Mechanical Characterization of Tungsten-Titanium-Lanthana alloy: Influence of Temperature and Atmosphere

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TARGET

Evaluate the mechanical behavior of Ti and La_2O_3 dispersed W alloy , processed by HIP and compared it with a reference pure-W.
Tests were performed in both oxidant (air) and inert (vacuum) atmosphere in a temperature range from -196 to 1200 °C.

MATERIAL & SAMPLES

- Both materials were processed by MA and HIP in an Ar atmosphere.
- Bend bar specimens were cut by electro-discharge-machining.
- Laser notches were perfomed in some of these samples for fracture toughness TPB tests. The size of these notches tips were smaller than 0.5 µm (smaller than the grain size).

RESULTS

TPB Tests

Dimentions: 1.6 x 1.6 x 25 mm^3
Span:
16 mm - flexural strenght tests
8.5 mm - fracture toughness tests

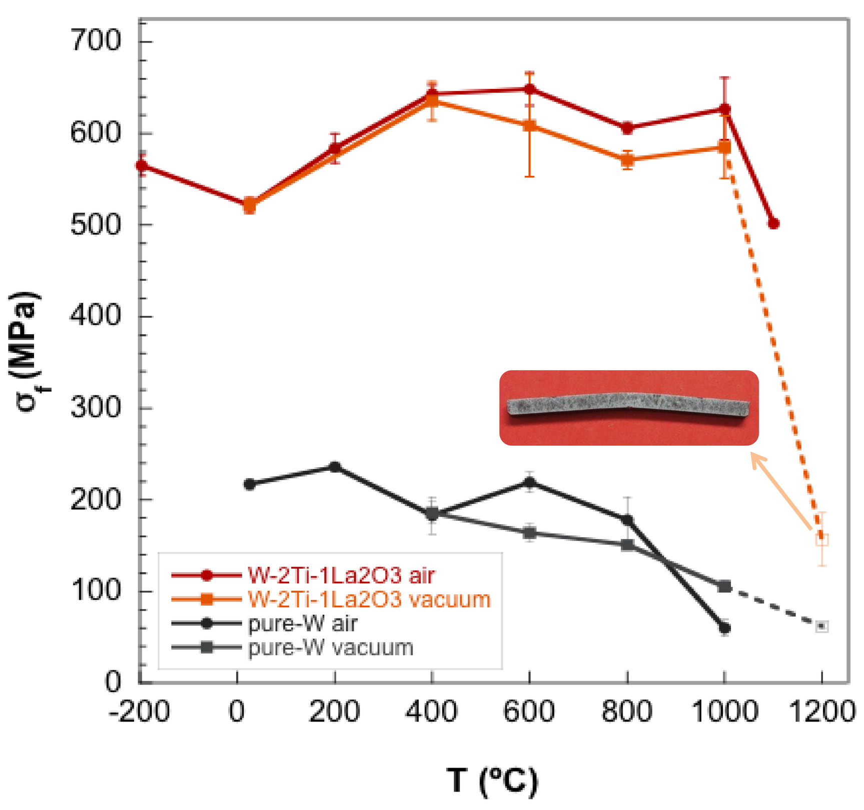

Fig. 1. *Average flexural strength versus temperature for the W-2Ti-1La$_2$O$_3$ alloy and pure-W in air and vacuum atmosphere. Open symbols and dashed lines represent yield strength at 0.2 %.*

According to the TPB tests, **the behavior is linear elastic** until failure up to 1200 °C. Plastic behavior was only found in the flexural strength tests at 1200 °C in vacuum, when the sample is macroscopically bended but not broken as is shown in Fig. 1. Moreover at this temperature, the values decrease drastically.

There is a slightly influence of the atmosphere in the alloy, as the results are most of the time overlapped. But a increase of the values compared to pure-W are observed in both tests (Fig. 1 and 2). The values remain stables in almost all the temperature range, so the alloying elements decrease the degradation processes.

