Passive Cooling Reinvented

Thursday 7 December, 2023

Cooling without using energy is the future. This is because it does not emit heat and mostly it is non-toxic, non-flammable and very long-lasting. (Long life beats recycling any day).

Widespread already

Such passive cooling is already widespread in the form of copper and aluminium conducting heat away in our devices and fins on our chips and engines. Those fins are sometimes called radiators but mostly they remove heat by convection as does immersion in cooling liquids. For thousands of years, Middle Eastern and African buildings have been shaped to both trap breezes and enhance convection, including passively directing air down to aquifers for cooling. That reappears in some modern houses and even skyscrapers.

Dramatic advances from something else

The more dramatic advances are now seen with genuine radiative passive cooling, notably so-called passive daylight radiative cooling PDRC both reflecting heat and radiating it into outer space through a specific infrared frequency window. Behind this is an urgent need to keep human habitation comfortable despite two unpleasant changes. First is global warming and second is the fact that emerging nations are not in the temperate regions where most of us live today. They are mostly in tropical regions. For example, India, hot already, is now seeing increasing excursions to a lethal 50C in several regions.

To the rescue – at least in part - PDRC is considered one of the most promising green cooling technologies for curbing soaring demand for space cooling, reducing environmental pollution, and combating global warming. And, yes, you can combine it with those traditional approaches.

November 2023 announcement

Current PDRC using nanophotonic structures is limited by its high cost and poor compatibility with existing end uses, while polymeric photonic alternatives lack weather resistance and effective solar reflection. To address this, ceramic versions are now in research with promising results, combining superior reflectivity with appropriate emissivity. See "*Hierarchically structured passive radiative cooling ceramic with high solar reflectivity*". Science 9 Nov 2023 Vol 382, Issue 6671 pp. 691-697 DOI: 10.1126/science.adi4725. Other recent work has resulted in glasses to perform a complementary task.

Beetles got there first

Mimicking a white desert beetle, the researchers developed a cellular ceramic that can achieve highly efficient light scattering and a near-perfect solar reflectivity of 99.6%. These qualities, coupled with high thermal emissivity, allow the ceramic to provide continuous sub-ambient cooling in an outdoor setting with a cooling power of over 130 watts per square meter at noon, demonstrating energy-saving potential on a worldwide scale. The color, weather resistance, mechanical robustness, and ability to depress the so-called Leidenfrost effect are key features ensuring the durable and versatile nature of the cooling ceramic, thereby facilitating its commercialization in various applications, particularly building construction.

Versatility

The material, known as cooling ceramic, has achieved high-performance optical properties for energy-free and refrigerant-free cooling generation. Its cost-effectiveness, durability and versatility make it highly suitable for commercialisation in numerous applications, particularly in building construction. Indeed, it can be made curved or patterned. By reducing the thermal load of buildings and providing stable cooling performance, even in diverse weather conditions in all climates, cooling ceramic enhances energy efficiency and can combat global warming.

Here comes multi-mode, multifunctional passive cooling

Dr Peter Harrop, CEO of analysts Zhar Research advises,

> "Nature teaches us that multifunctional cooling even in the form of multipurpose materials is the way to go. One example is those new beetle-like ceramics that cool by reflecting and transmitting

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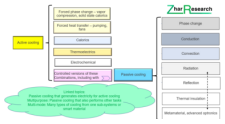

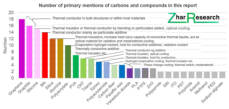

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> while also acting as structural and protective parts. There is much more coming along."

He adds that,

> "The big picture can be appraised as passive cooling which includes passively moved parts and convective gas and liquid. Alternatively, there is the partially overlapping subject of solid-state cooling which includes some powered "caloric" and other solids that use a fraction of the power – and therefore emit far less heat – than today's ubiquitous vapor compression cooling. Either way, the scope to create new billion-dollar materials and systems businesses is widespread. These many advances tick all three marketing boxes – we need them, we accept the importance of buying them and we can afford them."

New reports

Zhar Research has reports taking both perspectives. They are, "Passive Cooling Materials and Devices 2023-2043" and "Solid State Cooling Markets 2024-2044". These are available at www.zharresearch.com and www.giiresearch.com.

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