

Residual stress determination by X-ray diffraction in tungsten thin films

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In this study, the complete residual stress tensor has been determined by X-ray diffraction, using the $\sin^2\psi$ method, in 1000 and 2500 Å tungsten thin films deposited by ion beam sputtering on a silicon monocrystal. In the first case, we found very high tension stresses (about 1.5 GPa) for the as-prepared state and important compressive stresses (about -1.3 GPa) after an implantation with a dose of 10^{16} Xe^{2+} ions/cm² at 320 keV. In the second case, the film was almost detached from its substrate and the stresses were compressive (about -0.9 GPa). In all cases, the free-stress lattice parameter was different from the bulk one, indicating significant differences between the microstructure of these thin tungsten films and the one of the bulk. The size of the coherent domains of diffraction was also determined and was found to largely vary from one case to the other.

1. Introduction

The development of thin films is constantly increasing because of their electrical, optical, mechanical, tribological properties, and their corrosion resistance. Residual stresses influence the majority of these properties and their knowledge is therefore very important. The subject has been studied by various methods such as curvature measurements [1–3], symmetrical X-ray diffraction [4], Raman spectroscopy [5], photoelectric

effect [6], and non-symmetrical X-ray diffraction using the $\sin^2\psi$ method [7]. Contrarily to the other methods, the last one is the only one which allows the whole stress tensor to be determined without any hypothesis (except the necessary $\sigma_{33} = 0$, where 3 is the axis normal to the film surface (see fig. 1). This method is used in this study. We will recall here its main principles and for a complete presentation, see for example refs. [7–10].

2. Principles of the $\sin^2\psi$ method

The method is based on the derivative of the Bragg law

$$2d \sin \theta = \lambda, \quad (1)$$

which gives

$$\Delta d/d = \epsilon_{\phi\phi} = -\cos \theta \Delta \theta, \quad (2)$$

where ϕ and ψ are the Euler angles (see fig. 1), d is the interreticular distance of the diffracting family $\{hkl\}$, $\Delta \theta = \theta - \theta_0$, θ being the diffraction angle of the $\{hkl\}$ planes in the stressed film

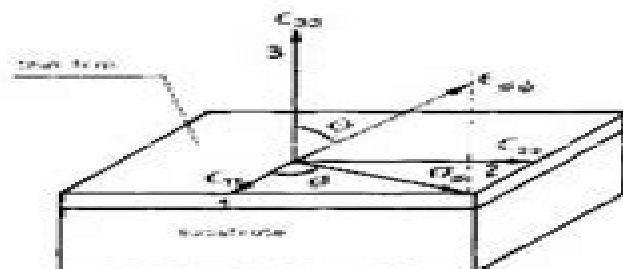


Fig. 1. Referential used in our study.

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Introduction to the Characterization of Residual Stress by Neutron Diffraction M.T.

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Structural and Residual Stress Analysis by Nondestructive Methods V. Hauk, 1997-11-10

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unsolved problems and conflicting results are discussed as well The assessment of the experimentally determined residual and structural stress states on the static and dynamic behavior of materials and components is handled in a separate chapter Students and engineers of materials science and scientists working in laboratories and industries will find this book invaluable *Fracture, Fatigue, Failure, and Damage Evolution, Volume 5* Jay Carroll, Samantha Daly, 2014-08-21 Fracture Fatigue Failure and Damage Evolution Volume 5 Proceedings of the 2014 Annual Conference on Experimental and Applied Mechanics the fifth volume of eight from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on a wide range of areas including Mixed Mode Fracture I Emphasis on Modeling Mixed Mode Fracture II Emphasis on Experimental Measurements Full Field Measurements of Fracture Microscale Microstructural Effects on Mechanical Behavior I Nanoscale Effects Microscale Microstructural Effects on Mechanical Behavior II MEMS Microscale Microstructural Effects on Mechanical Behavior III Microstructure Microscale Microstructural Effects on Mechanical Behavior IV Shape Memory Alloys Fracture Fatigue of Composites Fracture Fatigue for Engineering Applications Wave Based Techniques in Fracture Fatigue I Wave Based Techniques in Fracture Fatigue II Acoustic Emissions *Canadian Metallurgical Quarterly*, 2008 [SAE Technical Paper Series](#), 1964 Online version Technical papers portion of the SAE Digital Library references thousands of SAE Technical Papers covering the latest advances and research in all areas of mobility engineering including ground vehicle aerospace off highway and manufacturing technology Sample coverage includes fuels and lubricants emissions electronics brakes restraint systems noise engines materials lighting and more Your SAE service includes detailed summaries complete documents in PDF plus document storage and maintenance *Practical Applications of Residual Stress Technology* C. O. Ruud, 1991 Includes papers on the effects of residual stress on materials properties Measurement methods and techniques are covered in a number of papers that describe applications of X ray diffraction Barkhausen noise ultrasonic velocity and neutron diffraction Prediction of residual stresses described include applications to metal welding forging and forming as well as ceramic matrix composites and those developed by manufacturing processes **British Journal of Non-destructive Testing**, 1991

Subject Guide to Books in Print, 1975 [Residual Stresses](#) A. Niku-Lari, 2014-05-17 Residual Stresses presents a collection of articles that provides information regarding the use of surface treatment systems It discusses the developments in the technology and application of surface treatment It addresses the influence of minor stresses on the performance of materials Some of the topics covered in the book are the introduction to self equilibrating stresses existing in materials the stresses that form as a consequence of welding the stresses made by machining and the mechanical generation of self stresses The analysis of the stresses caused by thermal and thermochemical surface treatments is covered The minor stresses in composite materials are discussed The text describes the stresses in uranium and uranium alloys The Trepan or ring core method centre hole method and Sachs method are presented A chapter of the volume is devoted to the

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The Effect of Nuclear Radiation on Structural Metals Frederic R. Shober, 1961 The effect of fast neutron 1 Mev irradiation on the mechanical properties of structural metals and alloys was studied Although the yield strengths and ultimate tensile strengths are increased substantially for most materials the ductility suffers severe decreases This report presents these changes in properties of several structural metals for a number of neutron exposures within the 1.0×10^4 to the 1.8×10^8 to the 2.1×10^{10} n/cm² range Data summarizing these effects on several classes of materials such as carbon steels low alloy steels stainless steels Zr base alloys ni base alloys Al base alloys and Ta are given Additional data which show the influence of irradiation temperatures and of post irradiation annealing on the radiation induced property changes are also given and discussed Increases as great as 175% in yield strength 100% in ultimate strength and decreases of 80% in total elongation are reported for fast neutron exposures as great as 5.1×10^{10} n/cm² Author

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