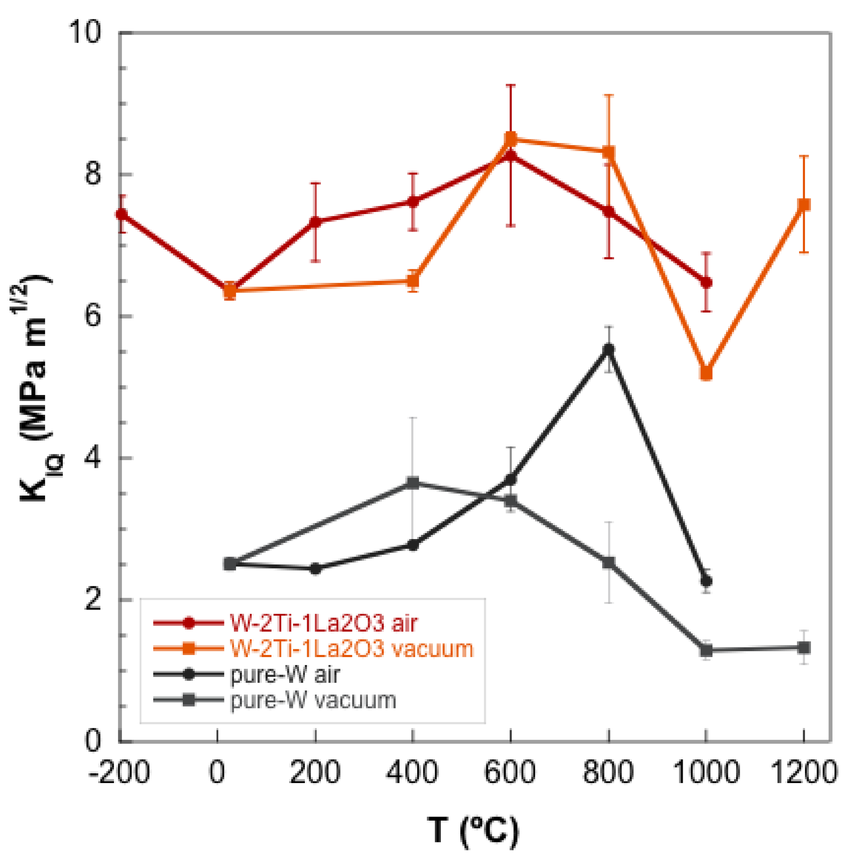

Fig. 2. *Average fracture toughness versus temperature for the W-2Ti-1La$_2$O$_3$ alloy and pure-W in air and vacuum atmosphere.*

Table 1. *Results obtained for density tests, Impulse Excitation Technique (IET) for dynamic modulus calculation, nanoindentation and Vickers tests.*

Material	ρ_{exp} (g/cm^3)	Porosity (%)	E_{IET} (GPa)	nE (GPa)	HV (GPa) 9.8 N	HV (GPa) 0.98 N	nH (GPa) 0.6 N
Pure-W	17.64±0.02	8.36	338±5	350±40	2.58±0.03	3.40±0.50	3.72±0.09
W-2Ti-1La$_2$O$_3$	16.86±0.02	4.74	350±1	440±30	12.83±0.10	13.68±0.33	15.2±1.8

Oxidation

Pure-W is highly reactive with oxygen above 400 °C, but with the addition of the alloying elements (Ti, La_2O_3), the **oxidation processes are decreased**. As a consequence the outer yellow scale remain thinner and the mass gain is lower in all the temperature range. The main difference is at 1000 °C, as can be seen in Fig. 3 and 4. Some cracks appears in the scale as a consequence of the stresses produced during oxide growing.

