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：2025.05.01】

課題データ / Project Data

課題番号 Project Issue Number	24NM5156
利用課題名 Title	希土類フリー/低希土類永久磁石材料の開発
利用した実施機関 Support Institute	物質・材料研究機構 / NIMS
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 計測・分析/Advanced Characterization
重要技術領域 Important Technology Area	革新的なエネルギー変換を可能とするマテリアル/Materials enabling innovative energy conversion マテリアルの高度循環のための技術/Advanced materials recycling technologies
キーワード Keywords	Magnetic Materials including permanent magnets and magnetocaloric materials.,X線回折/ X-ray diffraction,電子顕微鏡/ Electronic microscope,電子顕微鏡/ Electronic microscope,電子回折/ Electron diffraction

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)	セペリ アミン ホセイン
所属名 Affiliation	物質・材料研究機構
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,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	NM-204：多目的X線回折装置_Cu_SSL NM-207：電界放出形電子線プローブマイクロアナライザー装置

報告書データ / Report

概要（目的・用途・実施内容） Abstract (Aim, Use Applications and Contents)	Magnetic materials play a key role in achieving carbon neutrality because of their many uses in green energy solutions. For example, permanent magnets are commonly found in electric car motors, wind turbines, and robots. Another important type of magnetic material is magnetocaloric materials, which are used in eco-friendly magnetic cooling systems. In this research, we aimed in development of permanent magnets with a large energy density and resistance against magnetization reversal while considering elements criticality. The second objective is development of magnetocaloric materials with giant and reversible magnetocaoric effect for room temperature and cryogenic applications.
実験 Experimental	We used electron microscopy to evaluate the microstructural defects responsible for the poor performance of our materials. We also performed X-ray diffraction analysis at different temperatures to follow the magnetostructural phase transition in the magnetocaloric materials at different temperature ranges.
結果と考察 Results and Discussion	The giant magnetocaloric effect (MCE) in $(Mn,Fe)_2(P,Si)$-based alloys originates from a magnetoelastic ferromagnetic-to-paramagnetic (FM–PM) phase transition, which is typically accompanied by significant thermal hysteresis. This hysteresis introduces undesirable irreversibility during cyclic operation, limiting the practical use of these materials in solid-state magnetic refrigeration.In this study, we demonstrate that pre-existing PM (paramagnetic) nuclei play a critical role in reducing thermal hysteresis. Through a combinatorial approach using in situ X-ray diffraction (XRD) and magneto-optical Kerr effect (MOKE) microscopy, we reveal that residual PM phases, present even in the ferromagnetic state, serve as nuclei for the growth of the PM phase. This facilitates the FM–PM transition kinetically and reduces hysteresis through an extrinsic mechanism.Additionally, the smaller changes in lattice constants observed during the transition suggest a weakened first-order character of the phase change, indicating intrinsic contributions to the reduced hysteresis. As a result of these combined intrinsic and extrinsic effects, we achieved a large magnetic entropy change of 16 J kg^{-1} K^{-1} under a 2 T magnetic field, with a low thermal hysteresis of just 3.0 K in a simple Mn–Fe–Si–P quaternary system, suitable for room-temperature applications. Overall, our findings offer a practical strategy to minimize hysteresis while preserving a strong MCE, paving the way for more efficient magnetic refrigeration technologies. Additionally, we investigated how defects affect the magnetic properties of $SmFe_{12}$-based permanent magnets. A key challenge in developing high-performance $SmFe_{12}$-based magnets is translating their excellent intrinsic magnetic properties into superior extrinsic performance. One significant obstacle is the formation of twins, which limits the achievable coercivity and remanence. In this work, we demonstrate that adding cobalt (Co) to $Sm(Fe_{1-x}Co_x)_{10-11}M_{1-2}$ alloys—where M represents Ti or V—increases the density of twin structures. Microstructural analysis reveals that the atomic arrangement at the twin boundaries varies with the choice of stabilizing element. These structural differences directly impact the local intrinsic magnetic properties, offering insight into how twin formation influences overall magnetic performance.
図・表・数式 Figures, Tables and Equations	
その他・特記事項（参考文献・謝辞等） Remarks(References and Acknowledgements)	More informations about the above works can be found in below publications:https://doi.org/10.1016/j.scriptamat.2024.116491https://doi.org/10.1016/j.mtla.2024.102195

成果発表・成果利用 / Publication and Patents

DOI（論文・プロシーディング）[1] DOI (Publication and Proceedings)	P. Tozman, Effect of Co on twin formation and magnetic properties of Sm(Fe,Ti,V)12 alloys, *Scripta Materialia*, **258**, 116491(2025). DOI: https://doi.org/10.1016/j.scriptamat.2024.116491
DOI（論文・プロシーディング）[2] DOI (Publication and Proceedings)	Z. Wang, Insights into reduction of hysteresis in (Mn, Fe)2(P, Si) compounds by experimental approach and Landau theory, *Materialia*, **37**, 102195(2024). DOI: https://doi.org/10.1016/j.mtla.2024.102195
口頭発表、ポスター発表および、その他の論文 Oral Presentations etc.	
特許出願件数 Number of Patent Applications	0件
特許登録件数 Number of Registered Patents	0件