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Thermal Change of Microstructure and mechanical property of Dispersion Strengthened Tungsten

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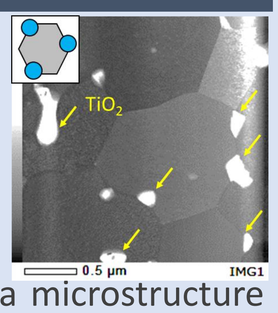
ABSTRACT

New dispersion strengthened tungsten (DS-W) including TiO_2 in grain boundary particles have been developed for an improvement of Plasma Facing Materials (PFM) on divertor heat removal component in the fusion reactor.

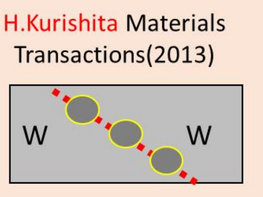
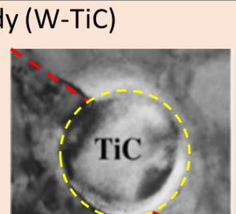


Compared with Pure Tungsten, the DS-W did not showed a microstructure change and a drastic decrease of the bending strength and the thermal conductivity after annealing at high temperature.

BACKGROUND

1. History of the research trend

1990s~ "Oxide Dispersion strathening" have be been focused as strengthening of ferritic steel for fusion.

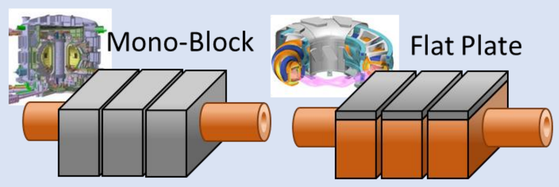
Grain interior	Grain boundary
Depressant of dislocation movement	Pinning effect
	
Increase of recrystallization Tem.	Depressant of coarsening of grain

Highest creep strength in the world as ferritic steel. And having resistance of irradiation

2000s~ The studies applying to other base materials(V,Ni etc…) have been started.

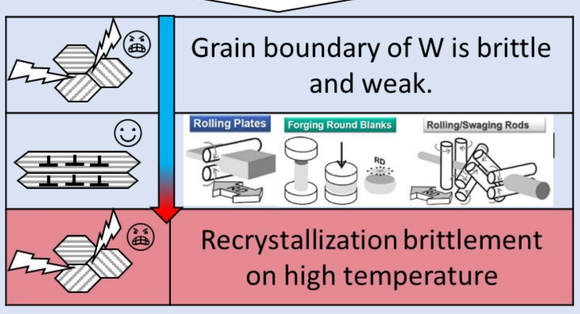
2011s~ Studies of new tungsten alloy have been actively started.

2. The designing for Solid Divertor



On each designing, Tungsten is expected as plasma facing materials.

However



Designing policy of new tungsten : strengthening of brittle tungsten

1. Strengthening of Tungsten (W)

Toughness of tungsten (W) is one of the critical issues for a future DEMO reactor application.

Global trend for the strengthening approach

- ✓ **Reinforce : Laminate, fiber**
- ✓ **Coating : VPS, CVD**
- ✓ **Solid Solution : W-(Re,Ta,V etc…)**
- ✓ **Bubble Dispersion : K-Dope-W**
- ✓ **Particle Dispersion : W-carbide**

In previous study (W-TiC)

H.Kurishita Materials Transactions(2013)

Decreased in brittle G.B. Strengthen by TiC

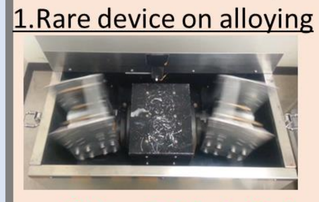
The particle dispersion in tungsten alloys is one of the interesting approaches to improve mechanical strength.

