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Radial X-ray diffraction study of the static strength and texture of tungsten to 96 GPa

Lun Xiong [a,b,c,*], Bin Li [a,b], Yumei Tang [a,b], Qiang Li [a,b], Jiabo Hao [a,b], Ligang Bai [c], Xiaodong Li [c], Jing Liu [c]

[a] School of Intelligent Manufacturing, Sichuan University of Arts and Science, Dazhou 635000, PR China
[b] DaZhou Industrial Technology Institute of Intelligent Manufacturing, Dazhou 635000, PR China
[c] Beijing Synchrotron Radiation Facility, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, PR China

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ABSTRACT

Investigations of equation of state, strength and texture of tungsten (W) have been performed under non-hydrostatic compression up to 96 GPa using an angle-dispersive radial X-ray diffraction (RXRD) techniques together with the lattice strain theory in a 2-fold paranomic diamond anvil cell (DAC) at ambient temperature. The ratio of t/G is found to remain constant above ~35 GPa, indicating that the W started to experience macro yield with plastic deformation at this pressure. Combined with independent constraints on the high-pressure shear modulus, we found that W sample could support a differential stress of ~4.57 GPa when it started to yield with plastic deformation at ~35 GPa under uniaxial compression. The differential stress in W ranges from 0.01 GPa to 1.46 GPa with pressure increasing from 6 GPa to 35 GPa and can be described as $t = -0.904(136) + 0.154(6)P$, where P is the pressure in GPa. A maximum differential stress, as high as ~6.46 GPa can be supported by W at the highest pressure of ~96 GPa. In addition, we have investigated the texture of W under nonhydrostatic compression up to the highest pressure of 96 GPa using the software package MAUD (Material Analysis Using Diffraction). It is convinced that the plastic deformation due to stress under high pressures is responsible for the development of texture.

1. Introduction

Tungsten (W) has been the focus of an intense research effort in previous dynamic and static compression experiments because of its high bulk modulus and strong X-ray diffraction (XRD) signal [1–4]. Hixson et al..s' [1] obtained the bulk modulus as 280(9) GPa with shock compression. Ming and Manghnani [2] derived the zero-pressure bulk modulus $K_0 = 307(11)$ GPa with its pressure derivate K_0' fixed at 4.32 from high pressure x-ray diffraction (XRD) data with methanol-ethanol mixture in the volume ratio of 4:1 as the pressure transmission medium. Dewaele et al. [3] performed the high pressure XRD and obtained $K_0 = 295.2(3.9)$ GPa and $K_0' = 4.32(1.1)$ from high-pressure XRD in diamond anvile cell (DAC) with helium as the pressure medium. Ma et al. [4] performed high-pressure diffraction study of nanocrystalline W to 31 GPa and obtained a bulk modulus of 318(14) GPa with $K_0' = 3(1)$ using methanol-ethanol mixture in the volume ratio of 4:1 as the pressure transmission medium. In addition, W, Mo, Cu, etc are used to calibrate the ruby fluorescence pressure scale [3,5], which is a widely used secondary pressure scale for DAC experiments. The effect of shear strength on compression curves is one important source of error in the ruby scale [6]. As well as Re, W has been used for the gaskets in diamond-anvil cells [7,8] and high-pressure apparatus [9,10] because of its high strength. The yield strength of W and its alloy have been widely investigated in the shock compression [11–16] and static compression from XRD [17]. It is interesting to note the loss of yield strength in W under shock compression compared with RXRD experiments performed by He et al. [17].

In this study, we have investigated the W sample under non-hydrostatic compression using angle-dispersive RXRD technique in a DAC. Together with the lattice strain theory [18,19], as well as the calculated high-pressure shear modulus, equation of state, the strength and texture of W up to a confining pressure of 96 GPa have been obtained.

* Corresponding author. School of Intelligent Manufacturing, Sichuan University of Arts and Science, Dazhou 635000, PR China.
E-mail addresses: 1094129778@qq.com (L. Xiong), binli1989@foxmail.com (B. Li), tym0123@126.com (Y. Tang), 412350067@qq.com (Q. Li), hjb20040618@126.com (J. Hao), bailg@ihep.ac.cn (L. Bai), lixd@ihep.ac.cn (X. Li), liuj@ihep.ac.cn (J. Liu).

