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Part II. Space Power Technology

12. High-Temperature Alloys for Isotopic Heat Sources

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The purpose of this program is to develop high-melting, oxidation-resistant alloys for space applications of isotopic heat source capsules operating between 800 and 1400°C. This requires alloys exhibiting superior performance under operational, abort, reentry, earth impact, and postimpact conditions. Potential applications are as fuel containment materials in $^{238}\text{PuO}_2$ - and $^{244}\text{Cm}_2\text{O}_3$ -fueled thermoelectric generators, such as the Multi-Hundred Watt (MHW) generator now under development and advanced versions of the SNAP-19 generator as used aboard the Pioneer space probe.

DEVELOPMENT OF IRIIDIUM-BASE ALLOYS

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Iridium alloys containing small amounts of Ru, Re, W, Nb, and Hf have been studied in an effort to develop high-melting, high-strength, oxidation-resistant materials for space power applications to 1400°C. The iridium alloys were fabricated by cladding them in a molybdenum jacket and hot rolling between 1100 and 1300°C, followed by cold working at room temperature with intermediate anneals. Good quality sheets 0.020 in. thick were obtained from 150-g alloy ingots containing up to 2 at. % alloying elements.

Alloying iridium with these elements raises the recrystallization temperature. Whereas unalloyed iridium recrystallizes at about 800°C, alloying with 2 at. % Ru, Re, and W increases the recrystallization temperature to 1100, 1300, and 1400°C, respectively.

The tensile properties of the alloys to 1316°C (2400°F) are shown in Table 12.1. Hafnium is the most effective strengthening element. Iridium-1 at. % Hf has a tensile strength (TS) of 70,000 psi and a yield strength (YS) of 23,000 psi at 1316°C, 3 to 4 times

Table 12.1. Comparison of the tensile properties of iridium-base alloys with iridium, TZM, T-111, and Pt-3008^a at 1316°C (2400°F)

Alloy (at. %)	Strength (psi)		Elongation (%)	Toughness (in.-lb/in. ³)
	Tensile	Yield		
Ir	26,300	5,500	50.2	8,000
Ir-1 Hf	70,000	23,000	37.4	17,400
Ir-2 Nb	46,800	14,800	30.3	9,300
Ir-2 W	45,200	17,000	36.0	11,200
Ir-2 Re	31,300	16,000	47.0	11,100
Ir-2 Ru	23,000	8,000	45.4	7,000
TZM	20,000	9,900	40.0	6,100
T-111	37,300	23,500	36.0	11,000
Pt-3008	22,500	15,900	48.0	9,200

^aPt-30 wt % Rh-8 wt % W.

those of unalloyed iridium. For the alloying elements studied, strengthening decreases in the order Hf, W, Nb, Re, and Ru. The alloys Ir-1 at. % Hf, Ir-2 at. % W, and Ir-2 at. % Nb are all stronger than the refractory alloys TZM and T-111. In terms of toughness [defined as fracture strain $\times (TS + YS)/2$] at 1316°C, the Ir-1 at. % Hf ranks first among all the candidate alloys.

The oxidation rate of the alloys in flowing air is equal to that of pure iridium at 1000°C but is generally lower at 770 and 870°C. Thus, in concentrations up to 2 at. %, these alloying elements do not significantly impair the oxidation resistance of iridium.

DEVELOPMENT OF PLATINUM-BASE ALLOYS

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Recently developed platinum alloys containing 26 to 30% Rh and 8% W continue to be characterized for use

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as the encapsulating material for isotopic fuels. Evaluation of alloy properties continues to show good fabricability and strength; however, in our efforts to scale up the production of these alloys, several problem areas have been identified. These include (1) compositional analyses and control; (2) melting, casting, and fabrication; and (3) inconsistency in the mechanical properties. Preliminary results suggest that difficulties in compositional analysis and control may be contributing to inconsistencies in fabricability and mechanical properties.

IRIDIUM PURIFICATION AND SCRAP RECYCLE

H. Inouye

High-purity iridium is required as the base for producing alloys to contain isotopic fuels at very high temperatures. Because of the high cost of iridium, a method of purifying and/or recycling iridium scrap was necessary. Zinc amalgamation, chlorination, and oxidation processes were investigated.¹ Of these methods, the oxidation process was most suitable. In principle,

1. R. G. Donnelly and A. C. Schaffhauser, *Space Power Materials Development Quart. Progr. Rep. Sept. 30, 1972*, ORNL-TM-4057, pp. 4-8.

impure iridium is oxidized in flowing oxygen at 1000 to 1200°C to produce $\text{IrO}_3(g)$, while the nonvolatile impurities remain as a residue in the furnace. The $\text{IrO}_3(g)$ then condenses as $\text{IrO}_2(s)$ in the cooler parts of the furnace. The acid-insoluble IrO_2 is digested in HF and aqua regia to remove any carry-over of volatile impurities, then reduced to metal with hydrogen at 600°C. A powder product assaying 99.98% Ir is produced.

SPECIAL PROBLEMS AND CONSULTING

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A variety of short-term tasks and consulting services were provided to SNS in connection with the Multi-Hundred Watt Thermoelectric Generator Project. Among these were problems related to the development of a method for fabricating iridium sheet, a method for cleaning iridium, mass-transport studies of iridium and carbon in a temperature gradient, and vent plugging. Current activities include a study of the influence of thermomechanical treatments on the structure and mechanical properties of iridium-tungsten alloys and the development of a chemical-thermal method for processing fabricated iridium hemispheres.