2. Production of New W alloy

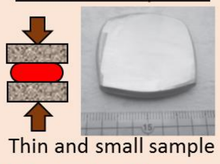
~Kurishita method(W-TiC)~

⇒ Difficulty of the process

1.Rare device on alloying



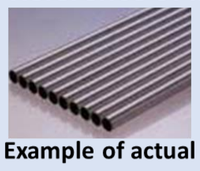
2.One axis press



Thin and small sample

Not suitable to industrial production

Reference of industrial production・・・



Example of actual production (ODS steel)

Mechanical alloying (MA)

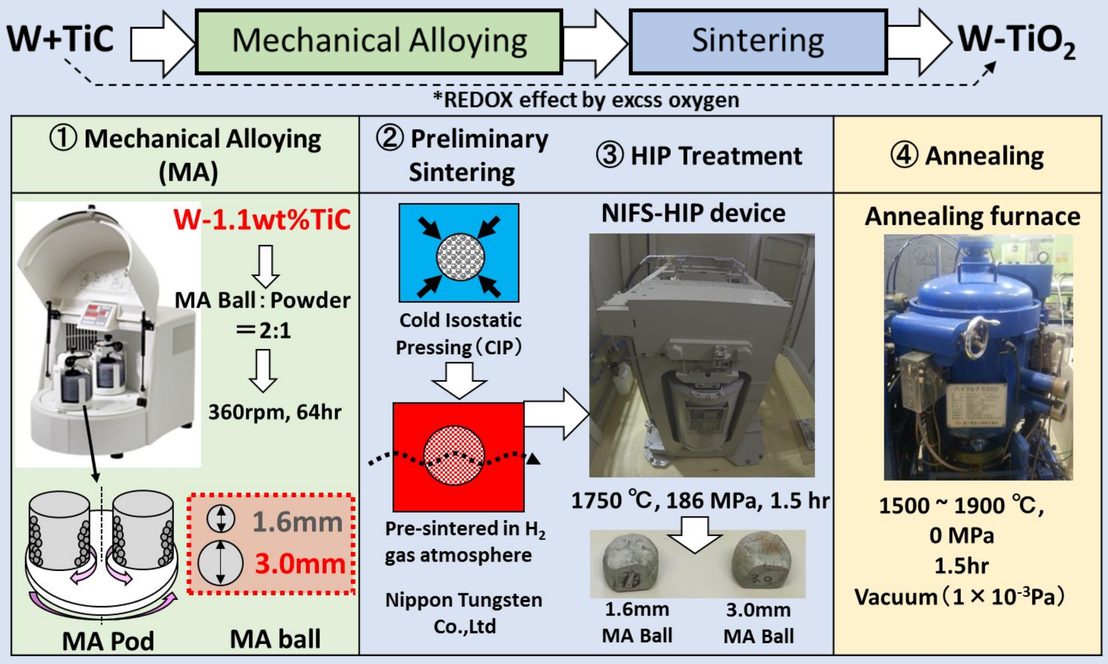
+

Hot Isostatic Press (HIP)

Simple and suitable for industrial production

We tried to develop new W-Ti alloys using mechanical alloying (MA) and Hot Isostatic Pressing (HIP) for the fist time.

METHODS



Effect of the DS-W on the thermal change of microstructure and the thermal conductivity at high temperature was investigated.

