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Authors: T. Ibn-Mohammed, I.M. Reaney, S.C.L. Koh, A. Acquaye, S.C. Derek, C.A. Randall, F.H. Abubakar, L. Smith, G. Schileo, L. Ozawa-Meida

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Life cycle assessment and environmental profile evaluation of lead-free piezoelectrics in comparison with lead zirconate titanate

Ibn-Mohammed, T.[1, 2, 5*], Reaney, I.M.[3], Koh, S.C. L[1, 2], Acquaye, A.[4], Derek, S.C.[3], Randall, C. A.[5], Abubakar, F.H.[1, 2], Smith, L.[3], Schileo, G.[3], Ozawa-Meida, L.[6]

[1]Centre for Energy, Environment and Sustainability, The University of Sheffield, Sheffield, S10 1FL, UK
[2]Advanced Resource Efficiency Centre, The University of Sheffield, Sheffield, S10 1FL, UK
[3]Departments of Materials Science and Engineering, The University of Sheffield, Sheffield, S1 3JD, UK
[4] Kent Business School, University of Kent, Canterbury, CT2 7PE, UK
[5]Materials Research Institute, The Pennsylvania State University, University Park, PA, 16802, USA.
[6]Institute of Energy and Sustainable Development, De Montfort University, Leicester, LE1 9BH, UK

*Corresponding email: t.ibn-mohammed@sheffield.ac.uk/taofeeq_m@yahoo.com

Abstract

The prohibition of lead in many electronic components and devices due to its toxicity has reinvigorated the race to develop substitutes for lead zirconate titanate (PZT) based mainly on the potassium sodium niobate (KNN) and sodium bismuth titanate (NBT). However, before successful transition from laboratory to market, critical environmental assessment of all aspects of their fabrication and development must be carried out in comparison with PZT. Given the recent findings that KNN is not intrinsically 'greener' than PZT, there is a tendency to see NBT as the solution to achieving environmentally lead-free piezoelectrics competitive with PZT. The lower energy consumed by NBT during synthesis results in a lower overall environmental profile compared to both PZT and KNN. However, bismuth and its oxide are mainly the by-product of lead smelting and comparison between NBT and PZT indicates that the environmental profile of bismuth oxide surpasses that of lead oxide across several key indicators, especially climate change, due to additional processing and refining steps which pose extra challenges in metallurgical recovery. Furthermore, bismuth compares unfavourably with lead due to its higher energy cost of recycling. The fact that roughly 90-95% of bismuth is derived as a by-product of lead smelting constitutes a major concern for future upscaling. As such, NBT and KNN do not offer competitive edge from an environmental perspective in comparison to PZT. The findings in this work have global practical implications for future Restriction of Hazardous Substances (RoHS) legislation for piezoelectric materials and demonstrate the need for a holistic approach to the development of sustainable functional materials.

Keywords:

Piezoelectric materials, Life cycle assessment, Environmental legislation, Policy and decision making