Porous Material for Continuous Radiative Cooling

Technology #7417

Passive radiation of heat is an energy efficient approach to cooling that requires no moving parts or power consumption. However, most state-of-the-art approaches cannot cool the object below the temperature of its surroundings, which is often insufficient. A relatively new approach utilizes materials that radiatively reject heat to Space (effectively at 3 K) by selectively emitting through the atmosphere’s transparency band (8-13 μm). This is a promising approach to reduce the energy consumption of our built environment and to improve off-the-grid thermal comfort and system reliability. Such systems are capable of cooling an object (e.g., building or photovoltaic panel) below the temperature of its surroundings, but must strongly emit infrared in the atmosphere’s transparency band while simultaneously preventing solar and atmospheric heat from reaching the IR emitter. Previous examples of this approach suffer from poor durability and low thermal resistance to ambient heat or rely on porous polymeric materials and fabrics that are permeable to water vapor and convective heat transfer.

High-Performance and Renewable Radiative Sky Cooling with Nanoporous Infrared Windows

The technology is a design that utilizes a thermally-insulating selectively transparent cover for high-performance passive radiative cooling. The cover allows heat generated in a building/body to be rejected to Space but prevents down-dwelling solar and atmospheric heat from reaching the building/body. By creating a barrier for atmospheric and solar (diffuse and direct) heating, the cover enables a broadband (e.g., a black surface, an enclosure) or selective radiative emitter to reach low temperatures (e.g. freezing point of water) and provide high cooling rates. Our simulation indicates that the radiative cooling performance of systems with the cover surpasses the cooling power and maximum temperature drop of state-of-the-art systems.

The achieve this performance, the cover is designed to meet several criteria. By implementing hierarchical porosity, the cover is optimized to minimize the spectral penetration depth of incident solar thermal radiation and to suppress thermal conduction. The transparency of the cover is designed to match the atmospheric transparency such that the emitter can radiate heat to through the atmosphere to Space. Specifically, the material is nanoporous, with pore and particle sizes smaller than the peak wavelength of emission (~10 μm), selectively transparent in the infrared, and has low thermal conductivity (< 0.04 Wm-1K-1). Additionally, the cover may contain condensed phase constituents that selectively absorb at long wavelengths where scattering by nanoscale porosity would otherwise insufficiently block down-dwelling atmospheric radiation. Overall, the cover acts as a radiation shield outside of the wavelength bands where the atmosphere is transparent.

An advantage of the technology is that the design may be achieved utilizing a variety of materials. Nanoporous inorganic-organic nanocomposites are particularly advantageous. Example materials include: ceramic matrices (e.g., barium fluoride with a polymer binder), nanofiber matrix (spun nanofibers such as polyethylene doped or decorated with barium fluoride), multilayer polymer sheets doped with ceramic particles, chalcogenide aerogels and xerogels, polymer foams doped with ceramic particles.

Applications

- Passive cooling of roofs, vehicle cabins for thermal management and air conditioning of buildings
- Cooling of photovoltaics for improved module efficiency and lifetime
· Off-the-grid applications requiring cooling (atmospheric dew harvesting, cold storage, etc.)
· Energy efficient cooling of wireless infrastructure
· Improved noise/sound insulation
· Hyper-spectral camouflage from aerial thermal imaging

**Advantages**
· Enhances cooling power and the below-ambient temperature drop
· Architecturally and esthetically preferred diffuse appearance
· Cost-effective
· Improved material durability

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