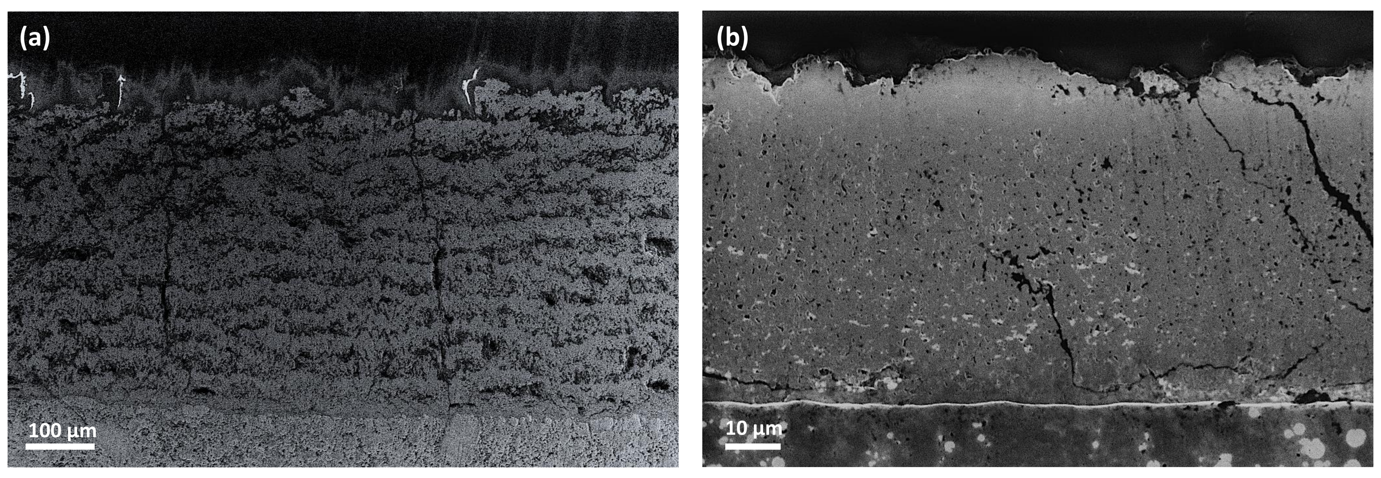

Fig. 3. *Cross sections of the scales developed of the samples oxidized in air after 15 min exposure at 1000 °C; **(a)** pure-W; **(b)** W-2Ti-1La$_2$O$_3$ alloy.*

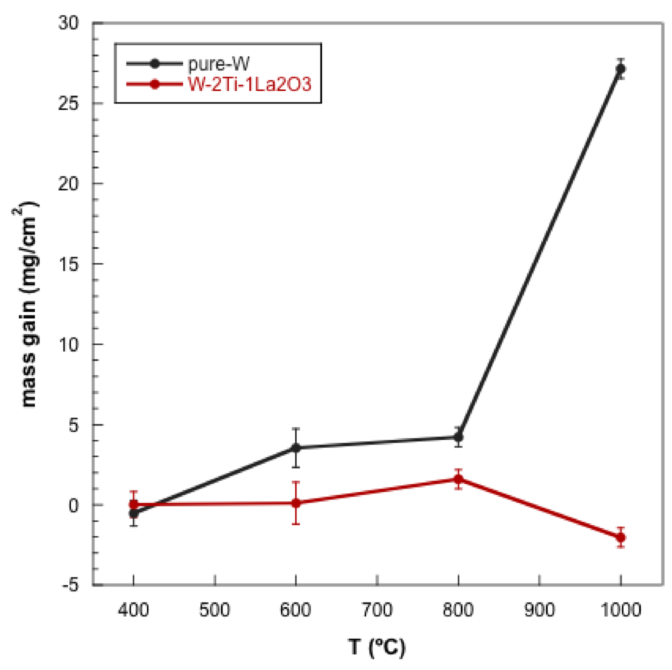

Fig. 4. *Mass gain curves versus temperature of the samples oxidized 15 min in air.*

Microstructure

With the addition of the alloying elements the grain size become nanometric, as shown in Fig. 5 and 6, and the porosity decreases, Table 1.

The microstructure change from polyedral coarse grains (pure-W) to coarse W grains and Ti pools surrounded by a W-Ti-La solid solution.

It is seems that the La nanoparticles are mostly in the grain boundaries, but further studies need to be developed.

