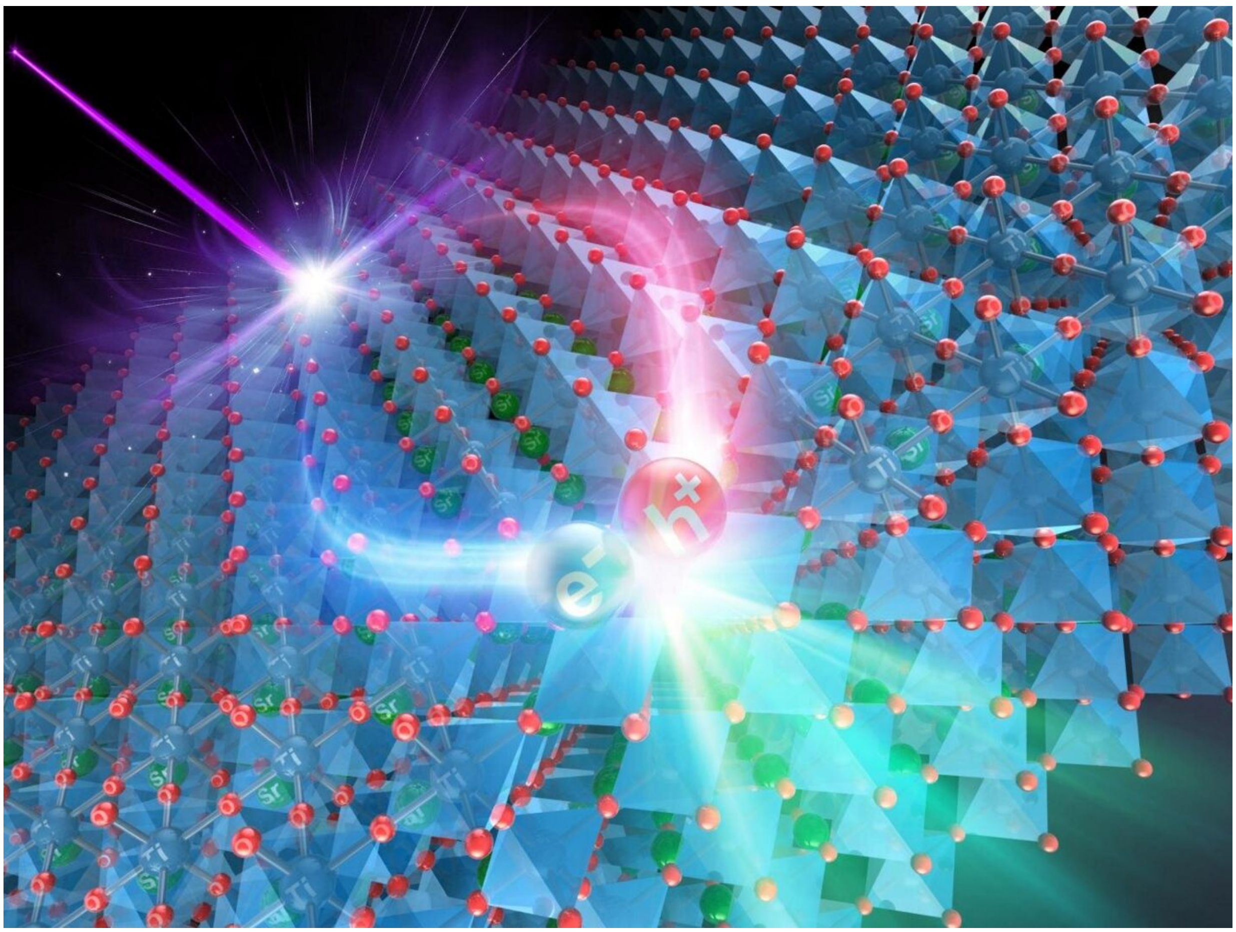
Paving the way to artificial photosynthesis: Effect of doping on the photocatalyst SrTiO3

