Large Electrocaloric Effect in $Al_xFe_{2-x}O_3$ Epitaxial Thin Films

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Abstract

There is an imminent need for efficient solid state cooling mechanisms in many electronic devices, as they become more and more compact. Electrocaloric effect is well suited for such applications, since the heat generated from the miniature devices can be extracted immediately. Many ferroelectric ceramics are being investigated for their electrocaloric properties. However, most of them show a temperature change (ΔT) of less than 1°, and they require high electric field which is difficult to apply in bulk ceramics [1]. Thin film ferroelectrics have been found to show better electrocaloric properties, and they can also be subjected to high electric fields at low voltages.

The κ-Al_2O_3 type $Al_xFe_{2-x}O_3$ (x-AFO) system is a metastable room temperature multiferroic, which can be stabilized as thin films [2]. In this work, we have investigated the electrocaloric properties of x-AFO ($0.5 \leq x \leq 1$) epitaxial films, using the indirect approach. Large temperature changes of about 10°, at temperatures less than room temperature could be obtained in some cases, which is very promising. Very few materials show electrocaloric effect close to room temperatures, and the currently known superior electrocaloric materials are operational only at higher temperatures (> 100°C) [3]. Also, large electrocaloric effect is generally expected only for samples exhibiting electric field induced phase transformation [4]. However, the x-AFO system is not known to exhibit any phase transition until the decomposition temperature. Alternatively, the large temperature change observed in this system is attributed to its complex polarization switching mechanism, which is highly dependent on the mobility of the oxygen vacancies. This makes the x-AFO system, a unique material with a different mechanism compared to the conventional electrocaloric materials. The results also encourage research on similar materials like $GaFeO_3$, $ScFeO_3$, and other complex ferroelectric systems.

References

[1] S. Kar-Narayan and N.D. Mathur, Ferroelectrics **433**, 107 (2012).
[2] Y. Hamasaki, T. Shimizu, H. Taniguchi, T. Taniyama, S. Yasui, and M. Itoh, Appl. Phys. Lett. **104**, 082906 (2014).
[3] X. Li, S.-G. Lu, X.-Z. Chen, H. Gu, X. Qian, and Q. M. Zhang, J. Mater. Chem. C **1**, 23 (2013).
[4] X. Moya, S. Kar-Narayan, and N.D. Mathur, Nat. Mater. **13**, 439 (2014).