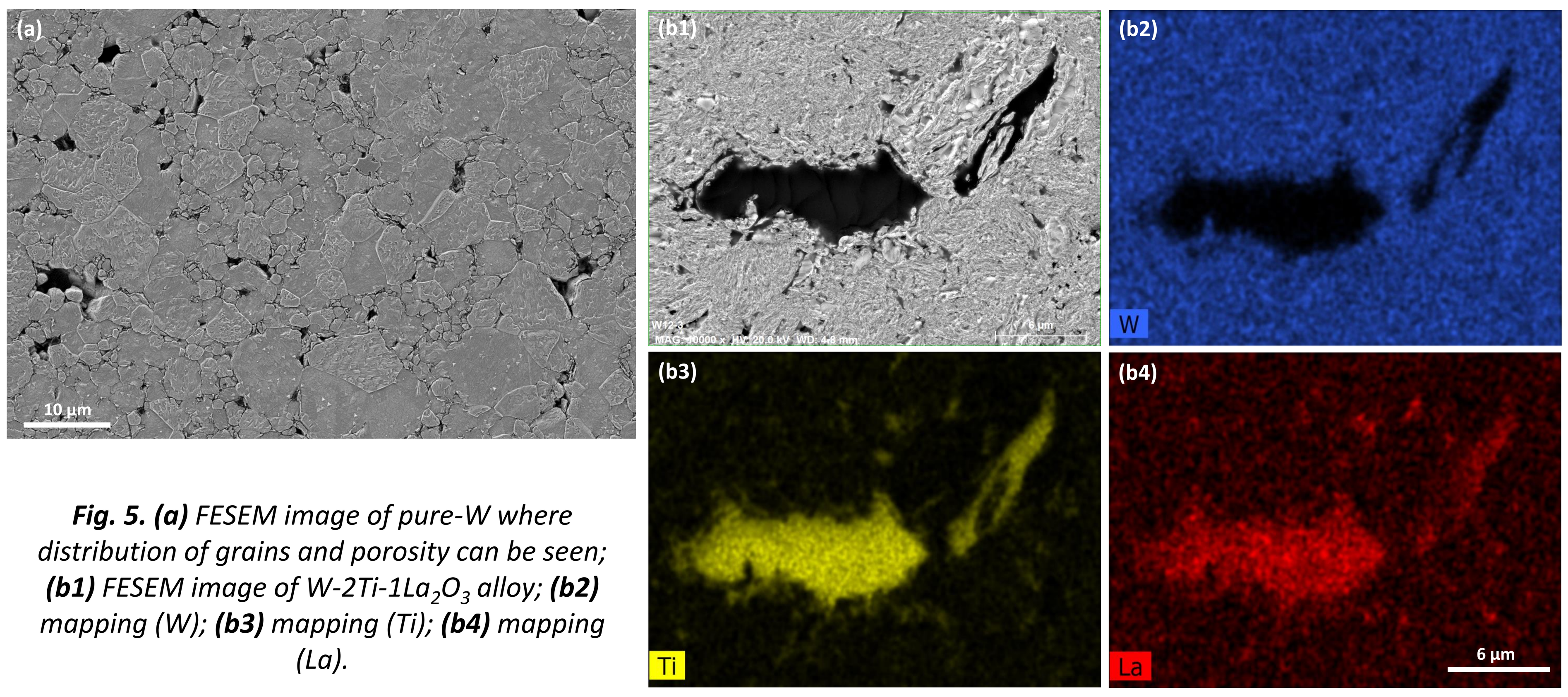

Fig. 5. ***(a)*** *FESEM image of pure-W where distribution of grains and porosity can be seen;* ***(b1)*** *FESEM image of W-2Ti-1La$_2$O$_3$ alloy;* ***(b2)*** *mapping (W);* ***(b3)*** *mapping (Ti);* ***(b4)*** *mapping (La).*

