁾

Figure 10. Variation of Unit Cell Size with Stoichiometry of 20 Wt % PuO₂ - 80 Wt % UO₂ Composition

REFERENCES

1. T. D. Chikalla, "Studies on the Oxides of Plutonium," presented at the Second International Conference on Plutonium, Grenoble, France (April 1960).
2. S. W. Pijanowski and L. S. DeLuca, "Melting Points in the System PuO_2 - UO_2 ," KAPL-1957 (April 1960).
3. W. L. Lyon and W. E. Baily, "The Solid-Liquid Phase Diagram for the UO_2 - PuO_2 System," GEAP-4878 (December 1965).
4. W. L. Lyon, "The Measurement of Oxygen to Metal Ratio in Solid Solutions of Uranium and Plutonium Dioxides," GEAP-4271 (May 1963).
5. W. L. R. Rice, "Nuclear Fuels and Materials Development," TID-1125 (3rd Ed.) page II. 101 (July 1964).
6. NUMEC Progress Report, "Development of Plutonium Bearing Fuel Materials," October through December 31, 1963, NUMEC-2389-1.
7. C. E. McNeilly, "The Electrical Properties of Plutonium Oxide," Jour. Nuc. Matls. 11, 1 (1964) p. 53-58.
8. R. A. Wolfe, "The Electrical Conductivity and Thermoelectric Power of Uranium Dioxide," WAPD-270 (April 1963).
9. S. Iida and Y. Takada, "Electrical Properties of Uranium Dioxide," Mitsubishi Atomic Power Industries, Inc: MAP I-No. 4-1; MAP I-RR-80.
10. R. N. Duncan and H. M. Ferrari, "Preparation and Properties of Hypostoichiometric Uranium Dioxide," Trans. Am. Nuclear Soc., 6, 1, June 1963.
11. Private Communications with the Authors and W. V. Cummings.
12. W. H. Zachariasen, "Crystal Structure Studies of Oxides of Plutonium," AECD-1787 (July 1946).
13. W. H. Zachariasen, "Metallurgical Progress Report," CN-2069, p. 35 (August 1964).
14. F. H. Ellinger, "A Review of the Intermetallic Compounds of Plutonium," The Metal Plutonium 281-308, The University of Chicago Press (1961).

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of K. J. Perry and W. M. Cavanaugh for their help in test apparatus assembly and test measurements. W. V. Cummings performed the x-ray diffraction analyses. Acknowledgment is also made to E. L. Zebroski for his many helpful comments and suggestions.

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