OUTCOME

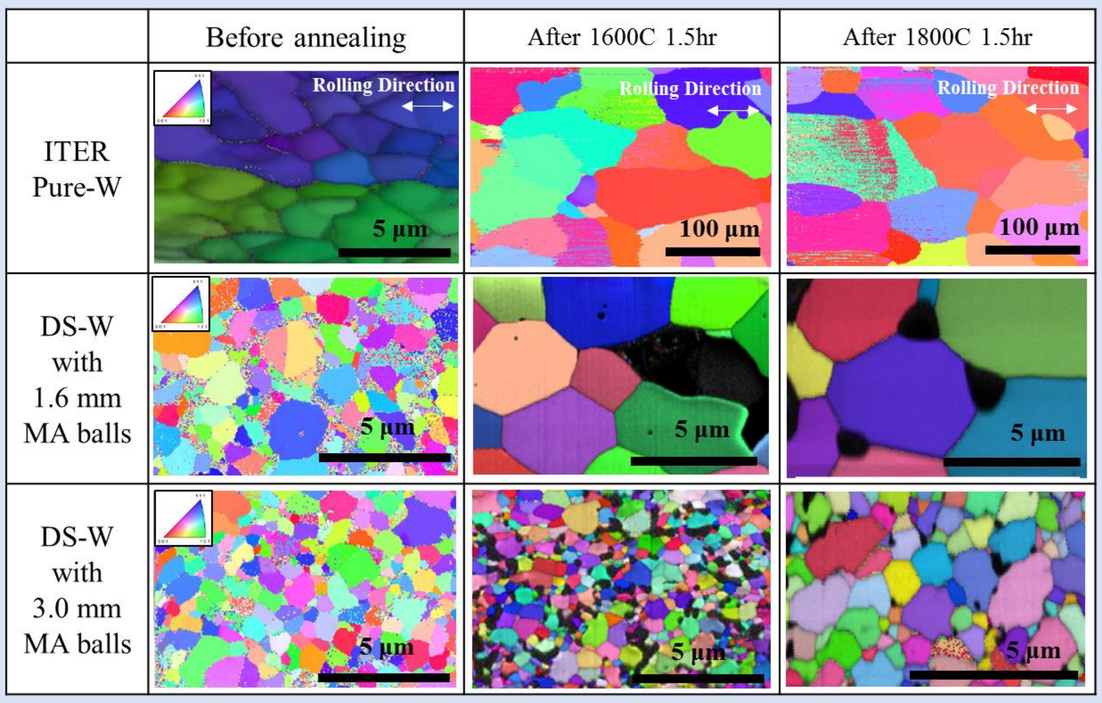


Figure 1 Electron Back Scattered Diffraction Pattern Map

ITER Pure-W: "rolled texture" to "recrystallization with grain coarsening"