June 29 2021



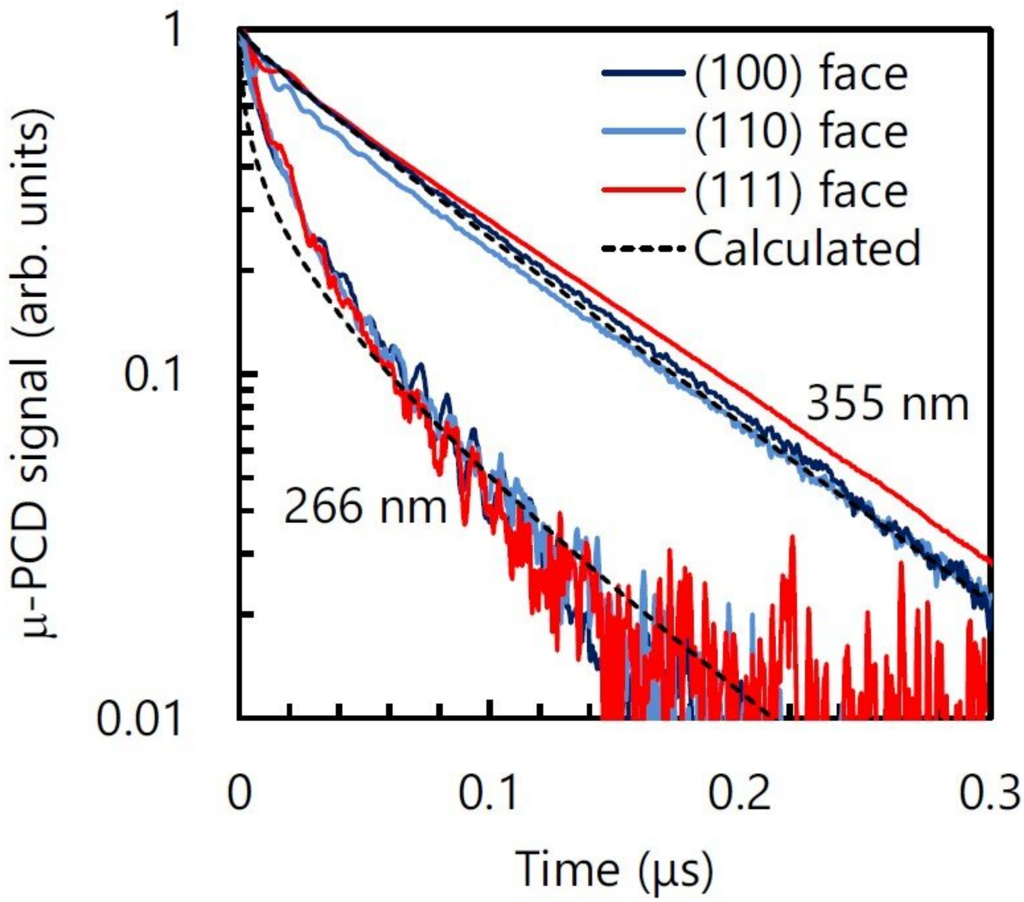
Charge recombination occurs when mobile charge carriers present in the material that are exposed to light annihilate each other and can hamper the energy efficiency of the photocatalyst. Credit: Masashi Kato from Nagoya Institute of Technology

For many years, researchers have been focused on developing technologies that can help us fight the imminent climate change crisis. They have one goal in common: Finding sustainable energy sources that can replace the environmentally toxic fossil fuels. Photocatalysts that drive an artificial process that replicates photosynthesis (in which solar energy is converted to useful materials) are promising in this regard, given that we are able to develop the technology needed for them. Crystalline materials, such as strontium titanate ($SrTiO_3$), which can serve as photocatalysts in solar devices, can lead us in the direction.

$SrTiO_3$ is attractive owing to various other reasons too, such as its potential applications in resistive switches and fuel cell components. The versatile nature of $SrTiO_3$ has motivated physicists to study its various materials properties in detail. But to dig deeper into the properties of $SrTiO_3$, we need to understand a little more about them.

Photocatalytic materials such as $SrTiO_3$ are usually "doped" with chemicals like niobium (Nb) that help to improve their electrical properties. But a process called charge recombination can occur in photocatalysts, which hampers with their efficiency. In this process, mobile charge carriers present in the material, such as electrons and holes, when exposed to light, can annihilate each other. Some studies have shown that charge recombination is affected by the presence of defects in crystals. So how does Nb doping affect the material properties of $SrTiO_3$? This is exactly what a team of researchers at Nagoya Institute of Technology, Japan, led by Prof. Masashi Kato, wanted to find out.

In their study published in *Journal of Physics D: Applied Physics*, the researchers looked at the effects of low-concentration Nb doping, as well as no doping, on the surface recombination in $SrTiO_3$ crystals. Prof. Kato explains, "Quantitatively measuring the effects of surfaces and niobium impurities in $SrTiO_3$ on carrier recombination can help us design photocatalysts with an optimal structure for artificial photosynthesis."



The figure shows μ-PCD decay curves for the undoped samples excited by the 266- or 355-nm laser. The dotted line is the calculated decay curve with τB = 90 ns and S = 106 cm/s. Credit: Masashi Kato from Nagoya Institute of Technology

The scientists first analyzed the surface recombination, or "decay" patterns of undoped $SrTiO_3$ samples as well as those doped with different concentrations of Nb, using a technique called microwave photoconductivity decay. To further probe into the bulk carrier recombination properties of doped samples and different energy levels introduced by Nb doping, another technique called time-resolved photoluminescence was used.

The researchers found that the recombination of excited carriers was not dependent on their concentration, indicating that they recombined via surface and Shockley-Read-Hall processes (which are insensitive to exciting carrier concentration). Moreover, the doped sample showed faster decay curves, which could be due to the introduction of a recombination center by Nb doping. Doping the material with high concentrations of Nb showed negative effects on carrier doping. Moreover, the size of the photocatalyst, and not its shape, influenced surface recombination and ultimately its overall efficiency.

The study concluded that moderately Nb-doped $SrTiO_3$ could actually be more beneficial than pure $SrTiO_3$, especially when operated at higher operating temperatures. These findings can help us design $SrTiO_3$ photocatalysts with a lower surface recombination and higher energy conversion, leading to the development of efficient, sustainable sources of energy.

Prof. Kato optimistically concludes, "We are confident that our findings can accelerate the development of artificial photosynthesis technologies, ultimately contributing towards a greener, more sustainable society."

More information: Masashi Kato et al, Carrier recombination in $SrTiO_3$ single crystals: impacts of crystal faces and Nb doping, *Journal of Physics D: Applied Physics* (2021). DOI: 10.1088/1361-6463/ac073e

Provided by Nagoya Institute of Technology