An approach to enhancing relaxors for energy storage devices

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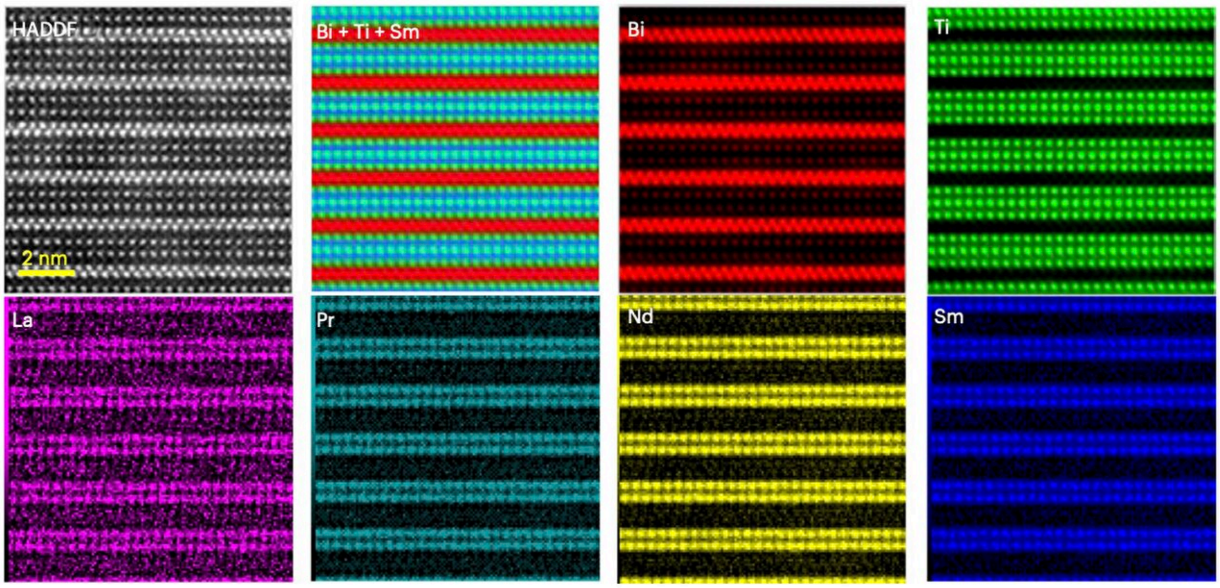

Atomically resolved elemental mappings for the film of x = 1.5, including HAADF images along [11¯0] zone axes, superimposing Bi + Ti + Sm mapping and individual distribution of Bi, Ti, La, Pr, Nd and Sm elements. Credit: Yang et al

Relaxor ferroelectrics are materials with ferroelectric properties and high electrostriction (i.e., the ability to contract or deform in response to electric fields). These materials can be used to create highly efficient energy storage devices, such as capacitors.

Capacitors are key electronic components composed of two electrical conductors with a given distance between them. These components can temporarily store electric charge, reducing the noise transmitted by individual integrated circuits (ICs) and thus improving the overall performance of electronics.

Researchers at Tsinghua University and other institutes in China recently introduced a new strategy to engineer effective relaxor ferroelectrics for energy storage devices. Their paper, introduced in *Nature Energy*, suggests using a so-called configurational entropy to evaluate the local inhomogeneity of a relaxor's composition.

"Relaxor ferroelectrics are the primary candidates for high-performance energy storage dielectric capacitors," Bingbing Yang, Qinghua Zhang, and their researchers wrote in their paper. "A common approach to tuning the relaxor properties is to regulate the local compositional inhomogeneity, but there is a lack of a quantitative evaluation way for compositional fluctuation in relaxors. Here we propose configurational entropy as an index for the quantitative evaluation of local compositional inhomogeneity."

Some recent studies have tried to improve the energy storage of capacitors using relaxors with with a single high-entropy composition. As part of their study, Yang, Zhang and their colleagues set out to explore the link between the features of relaxor ferroelectrics and entropy in greater depth. They found that as the entropy of relaxors increases, the local inhomogeneity increases, which in turn affects the features of the materials.

"Our results reveal that the local inhomogeneity increases with the entropy via scanning transmission electron microscopy, and relaxor features are accordingly modulated," Yang, Zhang and their colleagues wrote in their paper. "With the deliberate design of entropy, we achieve an optimal overall energy storage performance in $Bi_4Ti_3O_{12}$-based medium-entropy films, featuring a high energy density of 178.1 J cm^{-3} with efficiency exceeding 80% and a high figure of merit of 913."

The results gathered by Yang, Zhang and their colleagues demonstrate that the features of relaxor ferroelectric materials are dependent on entropy, particularly configurational entropy. This entropy can easily be calculated using a material's compositions as a predictive index.

This recent study thus unveils a new avenue to develop relaxors that could improve the performance of capacitors and other energy storage devices. The team's initial evaluations were highly promising, as they used their approach to engineer relaxor films that they could then use to create a highly performing capacitor.

"Using the medium-entropy films as dielectric layers, we demonstrate a multilayer film capacitor prototype that outperforms conventional multilayer ceramic capacitors," Yang, Zhang and their colleagues wrote.

In the future, the work by this team of researchers could inform the design of new ferroelectric relaxors with advantageous properties. These materials could in turn be used to create better capacitors, contributing to the development of next generation electronic devices.

More information: Bingbing Yang et al, Engineering relaxors by entropy for high energy storage performance, *Nature Energy* (2023). DOI: 10.1038/s41560-023-01300-0