DS-Ws: "recrystallization state" before and after annealing

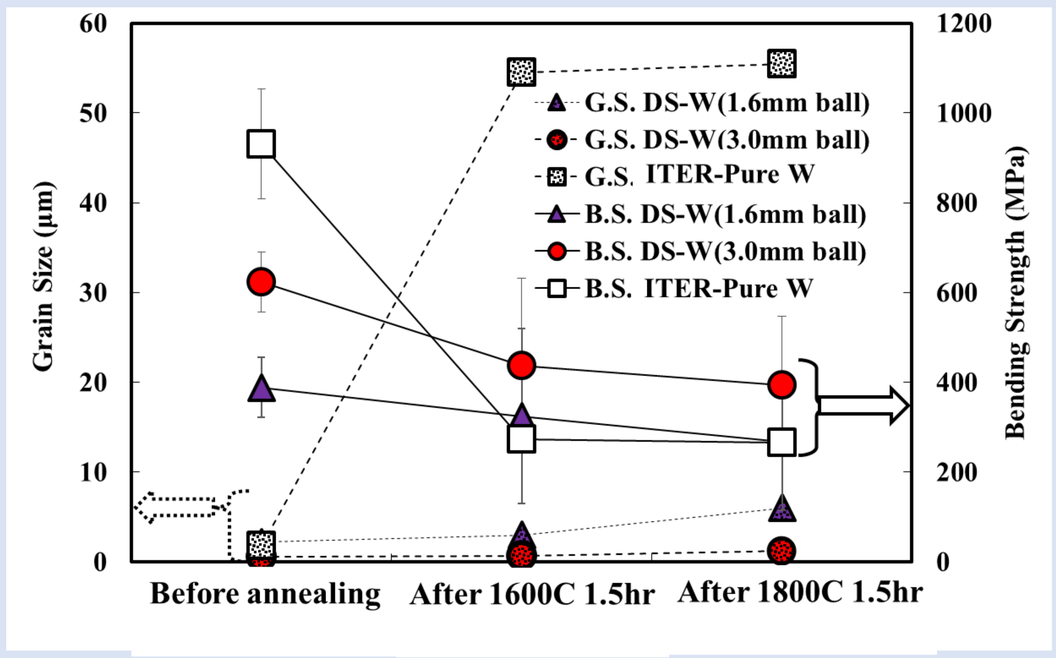


Figure 2 Bending strength and Grain Size

ITER Pure-W: the G.S. increased drastically with decrease of bending strength

DS-W(3.0mm ball MA): did not exhibit drastic change of the G.S and the B.S.

$$\alpha = \frac{\lambda}{\rho C} \qquad \lambda: Thermal\ conductivity\ (W/mK) \quad \alpha: Thermal\ diffusivity\ (m^2/sec) \qquad \rho: Density\ (g/m^3) \quad C: Specific\ heat\ (J/gK)$$

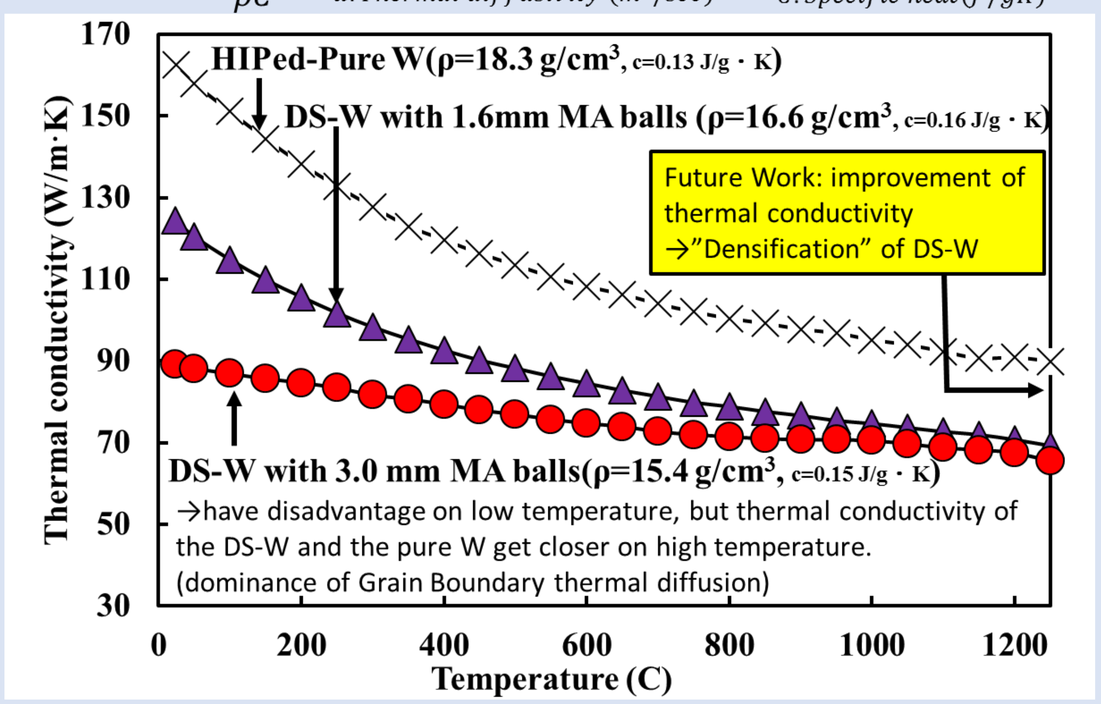


Figure 3 thermal conductivity and the density

CONCLUSION

- Bending strength of DS-W with 3.0 mm balls MA did not decrease drastically after annealing (1600~1800 C) with thermal change of microstructure relative to that of ITER-Pure Tungsten.
- Considering low density of DS-W with 3.0 mm balls MA, it is expected that the densification by HIP treatment can contribute to improvement of thermal conductivity.