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High-Temperature Mechanical Properties of a DOP-26 Iridium Alloy under Impact Loading

Bo Song, Kevin Nelson, Ronald Lipinski, John Bignell

G. B. Ulrich, E. P. George

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Outline

- Background
- Kolsky bar techniques for dynamic characterization of materials
 - High-temperature Kolsky compression bar technique
 - High-temperature Kolsky tension bar technique
- Dynamic high-temperature characterization of iridium
 - In compression
 - In tension
- Experimental Results
- Summary
- Acknowledgments

Background



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11A	2				CIN	ouic			/ ui		enic	13	14	15	16	6	Phy	sical properties		Miscellanea
Hydrogen 7,0079	IIA 2A											IIIA 3A	IVA 4A	VA 5A	6A 8	A	Phase	solid	Crystal structure	face-centered cubic
Lation	Be											B	C Cattor 12011	N Nitrapen 14.00074	0 0xya 15.99	2	Density	22.56 g·cm ⁻³	-	
Na Bastar	Magnesses	3 111B 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 - VIII	10	11 18 18	12 IIB 2B	Aureiture 26.021530	14 Si Stitum Stitutes	15 Pheepherse 30 9777802	16 54%	B	(near r.t.)			a a
¹⁹ K	Ca	²¹ Sc ²²	Ti ²³	V 24	Cr 2	Mn	Fe	Co	²⁸ Ni	²⁹ Cu	³⁰ Zn	Ga	³² Ge	³³ As	34 Se	e l	Liquid density at	19 g·cm ⁻³	Magnetic	paramagnetic ^[1]
37 Rb	38 Sr	39 40		Nb 42	Mo 4	³ Тс	Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	e	m.p.		ordering	
S5	Deveture 87.62	^{Ymturn} 25 88.60586 57-71 72	Prostan N P122N 00 73	1084am Mc 2.99834 74	BLDA 78	schneiten 66.0072	Ruthenium 101.07	Rhedbare 102,5665	Paterilan 101.42 78	08ver 187.8582 79	Cadmium 112.411 80	Indian 114,818	та 118.71 82	Artimony 121740	Tatlurk 127.0 84	1.0	Melting point	2739 K, 2466 °C, 4471 °F	Electrical	(20 °C) 47.1 nΩ·m
Cashen 192,000au	Ba Barkan 137:327	10.103	HT Internet Tal		VV Tats as	Re Iburitum 185.207	Oessize 196.23	1960 1972-22	Pt Platinum 195.08	AU Geld 196,9655	Hg Marcury 200.58	Thaillian 204.3833	PD Lese 2072	Bi Banut 208 98037	Polosi	0	Boiling point	4701 K, 4428 °C, 8002 °F	resistivity	
Fr	Ra		Rf D	Db violatin Se (292)	Sg	Bh Botram 204	Hs	Mt Hattadur	OS Server start	Rg	Cn Coopernatives [277]	Unamerican	Ununquadur	Uup			Heat of fusion	41.12 kJ·mol ⁻¹	Thermal	147 W·m ^{−1} ·K ^{−1}
and the second		57	58	⁵⁹ Pr	⁶⁰ Nd	Pm	Sm.	63 Et	-	i T					70	Ŷ	Heat of	563 kJ·mol ⁻¹	conductivity	
2 her				146.90705 91 Pa	92	93 No	94 P11	95	1	1					10	02	vaporization		Thermal	6.4 μm/(m·K)
-	50		A	Production of the local division of the loca	Service Service	an one	Constant Second	1000				-			μ		Molar heat	25.10 J·mol ⁻¹ ·K ⁻¹	expansion	
- Ale	A.	134	7	Alkalise Earth	Trensition Metai	n Das Met	sic Ger	nimetala			I				L		capacity		Speed of sound (thin rod)	(20 °C) 4825 m·s ^{−1}
6	AT PR									I	rid	iur	n						Young's	528 GPa
192.22										modulus										
																			Shear modulus	210 GPa
																			Bulk modulus	320 GPa

A very hard, brittle, silvery-white <u>transition metal</u> of the <u>platinum family</u>, iridium is the second-<u>densest</u> element (after <u>osmium</u>) and is the most <u>corrosion</u>-resistant metal, even at temperatures as high as 2000 C.

expansion	/
Speed of sound (thin rod)	(20 °C) 4825 m·s ^{−1}
(unit rou)	
Young's	528 GPa
modulus	
Shear modulus	210 GPa
Bulk modulus	320 GPa
Poisson ratio	0.26
Mohs hardness	6.5
Vickers	1760 MPa
hardness	
Brinell hardness	1670 MPa
CAS registry number	7439-88-5

Background





DOP-26 Iridium Alloy (developed by ORNL)

- By weight:
 - 0.3% tungsten to enhance weldability
 - 60-ppm (parts per million) thorium to increase ductility
 - 50-ppm aluminum
- Unique properties
 - High-melting point
 - Good high-temperature strength
 - Good oxidation resistance
 - Compatibility with the fuel and graphitic heatsource components
 - High impact ductility at high temperatures

Kolsky Bar (Split Hopkinson Bar) Techniques





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High-Temperature Kolsky Bar Principles in Stational Stationae Stationae Stat





- Avoid "hot" pressure bars
 - Heat specimen individually
 - Hot Specimen/Cold Bars
 - Heat transfer
 - Specimen temperature drops
 - Bar temperature increases thermal gradient in the bars

Cold Contact Time (CCT) is the time during which the "hot" specimen stays in contact with the "cold" pressure bars until being dynamically loaded



High-Temperature Kolsky Compression Bar



Follansbee et al. @LANL



Ramesh, et al. @ JHU











Additional Challenges for High-Temperature Kolsky Bar Testing of Iridium

- Small/Thin Iridium Specimen
 - Temperature drops very quickly when the specimen starts in contact with cold pressure bars
 - High strength at high temperature
 - High-Temperature Lubrication





Compression Test Setup and Procedure









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Compression Test at 1000 s⁻¹/750C

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High-Temperature Kolsky Tensile B

- Current high-temperature Hopkinson compression techniques are not applicable to tensile tests
- How?













Stress and Strain Measurements







Semiconductor strain gages – specimen stress measurem (GF: 139 vs. 2 for regular foil strain gage)



Typical Dynamic High-Temperature Tensile Test



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Specimen During and After Dynamic High-Temperature Test





			K3-6-6-2					
	Initial Mea	surements	After Measurements					
	(in.)	(mm)		(mm)				
	0.03590	0.9119	*	1.3406				
	0.03495	0.8877		Break				
	0.03495	0.8877	*	1.3467				
	0.03495	0.8877		1.3606				
	0.03485	0.8852		1.2579				
	0.03505	0.8903						
-	** One or	both indenta	tions were	e difficult t	o detec			
_	Measur	ement value	is suspect					
	Α							
	Ave	rage						
	0.03511	0.89175						
		3.5725		5.3058	0.485			



Engineering Compressive Stress-Strain Curves Different Strain Rates and Temperatures



Engineering Tensile Stress-Strain Curves at Different Strain Rates and Temperatures



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Tension vs Compression







Summary

- Kolsky bar (split Hopkinson bar) techniques have been properly modified to characterize Iridium in compression and tension at high temperatures
- DOP-26 iridium alloy has been dynamically characterized in compression and tension at different strain rates and temperatures
- The DOP-26 iridium has shown significant strain rate and temperature effects
 - Flow stress increases with increasing strain rate but decreases with increasing temperature



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