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Measurement of longitudinal wave velocities in tungsten by detection of elastic waves generated by pulsed laser

パルスレーザーにより励起された弾性波による
タングステン試料における縦波速度の計測

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In this study, the longitudinal wave velocity in tungsten and its dependence on grain size and impurities (hydrogen and tantalum(Ta) were studied. The waves were generated by Q-switched Nd:YAG laser and detected using a laser Doppler vibrometer. It was found that the longitudinal wave velocity depends weakly on hydrogen retention, and grain size difference in the µm range. However, ultra fine grained W with grain sizes in the order of a few hundred nms resulted in an increase in the wave velocity. The presence of Ta impurities resulted in a decrease in wave velocity since the wave velocity for pure Ta is lower than pure W.

1. Introduction

Tungsten (W) is a candidate plasma facing material for use in a fusion reactor. For a fusion reactor to be economical, W plasma facing components must have sufficient lifetime. However, W will be exposed to heat and particle loads that result in erosion, leading to a reduction in component lifetime. Such reduction will negatively impact the operational limit of a fusion reactor. Therefore, it is important to develop methods that allow monitoring of the thickness of W components installed inside the reactor. To date, no viable *in-situ* and *non-contact* method has been developed for such purpose. Our approach is to utilize elastic waves generated by pulsed laser to determine the W material thickness. However, to accurately determine the material thickness, the wave velocities (longitudinal, transverse) in the material must be known. Such wave velocities depend critically on the material parameters such as microstructure (grain size and orientation) or composition (impurities including hydrogen) [1-3]. It is anticipated that due to plasma material interactions, changes to such material parameters will occur with W components installed inside a reactor. Therefore, in this study we have examined the longitudinal wave velocity dependence on grain size and impurities (hydrogen and tantalum).

2. Experimental

Elastic waves were generated by a Q-switched Nd:YAG laser. The pulse width was approximately 10 ns, energy ≤4.5 mJ, and focused to a few µm diameter. The resulting displacement of the surface due to the propagation and reflection of elastic waves inside the material was detected using a He-Ne (633 nm) laser Doppler vibrometer (Polytec OFV-503, OFV-2570). The vibrometer can measure vibration amplitudes in a frequency range of 30 kHz to 24 MHz and pulse amplitudes up to 150 nm (peak to peak). The resolution bandwidth of the vibrometer was 10 kHz. The Nd:YAG laser and vibrometer measurements were performed at the same point. The measured displacement signal was Fourier-transformed and the longitudinal wave velocity determined.

The types of specimen used in experiments are summarized in Table1. All W specimens, except for the ultra fine grained W (UFG-W) were prepared by ALMT corp, Japan. W disk-A and W disk-B were 20 mm diameter polycrystal W annealed at 1300 °C. W disk-A was exposed to D plasmas using the linear plasma generator Magnum-PSI [4]. At present, the total D retention in the specimen is unknown. W disk B specimen corresponds to an unexposed specimen. UFG-W, W plate-A and W plate-B were focused on grain size. The UFG-W was 10 mm in diameter, while the plate specimens were 10×10×1 mm. The grain size of UFG-W, W plate-A and W plate-B were ~500 nm, ~5 µm, and ~10 µm, respectively. W plate-A (4N), W plate-C (5N), W-2%Ta and pure tantalum (Ta) were focused on the sample composition and purity. All samples were 10×10×1 mm.

Table1. Summary of specimens used in experiments.

Specimen	parameter	detail
W-disk A	D retention	D retention (one surface)
W-disk B	D retention	No D retention
W-plate A	Grain size	4N,1300℃ anneal size ~5μm [5]
W-plate B	Grain size	4N, 2000℃ anneal size ~10 μm [5]
UFG-W	Grain size	size ~500 nm
W-plate C	Purity	5N, 1300℃ anneal
W-Ta	Purity	Ta: 2 at%
pure Ta	Purity	4N

3. Result

The longitudinal wave velocity for the specimens in Table 1 is summarized in Figure 1. Comparison of D exposed and unexposed samples showed D retention has a small influence on longitudinal wave velocity. The change in grain size from approximately 5 to 10 μm showed little influence on the measured velocity (compare 1300°C W and 2000°C W). However, the smaller grain sizes in UFG-W, resulted in an increase in the wave velocity. Comparison of 1300°C 4N W and 1300°C 5N W experiment showed W purity had a small influence in the range of 4N-5N. However, 2 % addition of Ta impurity resulted in a decrease in the wave velocity. This is attributed to the fact that the wave velocity for pure Ta is much slower than pure W (4100 [m/s] vs 5200 m/s [3]).

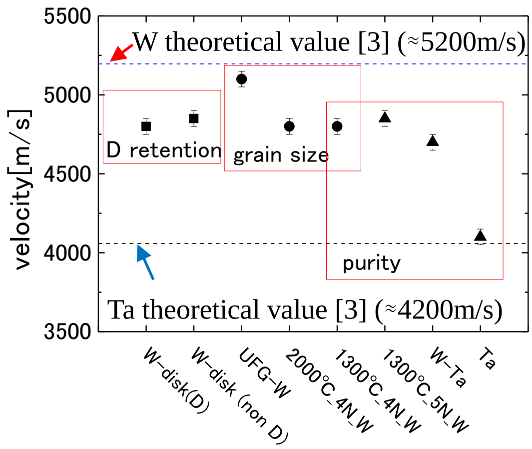

Figure.1. Sumary of longitudinal wave velocity for the specimens in Table 1.

4. References

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