

Highly Sensitive SWCNT-Based Pyroelectric Phototransistors Enable Broadband Room-Temperature Infrared Detection

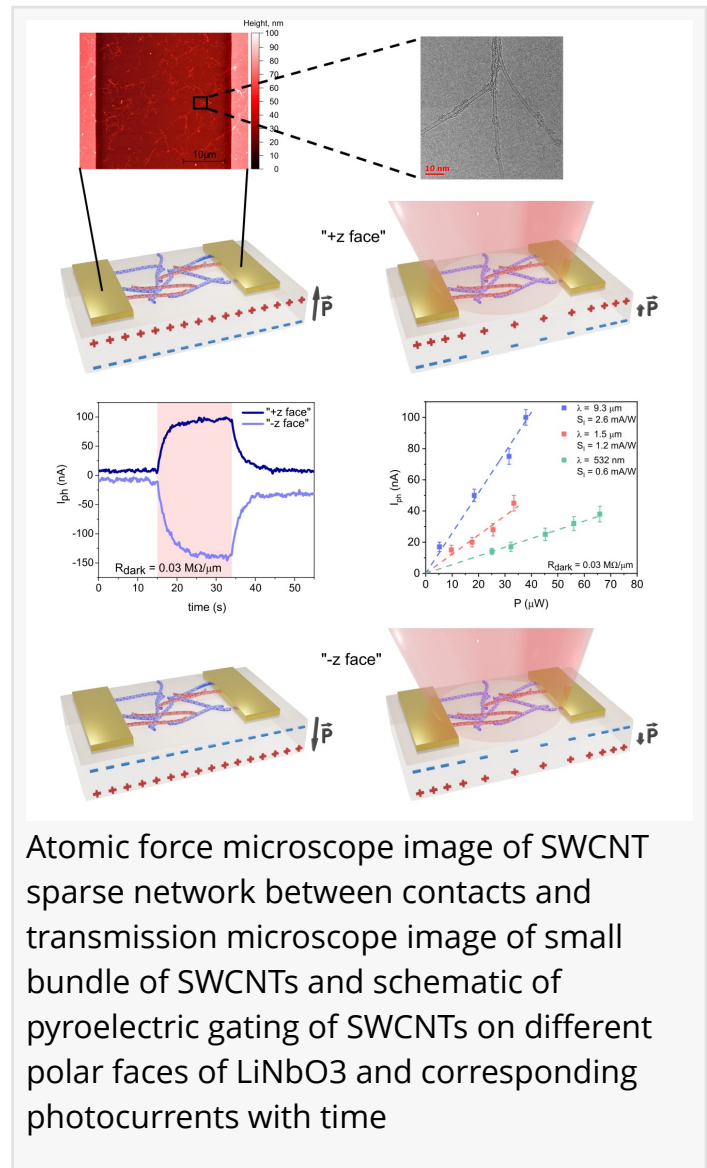
Carbon nanotubes paired with a pyroelectric lithium niobate crystal deliver cooling-free infrared sensing across the visible-to-mid-infrared range

CHINA, July 15, 2026 /EINPresswire.com/ --

Infrared (IR) light is invisible to the human eye, yet it underpins technologies that touch everyday life—from thermal cameras used by firefighters and the night-vision systems in cars to gas sensors that monitor air quality and the optical links that carry internet traffic. The catch is that the most sensitive IR detectors usually have to be chilled to very low temperatures. The cooling hardware is bulky, power-hungry, and expensive, which keeps high-performance IR sensing out of reach for many portable and low-cost applications.

A team, led by Dr. Svetlana I. Serebrennikova and Professor Albert G. Nasibulin at the Skolkovo Institute of Science and Technology (Skoltech), Russia, has demonstrated a detector that delivers high sensitivity while operating at ordinary room temperature. The device marries two materials, each chosen for a complementary strength. The first is a network of single-walled carbon nanotubes

(SWCNTs)—hollow cylinders of carbon, roughly a nanometer wide, whose electrical conductivity is extraordinarily sensitive to small changes in gate voltage. The second is lithium niobate (LiNbO₃), a crystal already valued in optics for working across a wide range of IR wavelengths and nonlinear properties. It was made available online on May 06, 2026, and published in Volume 9, Issue 5 of the Opto-Electronic Advances journal on May 14, 2026.



The key idea is to harness the pyroelectric effect in LiNbO₃. When the crystal absorbs IR light, it warms slightly, and that tiny temperature change shifts its internal electric polarization, briefly generating an electric field. In this device, that field behaves like a gate voltage that switches the conductivity of the attached carbon-nanotube network—by a factor of up to 105. In effect, heat from the incoming light is converted into a strong electrical signal, turning the assembly into a pyroelectric phototransistor.



Members of the Laboratory of Nanomaterials at the Skolkovo Institute of Science and Technology (Skoltech), led by Professor Albert G. Nasibulin. The laboratory conducts interdisciplinary research on nanomaterials, including single-walled carbon nanotubes,

The research was prompted by the disappointing performance of earlier graphene-based pyroelectric detectors. Graphene has no electronic bandgap, so its conductivity barely responds to the gating field, limiting sensitivity. Semiconducting carbon nanotubes do have a bandgap, which is exactly what allows their conductivity to swing so dramatically.

