Nanoribbons reveal potential source of light for quantum technologies

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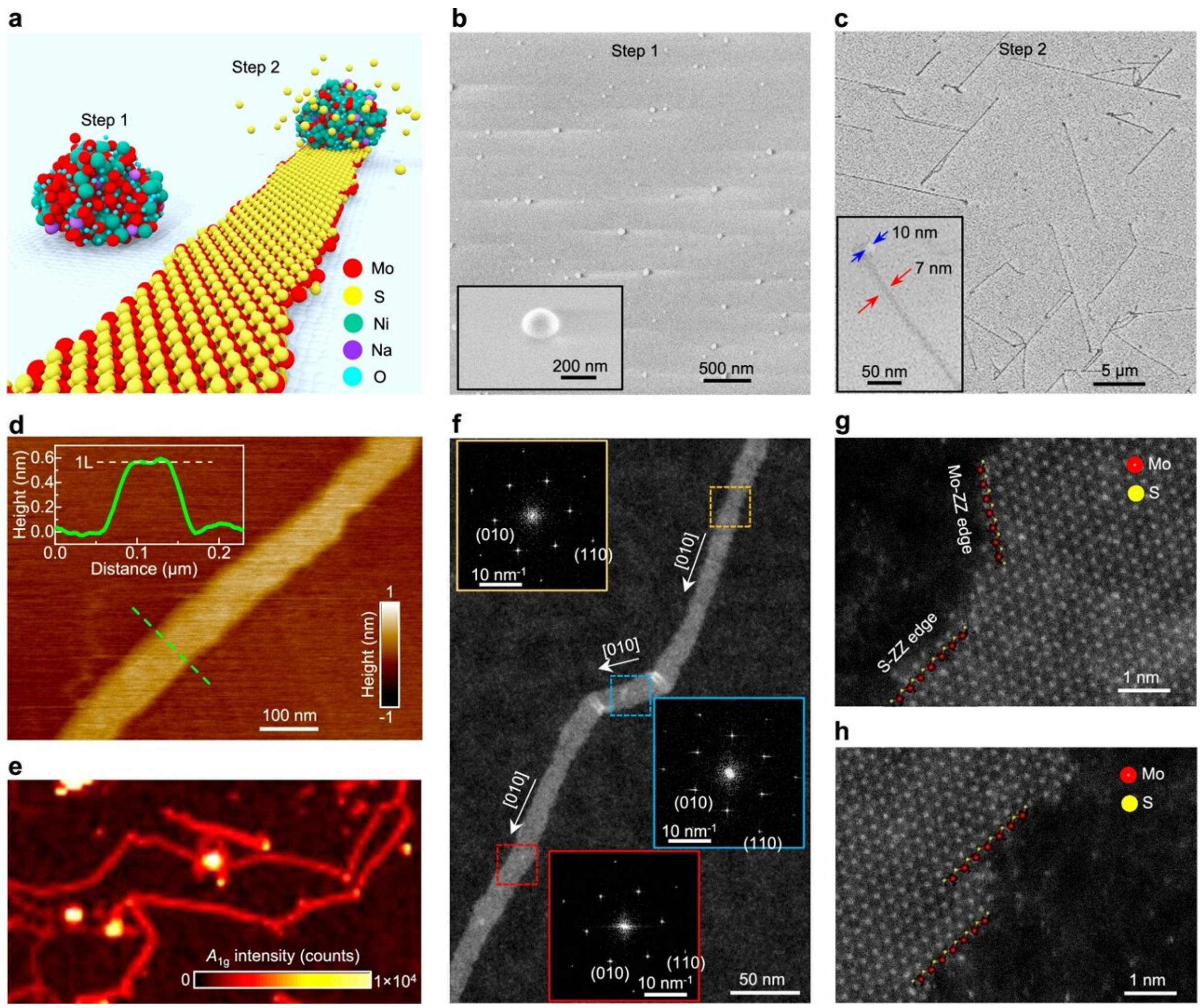

SL MoS_2 NRs grown on F-mica substrate. Credit: *Nature Communications* (2024). DOI: 10.1038/s41467-024-54413-9

Experiments conducted at Montana State University in collaboration with Columbia University and the Honda Research Institute have resulted in the emission of single photons of light in a new type of quantum material—a feat that could lead to the development of controllable light sources for use in quantum technologies.