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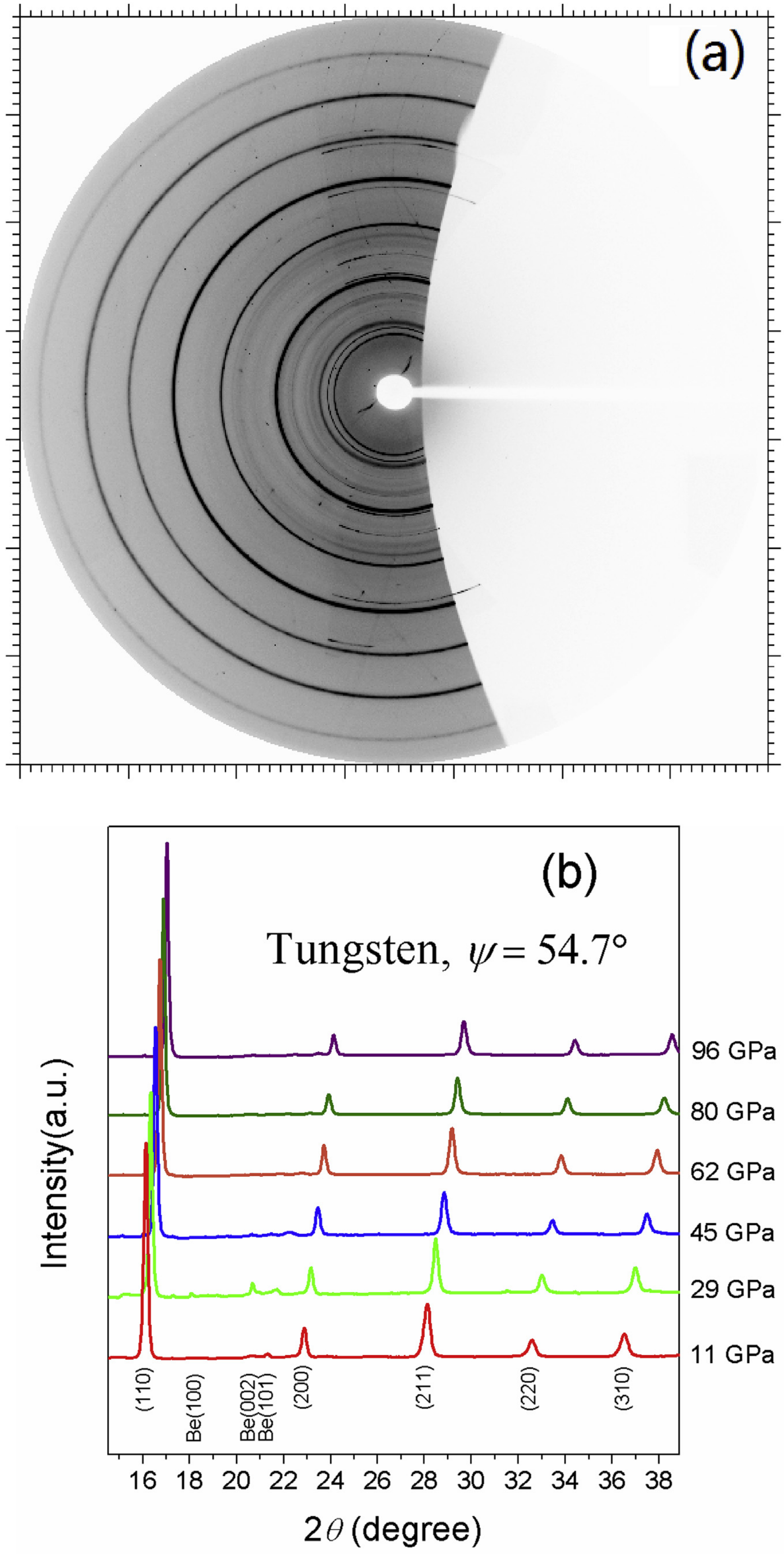

Fig. 1. (a) Diffraction pattern of W at 45 GPa. (b) Selected diffraction patterns of W under nonhydrostatic compression taken at $\psi = 54.7^{\circ}$. The pressures are determined from ruby marker.