To build the devices, the team grew high-quality, sparse SWCNT networks using a refined aerosol chemical vapor deposition (CVD) method, then transferred the sub-percolating films onto a z-cut LiNbO₃ surface with a novel capillary transfer technique. This dry transfer avoids the surfactants and contaminants that degrade nanotube electronics in conventional deposition. Metal contacts were patterned by lithography. The finished detectors work at room temperature from the visible range out to 9.3 μm , reaching specific detectivities on the order of $10^{10} \text{ cm} \cdot \text{Hz}^{1/2} / \text{W}$ —outperforming graphene-based devices by several orders of magnitude and approaching the theoretical limit for uncooled thermal detection.

Significance

The research group of Prof. Albert G. Nasibulin at Skoltech introduces a new class of room-temperature infrared phototransistors that combine sparse SWCNT networks with a pyroelectric LiNbO₃ substrate.

Because the detectors are sensitive across a broad spectral range—from the visible to 9.3 μm —without any cryogenic cooling, they are especially well suited to portable, low-power IR sensing. Promising applications include thermal imaging for firefighting and building inspection, non-dispersive gas sensing for environmental monitoring, quality control in manufacturing, and short-range optical communications. Where conventional IR cameras depend on heavy, costly coolers, these lightweight devices could enable handheld thermal sensors and drone-mounted detectors for spotting gas leaks.

The societal payoff could be substantial. Affordable, uncooled IR detection would let thermal cameras be deployed far more widely—improving public safety in smoke-filled search-and-

rescue operations and enabling continuous monitoring of industrial emissions. In daily life, the same technology could support low-cost automotive night vision, smart-home sensors that improve energy efficiency, and better, non-contact thermometers for healthcare. By doing away with cryogenics, it also cuts operating costs and energy use, pointing toward more sustainable and accessible sensing.

The next steps focus on speed. Response is currently limited to about 2 seconds by heat diffusing through the 500 μm -thick LiNbO₃ substrate; thinner substrates or membrane structures should accelerate the thermal response considerably. The team also aims to stabilize performance with protective coatings that reduce hysteresis, improve the reproducibility of the semiconducting-channel networks, and optimize thermal coupling to heat sinks to sharpen both speed and spatial resolution in beam imaging.

Taken together, the results show that SWCNT-based pyroelectric phototransistors can approach the theoretical detectivity limit for uncooled thermal detectors. They open a path to a new generation of compact, broadband, room-temperature IR sensors that match cooled detectors on sensitivity while offering lower cost and greater portability—with potential to reshape fields ranging from environmental monitoring to consumer electronics.

About the Research Group

The Laboratory of Nanomaterials at Skoltech, led by Professor Albert G. Nasibulin, ranks among the world's leading laboratories in its field. Its mission is to carry out high-impact fundamental and applied research on nanomaterials, and to translate those scientific results into innovation and commercial technologies. The lab offers a uniquely interdisciplinary environment, drawing on an international team and a proven record of productive national and international collaboration. Its main research areas are:

- The aerosol synthesis of nanomaterials, including SWCNTs, graphene, and metal-oxide nanowires, together with the study of their growth mechanisms
- The application of these nanomaterials in transparent, flexible and stretchable electronics; optoelectronics; photovoltaics; photonics; nanocomposites; and chemical sensing.

Since June 2014 the laboratory has published over 150 peer-reviewed papers in journals including Nature Communications, Advanced Materials, Angewandte Chemie, Advanced Science, JACS, Nano Energy, Advanced Functional Materials, Nano Letters, Journal of Materials Chemistry A, Nano Research and many others. The group has filed 20+ patent applications and has spun out three start-up companies. The laboratory has been awarded more than 20 research grants and sustains its standing through dissemination in high-quality journals, the organization of scientific conferences, and teaching.

Reference

Title of original paper: Highly sensitive SWCNT-based pyroelectric phototransistors for broadband room temperature infrared detection

Journal: Opto-Electronic Advances

DOI: <https://doi.org/10.29026/oea.2026.260019>

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Dr. Albert G. Nasibulin is a Professor at the Skolkovo Institute of Science and Technology (Skoltech) in Russia. He heads the Laboratory of Nanomaterials at Skoltech and is a globally recognized physicist and materials scientist specializing in the aerosol synthesis of nanomaterials, including carbon nanotubes, graphene, and metal oxides. He earned a Ph.D. in Physical Chemistry from Kemerovo State University in 1996 and a Doctor of Science degree from Saint-Petersburg Technical State University in 2011. His research focuses on nanomaterial growth mechanisms and their applications in flexible, transparent, and stretchable electronics, photonics, and energy technologies.

Funding information

RSF grant (number 22-13-00436-П, SWCNT synthesis and characterization).

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