Development of composite materials for adsorption cooling/heating applications

Animesh Pal, Ph.D.
JSPS Postdoctoral Research Fellow
Multiscale Science and Engineering for Energy and the Environment Thrust,
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University, Japan

Conventional cooling/heating systems are responsible for the carbon footprints from the usage of a considerable amount of electricity and chemical refrigerants having ODP and high GWP. Owing to the energy crisis and the imposing of international regulations on the production and use of environmentally harmful refrigerants, research on adsorption cooling systems has been greatly intensified worldwide. Adsorption cooling systems being driven by industrial waste heat or solar heat offer a promising alternative to tackle the energy crisis and environmental issues. However, their widespread adoption is hindered by advancements in the adsorbent material.

Several kinds of porous adsorbents, including zeolites, metal-organic frameworks, silica gel, and carbonaceous materials, have been studied so far for adsorption cooling applications. Among the various adsorbents studied so far, activated carbon (AC) has been proven to be a potential adsorbent for cooling applications due to its high surface area and pore volume. However, AC is a powder or granular form that possesses low thermal conductivity and is loosely packed as a result of low volumetric cooling/refrigeration capacity, and the system becomes bulky. Consequently, adsorption characteristics and thermal conductivity are two vital properties that are needed to improve for making the cooling system more promising. Since AC possesses very high adsorption uptake compared to other adsorbents. Therefore, it is necessary to enhance the heat transfer properties of AC for more widespread use. Consequently, heat intensification of AC could be done by making consolidated composite adsorbents using various additives materials during synthesis which have attracted much attention by many researchers in recent years. Therefore, we developed several types of composites and investigated their performance. Composite is a blend of activated carbon, namely MSC-30 or Maxsorb III, thermal conductivity enhancer (e.g., graphite, graphene nanoplatelets, h-BN), and binder (ionic liquid, polyvinyl alcohol). Composite samples with different mass ratios of constituent materials are studied. Thermal diffusivity, as well as thermal conductivity, increases by introducing GNPs into the AC and binder. Experimental results show that H-grade GNPs are superior for enhancing the thermal conductivity of AC composite compared to C-grade. The addition of both the GNPs in the composite increases the packing density. Furthermore, the thermal conductivity increases with the increasing packing density, and the highest thermal conductivity is found at 1.55 W m^{-1} K^{-1} for composite 3 at a packing density of 614 kg m^{-3}, which is about 23.5 times higher than AC powder. In conclusion, the composite exhibits notably high thermal conductivity compared to the parent material, suggesting the potential for a more efficient and compact design in adsorption cooling systems.

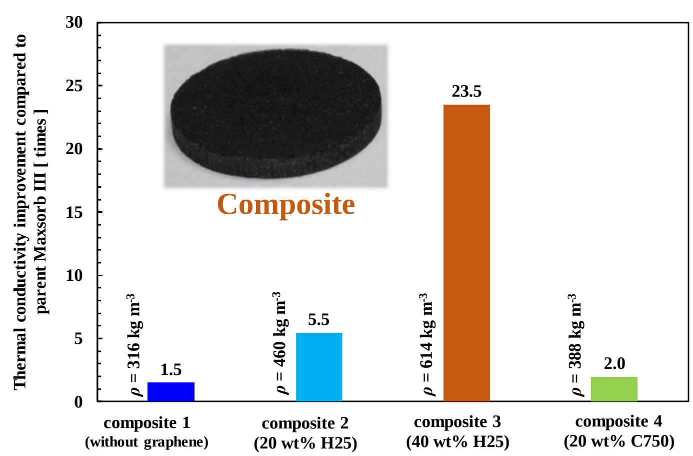

Fig. 1: Thermal conductivity enhancement compared to Maxsorb III.