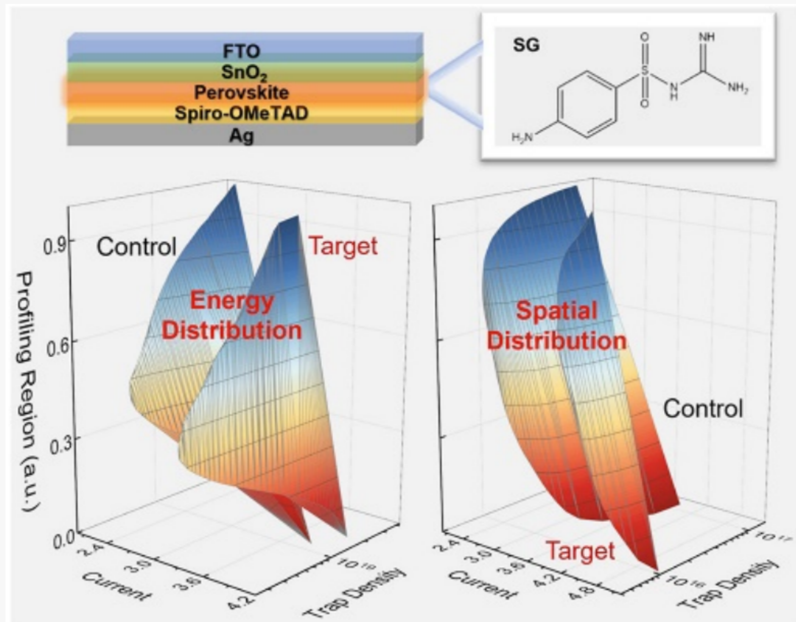
A clearer view of traps: full-dimensional imaging boosts solar efficiency

FAYETTEVILLE, GA, UNITED STATES, August 15, 2025 /EINPresswire.com/ -- A team of researchers has unveiled a powerful imaging technique that captures a full-dimensional portrait of elusive trap states—defects that hinder the performance of perovskite solar cells. By combining scanning photocurrent measurement system (SPMS) with complementary tools like thermal admittance spectroscopy (TAS) and drive-level capacitance profiling (DLCP), the team produced detailed spatial and energy maps of these hidden imperfections. Leveraging these insights, they introduced a passivation strategy using sulfa guanidine molecules that dramatically improved device performance. The result: a record-breaking solar cell achieving 25.74% efficiency. This breakthrough not only unlocks a deeper understanding of device physics but also provides a practical pathway to next-generation solar technologies.



3D Mapping Reveals Defect Suppression in SG-Passivated Perovskite Devices.

Perovskite solar cells (PSCs) have emerged as game-changers in the photovoltaic arena due to their high efficiency and cost-effective fabrication. However, their path to commercialization remains obstructed by the presence of trap states—microscopic defects that disrupt carrier transporting and limit stability. Existing diagnostic tools often fall short, focusing on isolated dimensions or only thin-film samples. A critical gap exists in mapping horizontal defect distributions across complete devices, especially in correlating trap positions with performance. Due to these challenges, a holistic characterization framework that integrates spatial and energy information is urgently needed to guide material engineering and device design.

In a recent study (DOI: 10.1016/j.esci.2024.100326) published March 2025, in eScience, scientists from Soochow University introduced a cutting-edge diagnostic method that brings hidden defect landscapes to light in working solar devices. By merging scanning photocurrent measurement system (SPMS) with thermal admittance spectroscopy (TAS) and drive-level capacitance profiling (DLCP), the team constructed panoramic maps revealing where and how trap states exist within perovskite solar cells. These insights were pivotal in designing a defect passivation strategy that boosted solar efficiency to an impressive 25.74%. This research introduces a previously unreported characterization technique, providing a novel blueprint for understanding and optimizing perovskite performance from a fundamentally new perspective.

At the core of the study lies the use of SPMS, which enables non-invasive imaging of photocurrent behavior across a device's surface. When combined with TAS and DLCP, this approach yields a three-dimensional view of trap states—capturing both their spatial locations and energy-level profiles. To validate this method, the team tested three cases of defect passivation: surface treatment with butylammonium iodide (BAI), buried interface treatment with aminoacetamide hydrochloride (AHC), and internal bulk passivation using sulfa guanidine (SG).While BAI and AHC showed partial improvements, only SG passivation dramatically reduced trap densities throughout the device. The SG-treated cells exhibited longer carrier lifetimes, improved crystallinity, and significantly suppressed non-radiative recombination. As a result, the device's power conversion efficiency rose to 25.74%, with a fill factor of 82.66% and excellent stability—retaining over 92% efficiency after 950 hours of continuous illumination. These findings confirm that targeting defects at the molecular level, guided by precise imaging, is key to unlocking the full potential of perovskite photovoltaics.

"Our goal was to see the invisible—and act on it," said Prof. Zhao-Kui Wang, corresponding author of the study. "By capturing where trap states form and how they behave, we've created a new lens for understanding and fixing performance bottlenecks in perovskite devices. This isn't just about imaging—it's about engineering smarter, longer-lasting solar technologies. With this insight, we can now passivate more effectively and design better from the ground up."

This diagnostic breakthrough opens the door to smarter, defect-aware manufacturing for perovskite solar cells. Beyond immediate efficiency gains, the ability to map and suppress trap states with such precision paves the way for mass production of stable, high-performance devices. The method could be readily extended to other semiconducting materials, offering a universal toolkit for defect management. As clean energy demands surge globally, this work equips scientists and engineers with a clearer roadmap for delivering reliable and affordable solar technologies—bringing us one step closer to scalable, sustainable energy solutions.

References
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