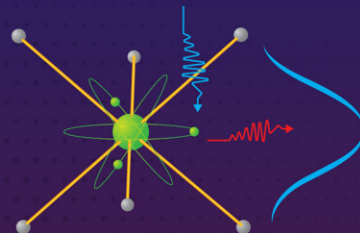


Enhancing electron–phonon coupling strength in low-dimensional strontium ruthenate

June 21 2023

Dimensionality Control for Enhancing Electron–Phonon Coupling in Strontium Ruthenate

Electrons inside crystals interact closely with crystal vibrations (phonons)



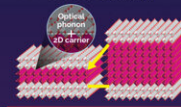
The coupling of electrons with phonons makes for interesting material properties

Coupling strength is believed to be an intrinsic property with no prospects for tuning it

Is it possible to control the electron–phonon coupling strength in synthetic crystals? ?

Atomic-scale engineering of electron–phonon coupling in synthetic strontium ruthenate/strontium titanate (SRO/STO) superlattices (SLs)

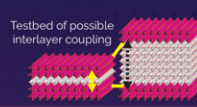
1 Control of electronic dimensionality



Electronic


2 Modulation of interlayer distance

Testbed of possible interlayer coupling



3 Enhancement of synthetic atomic network

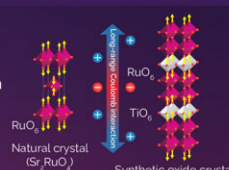
Increasing periodicity



Phononic

~300-fold increase in the coupling strength by changing the structure from 3D (bulk) to quasi-2D

Non-local electron–phonon coupling in synthetic 2D electronic state



Natural crystal (SrRuO₃) Synthetic oxide crystal (SRO/STO SL)

Sr - Strontium, Ru - Ruthenium, Ti - Titanium, O - Oxygen

- Novel engineering opportunities for tuning electron–phonon coupling in crystals
- A deeper understanding of quantum materials
- New advancements in electronic and phononic devices

The ability to tune electron–phonon coupling in low-dimensional strontium ruthenate can pave the way for a fundamental understanding and advanced applications of quantum materials

Giant Enhancement of Electron–Phonon Coupling in Dimensionality-Controlled SrRuO₃ Heterostructures
Choi et al. (2023)
Advanced Science | 10.1002/advs.202300012

Gwangju Institute of Science and Technology

Researchers from Gwangju Institute of Science and Technology (GIST) in Korea managed to tune the electron–phonon coupling strength in strontium ruthenate by controlling its electronic dimensionality and interlayer distance. This novel method could potentially be applied to synthesize materials with desired coupling strength for advanced applications. Credit: Professor Jong Seok Lee from GIST, Korea

Electrons inside crystals interact closely with phonons, defined as the discrete unit of crystal vibrations. The electron–phonon coupling strength is an important fundamental physical quantity in solid state physics, determining electrodynamic behaviors and correlated functionalities of a material. This, in turn, makes for interesting material properties with advanced applications.

However, the coupling strength is typically considered an intrinsic material property without any provision for controlling it for desired applications.

Against this backdrop, a group of researchers, led by Professor Jong Seok Lee of the Gwangju Institute of Science and Technology in Korea has now demonstrated the ability to tune this coupling and achieve a massive enhancement in its strength using synthetic heterostructures of transition metal oxides. The researchers have detailed their findings in a paper in *Advanced Science*.

"Unfortunately, electron–[phonon](#) coupling is innately determined by the [crystal structure](#) of a solid, hence it was crucial to find a new method to control or enhance the coupling," says Prof. Lee, explaining the motivation behind the present work.

In their study, the researchers demonstrated an atomic-scale engineering of the electron–phonon coupling strength in synthetic strontium ruthenate/[strontium titanate](#) (SRO/STO) superlattices (a periodic structure of layers of two materials). They achieved this remarkable feat by artificially heterostructuring the SRO/STO system. This entailed controlling the electronic dimensionality, modulating the interlayer distance, and increasing the periodicity of the synthetic atomic network.

Remarkably, a reduction in the dimensionality from 3D (bulk) to quasi-2D led to a 300-fold increase in the electron–phonon coupling

strength. The researchers attributed this huge enhancement to the non-local nature of the coupling in synthetic SRO/STO superlattices, which becomes prominent in the 2D electronic state.

In addition, they found that the [electrons](#) in the 2D SRO layers coupled to optical phonons (vibrations capable of absorbing or emitting light) as revealed by the temperature-dependent electron–phonon coupling measurements, which further contributed to the coupling enhancement.

This development paves the way for novel engineering opportunities for tuning electron–phonon coupling strength in crystals. In addition, it facilitates a deeper understanding of quantum materials.

"The electron–phonon coupling is closely related not only to the performance of thermoelectric devices but also the energy harvesting efficiency of solar cells. Currently, researchers are struggling to solve the overheating issue in nano-scale devices. This problem limits the performance of such devices. The present work can contribute to solving the overheating issue, resulting in an improved performance of nano-scale devices," says Prof. Lee.

Overall, these findings provide new insights into the tuning knobs available in synthetic crystals for controlling the electron–phonon [coupling strength](#), useful not only for advancing technology but also for a deeper understanding of quantum phenomena like strongly coupled charge and lattice dynamics in quantum materials.

More information: In Hyeok Choi et al, Giant Enhancement of Electron–Phonon Coupling in Dimensionality-Controlled SrRuO₃ Heterostructures, *Advanced Science* (2023). [DOI: 10.1002/advs.202300012](#)

Provided by GIST (Gwangju Institute of Science and Technology)

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