NTU Singapore scientists invent energy-saving glass that 'self-adapts' to heating and cooling demand

Nanyang Technological University

An international research team led by scientists from Nanyang Technological University, Singapore (NTU Singapore) has developed a material that, when coated on a glass window panel, can effectively self-adapt to heat or cool rooms across different climate zones in the world, helping to cut energy usage.

Developed by NTU researchers and reported in the top scientific journal Science, the first-of-its-kind glass automatically responds to changing temperatures by switching between heating and cooling.

The self-adaptive glass is developed using layers of vanadium dioxide nanoparticles composite, Poly(methyl methacrylate) (PMMA), and low-emissivity coating to form a unique structure which could modulate heating and cooling simultaneously.

The newly developed glass, which has no electrical components, works by exploiting the spectrums of light responsible for heating and cooling.

During summer, the glass suppresses solar heating (near infrared light), while boosting radiative cooling (long-wave infrared) – a natural phenomenon where heat emits through surfaces towards the cold universe – to cool the room. In the winter, it does the opposite to warm up the room.

In lab tests using an infrared camera to visualise results, the glass allowed a controlled amount of heat to emit in various conditions (room temperature – above 70°C), proving its ability to react dynamically to changing weather conditions.

New glass regulates both heating and cooling

Windows are one of the key components in a building's design, but they are also the least energy-efficient and most complicated part. In the United States alone, window-associated energy consumption (heating and cooling) in buildings accounts for approximately four per cent of their total primary energy usage each year according to an estimation based on data available from the Department of Energy in US.[1]

While scientists elsewhere have developed sustainable innovations to ease this energy demand – such as using low emissivity coatings to prevent heat transfer and electrochromic glass that regulate solar transmission from entering the room by becoming tinted – none of the solutions have been able to modulate both heating and cooling at the same time, until now.

The principal investigator of the study, Dr Long Yi of the NTU School of Materials Science and Engineering (MSE) said, "Most energy-saving windows today tackle the part of solar heat gain caused by visible and near infrared sunlight. However, researchers often overlook the radiative cooling in the long wavelength infrared. While innovations focusing on radiative cooling have been used on walls and roofs, this function becomes undesirable during winter. Our team has demonstrated for the first time a glass that can respond favourably to both wavelengths, meaning that it can continuously self-tune to react to a changing temperature across all seasons."

As a result of these features, the NTU research team believes their innovation offers a convenient way to conserve energy in buildings since it does not rely on any moving components, electrical mechanisms, or blocking views, to function.

To improve the performance of windows, the simultaneous modulation of both solar transmission and radiative cooling are crucial, said co-authors Professor Gang Tan from The University of Wyoming, USA, and Professor Ronggui Yang from the Huazhong University of Science and Technology, Wuhan, China, who led the building energy saving simulation.

"This innovation fills the missing gap between traditional smart windows and radiative cooling by paving a new research direction to minimise energy consumption," said Prof Gang Tan.

The study is an example of groundbreaking research that supports the NTU 2025 strategic plan, which seeks to address humanity's grand challenges on sustainability, and accelerate the translation of research discoveries into innovations that mitigate human impact on the environment.

Innovation useful for a wide range of climate types

As a proof of concept, the scientists tested the energy-saving performance of their invention using simulations of climate data covering all populated parts of the globe (seven climate zones).

The team found the glass they developed showed energy savings in both warm and cool seasons, with an overall energy saving performance of up to 9.5%, or ~330,000 kWh per year (estimated energy required to power 60 household in Singapore for a year) less than commercially available low emissivity glass in a simulated medium sized office building.

First author of the study Wang Shancheng, who is Research Fellow and former PhD student of Dr Long Yi, said, "The results prove the viability of applying our glass in all types of climates as it is able to help cut energy use regardless of hot and cold seasonal temperature fluctuations. This sets our invention apart from current energy-saving windows which tend to find limited use in regions with less seasonal variations."

Moreover, the heating and cooling performance of their glass can be customised to suit the needs of the market and region for which it is intended.

"We can do so by simply adjusting the structure and composition of special nanocomposite coating layered onto the glass panel, allowing our innovation to be potentially used across a wide range of heat regulating applications, and not limited to windows," Dr Long Yi said.

Providing an independent view, Professor Liangbing Hu, Herbert Rabin Distinguished Professor, Director of the Center for Materials Innovation at the University of Maryland, USA, said, "Long and co-workers made the original development of smart windows that can regulate the near-infrared sunlight and the long-wave infrared heat. The use of this smart window could be highly important for building energy-saving and decarbonization."

A Singapore patent has been filed for the innovation. As the next steps, the research team is aiming to achieve even higher energy-saving performance by working on the design of their nanocomposite coating.