A comprehensive article about the breakthrough was published in the journal *Nature Communications*. It describes ultra small, two-dimensional, ribbon-shaped materials measuring one atom thick and tens of atoms wide—about a thousand times narrower than the width of a human hair.

The nanoribbons were grown by the Honda Research Institute, stretched over specialized surfaces developed by Columbia to stimulate photon emission, then manipulated and tested by the MSU team, which analyzed and described the nanoribbons' characteristics, including their ability to emit single photons.

"When the Columbia and HRI teams approached us, we were very enthusiastic to investigate the new system," said Nicholas Borys, associate professor in MSU's Department of Physics in the College of Letters and Science and associate director of the MonArk NSF Quantum Foundry at MSU. "These first experiments revealed that microscopic areas of the material engineered by the Columbia team were capable of emitting single photons of light, launching a much bigger effort to develop the system further."

The MonArk NSF Quantum Foundry is a partnership between MSU and the University of Arkansas. It provides scientists with access to advanced manufacturing and measurement tools for the study of 2D materials for quantum technologies. These tools enable researchers to quickly process new materials, measure their properties and behavior, and test their performance in model quantum devices.

Three-dimensional materials, made up of stacked layers of atoms, exhibit various properties, such as thermal and electrical conductivity or—in this case—the ability to emit single photons at a time. Two-dimensional materials are single layers of atoms that retain the behaviors they exhibit in their 3D forms, but with enhanced properties that emerge because they are atomically thin.

Though the ability to emit single photons at a time was known to occur in large sheets of 2D materials, Borys said the observation made by the project team was the first demonstration that it also occurs in these much smaller ribbon structures.

Avetik Harutyunyan, HRI senior chief scientist, said, "Our technology provides a new pathway for the synthesis of quantum nanoribbons with precise width control, leveraging their unique mechanical and electronic properties as a single photon light source to realize secure communication known as quantum communication."

The collaborators on this project were able to encode information on a stream of individual photons emitted by the new nanoribbon material. They say that such streams could be used to create and distribute encrypted information between selected transmitters and receivers. Those communications would be secure, they added, because any attempt to eavesdrop on the communications would interfere with the quantum states being regulated by the receiver, introducing errors that could be detected immediately.

Samuel Wyss, a co-author of the recently published paper and one of two MSU doctoral students who worked on the nanoscale manipulation of the 2D materials, said these nanoribbons are unlike any other materials that have been studied to date.

"Studying the fundamental physics and these interactions in 2D semiconductors will allow us to engineer these materials for new electronic devices and unseen and unthought of applications," Wyss said.

Borys said the collaboration began about 2 ½ years ago, when Columbia and HRI asked MonArk to run optical tests on new ribbon structures of 2D materials that Honda had grown from molybdenum and tungsten. After stretching the materials over structures provided by the Columbia team, the MSU scientists studied how wrinkles in the ribbons interacted with light at ultracold temperatures near absolute zero.

Borys said the study of HRI's nanoribbons has yielded valuable information about 2D materials in general, and he described them as "potentially the highest quality of 2D materials we've studied." He said the team will continue to test their fundamental quantum limits.

"There's a possibility of shrinking the ribbons further," he said. "We're going to gain a lot of insight into generating a single photon of light with 2D materials by studying these nanoribbon structures."

The MonArk team will also explore how to overcome challenges related to using the materials in industry. Because the single photons are emitted rapidly and unpredictably, Borys said the team will investigate whether it's possible to use an electrical source like a battery to act as a photon-activation switch. MonArk is also testing how the nanoribbons perform in an actual quantum technology platform.

Borys credited the leadership of Xufan Li of the Honda Research Institute and James Schuck of Columbia University for the success of the collaboration.

"It's been very enriching and exciting working with the team at the Honda Research Institute," he said. "They are very motivated to see scientific discoveries rapidly translated into usable technologies. It has been a great experience for the students working on the project, with first results that are exciting for quantum technologies."

More information: Xufan Li et al, Width-dependent continuous growth of atomically thin quantum nanoribbons from nanoalloy seeds in chalcogen vapor, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-54413-9](https://doi.org/10.1038/s41467-024-54413-9)

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