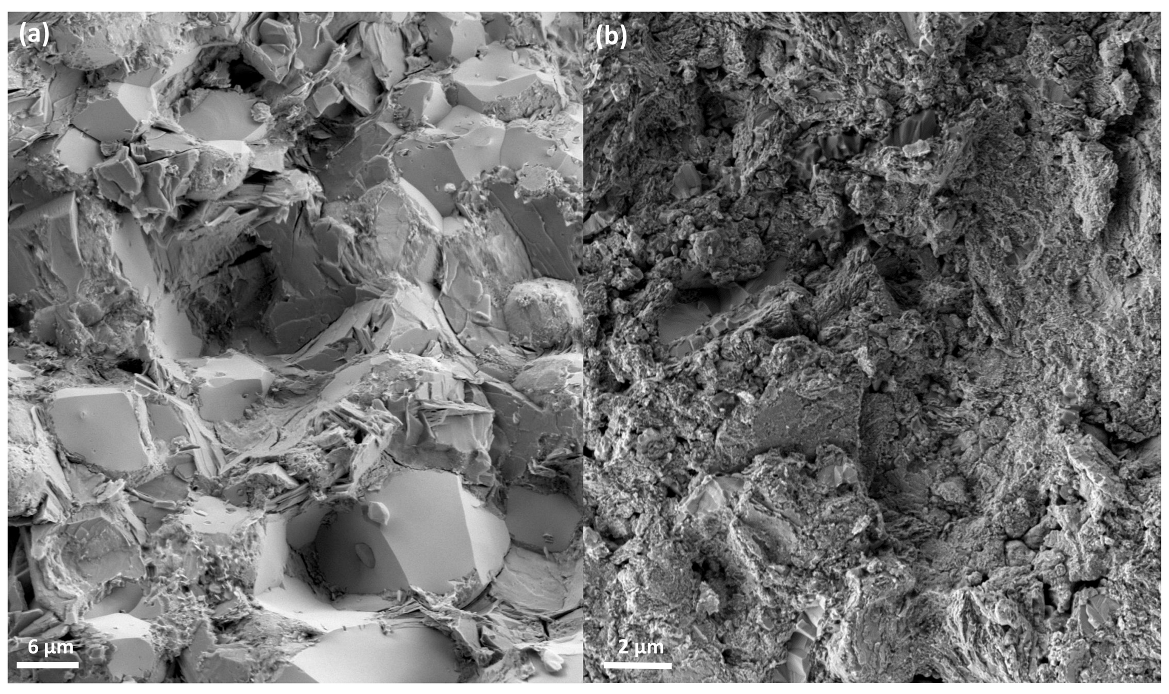

Fig. 6. *Fracture surface at 25 °C **(a)** pure-W; **(b)** W-2Ti-1La$_2$O$_3$.*

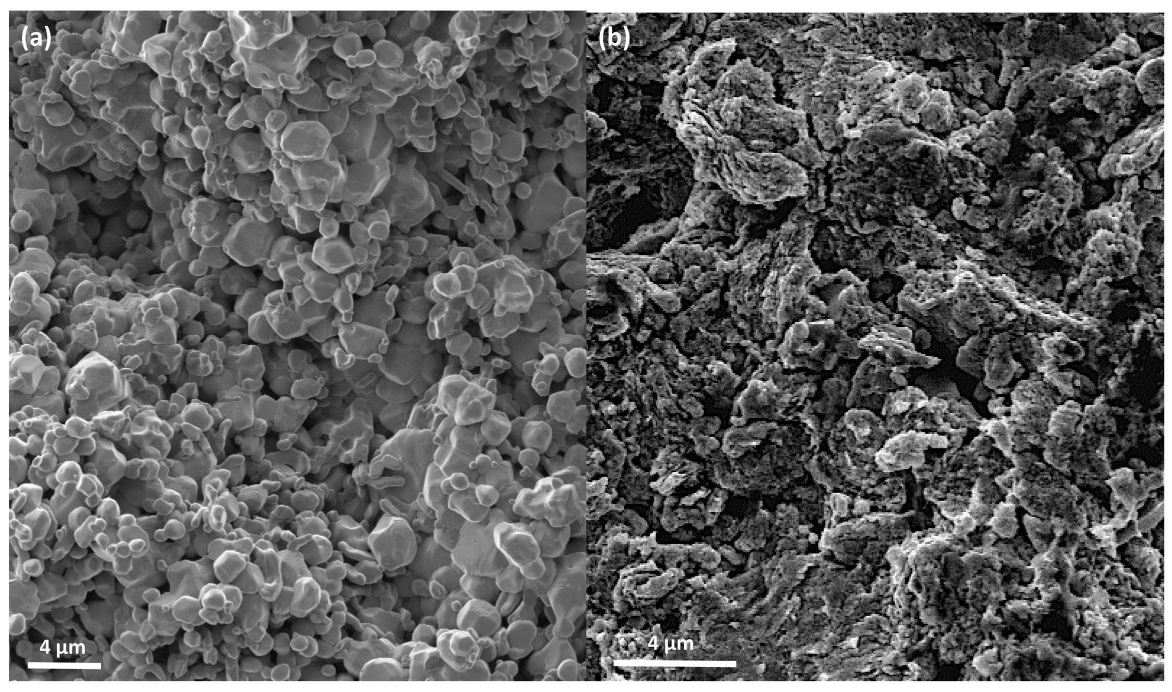

Fig. 7. *Fracture surface at 1000 °C **(a)** pure-W; **(b)** W-2Ti-1La$_2$O$_3$.*

Fracture surfaces of the materials tested are flat and show fracture decohesion by grain boundary (Fig. 6, 7).

CONCLUSIONS

- With 2Ti-1La$_2$O$_3$ addition the porosity of the samples slightly decreases and the grain size became **nanostructured**.
- **Mechanical properties** of the W-2Ti-1La$_2$O$_3$ according to TPB tests, increase from those for pure-W. The values remain **stables** in all the temperature range with the exception of 1200 °C in vacuum when the values drop drastically and the material experiment ductile behavior.
- Fracture surfaces remain flat and show **intergranular breakage between grain boundaries** although the nanostructure of the W-2Ti-1La$_2$O$_3$ alloy. Supported by brittle behavior of the performed TPB tests.
- TPB tests values for air and vacuum atmospheres are overlapped so the alloying elements act against oxidation. Large reduction of the scale at 1000 °C in the Ti-La alloy.

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