

マテリアル先端リサーチインフラ利用報告書

ARIM User's Report

[Release : 2025.06.10] [Update : 2025.05.08]

課題データ / Project Data

課題番号 Project Issue Number	24UT0013
利用課題名 Title	Cu/Nb multilayered fatigue
利用した実施機関 Support Institute	東京大学 / Tokyo Univ.
機関外・機関内の利用 External or Internal Use	内部利用 (ARIM事業参画者以外) / Internal Use (by non ARIM members)
ARIM半導体基盤PF 関連課題 Related to ARIM-SETI	指定なし / No Designation
横断技術領域 Cross-Technology Area	計測・分析/Advanced Characterization
重要技術領域 Important Technology Area	次世代ナノスケールマテリアル/Next-generation nanoscale materials
キーワード Keywords	nanolaminates, 電子顕微鏡 / Electronic microscope, イオンミリング / Ion milling

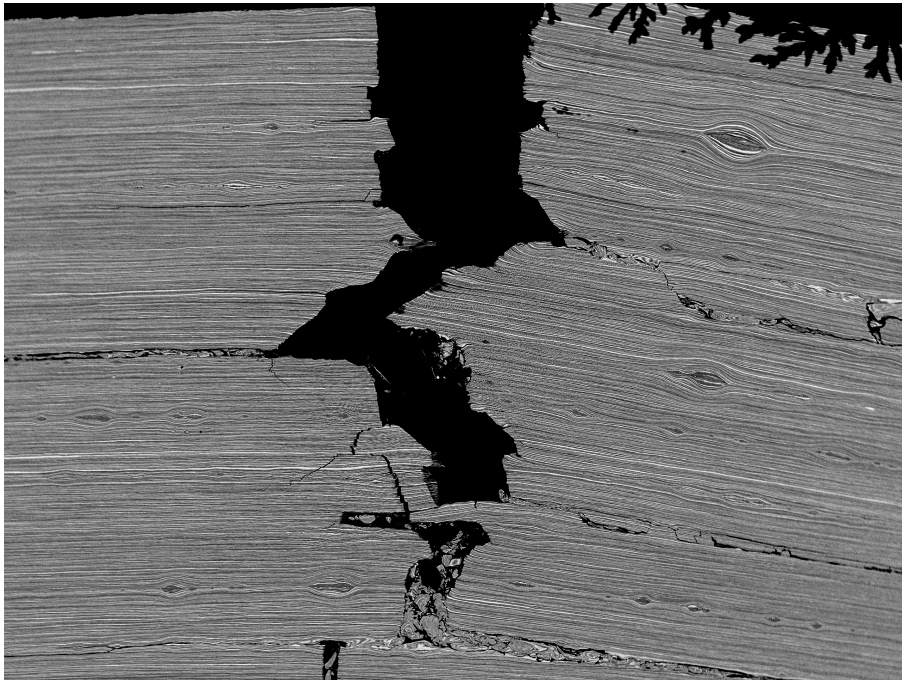
利用者と利用形態 / User and Support Type

利用者名 (課題申請者) User Name (Project Applicant)	Briffod Fabien
所属名 Affiliation	東京大学大学院工学系研究科マテリアル工学専攻
共同利用者氏名 Names of Collaborators Excluding Supporters in the Hub and Spoke Institutes	
ARIM実施機関支援担当者 Names of Supporters in the Hub and Spoke Institutes	
利用形態 Support Type	機器利用/Equipment Utilization

利用した主な設備 / Equipment Used in This Project

利用した主な設備 Equipment ID & Name	UT-153 : クロスセクションポリッシャー (CP) UT-102 : 高分解能走査型分析電子顕微鏡
---------------------------------	---

報告書データ / Report

<p>概要 (目的・用途・実施内容) Abstract (Aim, Use Applications and Contents)</p>	<p>This study examines how layer thickness and loading direction influence the fatigue and fracture behavior of Cu/Nb multilayered nanolaminates (MNLs) fabricated via accumulative roll-bonding (ARB). Three MNLs with layer thicknesses from 4.4 μm to 44 nm were analyzed. Uniaxial tensile tests showed that as layer thickness decreased, yield strength increased following a Hall-Petch relationship, while ductility declined. Crystal plasticity simulations attributed in-plane anisotropy between the rolling and transverse directions to crystallographic texture. Four-point bending fatigue tests revealed that reducing layer thickness significantly enhanced fatigue strength and limit, with minimal anisotropy in response to loading direction. Fatigue crack propagation was governed by interface delamination and crack deflection, which improved fatigue resistance by dissipating strain energy. Fracture toughness tests indicated that finer layers enhance toughness, likely due to increased interface sliding and stronger interface bonding.</p>
<p>実験 Experimental</p>	<p>Cross polishing was done on broken samples using CP SM-09010, SM-09020 machines. Specimen observations were carried out using the SEM JSM-7800F.</p>
<p>結果と考察 Results and Discussion</p>	<p>This study investigated the fatigue and fracture behavior of Cu/Nb multilayered nanolaminates (MNLs) processed via accumulative roll-bonding (ARB), focusing on the effects of layer thickness and loading direction. The key findings are as follows: The MNLs exhibited significant anisotropy in tensile strength and ductility between the rolling direction (RD) and transverse direction (TD), which was linked to crystallographic texture. A Hall-Petch-like relationship between yield strength and layer thickness suggests that confined layer slip mechanisms become more dominant as the layers reach the nanometer scale. Fatigue performance improved with decreasing layer thickness, primarily due to interface-related mechanisms such as delamination and crack deflection. These mechanisms dissipated strain energy and inhibited straight crack propagation, indicating that the interface toughness was lower than that of the individual Cu and Nb phases. Fracture toughness was also influenced by layer thickness, with finer layers exhibiting enhanced toughness. This improvement is likely attributed to increased interface shear strength and interface sliding, as texture evolution promotes semi-coherent interfaces.</p>
<p>図・表・数式 1 Figures, Tables and Equations 1</p>	 <p>Crack path of a Cu/Nb nanolaminate subjected to bending fatigue</p>

<p>その他・特記事項 (参考文献・謝辞等) Remarks(References and Acknowledgements)</p>	<p>This work was supported by JST SICORP Grant Number JPMJSC21E1, Japan. MHJ acknowledges support from A*STAR, Singapore (Grant No. A18B1b0061).</p>
---	--

成果発表・成果利用 / Publication and Patents

<p>DOI (論文・プロシーディング) [1] DOI (Publication and Proceedings)</p>	<p>Fabien Briffod, Fatigue and fracture of accumulative roll-bonded Cu/Nb materials: Effects of layer thickness and loading direction, <i>International Journal of Fatigue</i>, 193, 108772(2025). DOI: https://doi.org/10.1016/j.ijfatigue.2024.108772</p>
<p>口頭発表、ポスター発表 および、その他の論文 Oral Presentations etc.</p>	
<p>特許出願件数 Number of Patent Applications</p>	0件
<p>特許登録件数 Number of Registered Patents</p>	0件