Smart passive materials capable of heating or cooling to temperatures different than ambient without additional power supply

In recent years, the view that one of humanity's greatest challenges to face are man-made climate changes has been well-established. The scientific community agrees that actions to stop this process must be taken as soon as possible. Currently, one of the most pressing issues is the intensification of efforts to develop new solutions to save energy, which comes mainly from fossil fuels. In this context, the possibility of efficient and preferably zero-carbon cooling (or heating) of buildings or equipment is becoming an issue of increasing relevance to modern civilization's needs. And while there are natural processes to regulate heat, since the flow of heat always takes place from a higher-temperature body to a lower-temperature body, cooling an object to temperatures below that of the receiver requires an expenditure of energy and the use of a special system such as, e.g., a compressor. However, there is an ideal heat receiver with a temperature close to -270^{o}C and a virtually infinite heat capacity, and that is... space. To exploit this potential, the transport of heat between the object to be cooled and space must take place through thermal radiation (radiation), emitted in the range of wavelengths for which the Earth's atmosphere is transparent (i.e., in 8-12 µm band). At the same time, to provide daylight cooling operation, the device's optical properties in the visible range should be designed so that direct solar radiation does not cause it to heat up. Although simultaneous fulfillment of all of the above conditions seemed unattainable, thanks to recent advances in materials science involving improvements in nano- and micro-structuring processes, it was possible to make the first prototypes of such devices. It has been shown that temperatures up to several tens of degrees lower than ambient temperature can be achieved without any energy input and with the most direct sunlight.

In this project, we plan interdisciplinary basic research to discover new structures, ways of shaping and managing the emissivity/absorptivity characteristics and identify the most suitable polymer materials for future thermal management applications. It addresses the most crucial factors currently holding further progress in developing smart radiative devices. The envisioned numerical work will increase the understanding of the coupling mechanism between optical, thermal and mechanical properties. The experimental work will provide useful knowledge regarding the temperature-dependent optical constants of commonly used polymers. The project aims to develop a new type of structured material in which emissivity/absorptivity characteristics can be adjusted on the fly to manage the thermal balance of the target object and thus control its temperature. The expected result that moves beyond the current state of the art, is the envisioned functionality that the proposed material's operation mode can fluently change to the state between two extreme ones when exposed to external stimuli – the tension**.** The first extreme mode refers to the situation when the structured material works as a passive radiative cooling device, capable of reaching temperatures below the ambient, without requiring an external power supply and under direct sunlight. In the second regime, it will harvest the sun's energy to heat the object to temperatures much higher than the ambient, simultaneously minimizing the parasitic heat loss. The envisioned structured material will differ from present radiative cooling devices not only in a number of available functionalities but also in terms of geometry, constitutive materials, and the switching mechanism. We believe that the successful realization of this project will lead to the development of a new generation of smart thermal management systems.