Structural phase transformations study of brittle refractory metals and intermetallics with L1₂ structure using synchrotron radiation

PILYUGIN, Vitaliy
SOLOV’EVA, Yulia
ANCHAROV, Alexey
STARENCHENKO, Vladimir
STARENCHENKO, Svetlana
TOLMACHEV, Timofey

M.N. Mikheev Institute of Metal Physics of the Ural Branch of the Russian Academy of Sciences (IMP UB RAS)
Tomsk State University of Architecture and Building
Institute of Solid State Chemistry and Mechanochemistry SB RAS
Aims, materials and methods

Study of microstructure and phase state:
intermetallic Ni$_3$Ge, with anomalous properties,
transitional 3d-4d metals (Fe, Ti, Zr), including
refractory fragile (Mo, Ir, Re) after deformation
under high pressure (HPT)

SR, NGR, TEM, SEM, metallography, mechanical
tests
SCSTR Budker INP SB RAS
Diffractometry in hard X-rays $\lambda=0.3686$ Å°
HPT in Bridgman anvils - shear under pressure. Ag in situ under pressure 12 GPa between c-NB, SR, $\lambda=0.3686\,\text{Å}^\circ$
The microstructure of superalloys with intermetallic phase (Ni$_3$Ge, Ni$_3$Al, Ni$_3$Fe)
Alloys with anomalous temperature dependence of the flow stresses: Ni$_3$Ge, Ni$_3$Al, Ni$_3$Fe, Ni$_3$W

The data of different authors

SFR-2016
Superstructure $L_1^2$

- **FCC - lattice**

- • – A atoms
- ○ – B atoms
Plastic deformation superlocalization

\[ \frac{T}{T_{\text{m}}} > 0.6 \]
Plastic deformation superlocalization

$T=923 \text{K}$, $\varepsilon \approx 13\%$
Plastic deformation superlocalization

$T=973\,K, \varepsilon \approx 9\%$ (SCAN)
Single crystal: (001) (031) (301)
Polycrystalline
Phase transitions
Fe phase diagram
$\lambda = 0,368 \, \text{Å}:
Anvils c- NB;
Fe: c-NB + $\varepsilon$-phase, P=14 GPa
Mössbauer spectra of strained iron under pressure. Left: CG sample. a – initial state b – 14.5 GPa, 45 % hcp; c – 16 GPa, 70 % hcp. Right: NC sample. a – initial state of the sample outside of anvils; b – 8.0 GPa 0 % hcp ; c – 16.8 GPa 11 % hcp; d – 18.5 GPa 48 % hcp; e – 19.5 GPa 72 % hcp.
HYSTERESIS OF $\alpha$-\(\varepsilon\) TRANSITION IN IRON

In situ data NGR and SR

$\Delta H = 4$ ГПа
Ti
Ti
The mechanical properties of refractory 4d-metals

<table>
<thead>
<tr>
<th></th>
<th>B, GPa</th>
<th>G, GPa</th>
<th>µ</th>
<th>σ_B, MPa</th>
<th>δ,%</th>
<th>Ψ,%</th>
<th>H_µ,GPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>350-400</td>
<td>125-155</td>
<td>0.3</td>
<td>1000</td>
<td>0.6%</td>
<td>0%</td>
<td>3.480-3.800</td>
</tr>
<tr>
<td>Ir</td>
<td>520-590</td>
<td>199-266</td>
<td>0.28</td>
<td>490</td>
<td>6-10% (70% m/К)</td>
<td>10-15%</td>
<td>1.960-2.350</td>
</tr>
<tr>
<td>Ta</td>
<td>190</td>
<td>70</td>
<td>0.35</td>
<td>204</td>
<td>30%</td>
<td>75%</td>
<td>2.310</td>
</tr>
</tbody>
</table>
Products made of iridium

Iridium crucibles of different shapes, wire, rolled, tubes, ingotshigh-processed metal, massive single crystals (Ekaterinburg plant)

Container of plutonium oxide alloy Ir-0.3% W for thermoelectric generator, Galileo, 1989

Platinum Metals Rev.-1997.-vol. 41, No 4, pp. 154 – 163 (Окриджская национальная лаборатория, США)
Ir Poly Discs Indented (m=100g)

Deformed               Initial

20-10-2007
Ir, HPT $\varepsilon \geq 5$, 14 GPa

Nanostructure of iridium
Ta diffraction patterns in SR
Ta texture after HPT

Initial

n=1

n=5
THANK YOU!