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Superlyophobic Surfaces for Increased Heat Transfer during Condensation of CO_2

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Abstract : CO_2 capture, transport and storage (CCS) is essential to mitigate global anthropogenic CO_2 emissions. To make CCS a widely implemented technology in, e.g. the power sector, the reduction of costs is crucial. For a large cost reduction, every part of the CCS chain must contribute. By increasing the heat transfer efficiency during liquefaction of CO_2, which is a necessary step, e.g. ship transportation, the costs associated with the process are reduced. Heat transfer rates during dropwise condensation are up to one order of magnitude higher than during filmwise condensation. Dropwise condensation usually occurs on a non-wetting surface (Superlyophobic surface). The vapour condenses in discrete droplets, and the non-wetting nature of the surface reduces the adhesion forces and results in shedding of condensed droplets. This, again, results in fresh nucleation sites for further droplet condensation, effectively increasing the liquefaction efficiency. In addition, the droplets in themselves have a smaller heat transfer resistance than a liquid film, resulting in increased heat transfer rates from vapour to solid. Surface tension is a crucial parameter for dropwise condensation, due to its impact on the solid-liquid contact angle. A low surface tension usually results in a low contact angle, and again to spreading of the condensed liquid on the surface. CO_2 has very low surface tension compared to water. However, at relevant temperatures and pressures for CO_2 condensation, the surface tension is comparable to organic compounds such as pentane, a dropwise condensation of CO_2 is a completely new field of research. Therefore, knowledge of several important parameters such as contact angle and drop size distribution must be gained in order to understand the nature of the condensation. A new setup has been built to measure these relevant parameters. The main parts of the experimental setup is a pressure chamber in which the condensation occurs, and a high-speed camera. The process of CO_2 condensation is visually monitored, and one can determine the contact angle, contact angle hysteresis and hence, the surface adhesion of the liquid. CO_2 condensation on different surfaces can be analysed, e.g. copper, aluminium and stainless steel. The experimental setup is built for accurate measurements of the temperature difference between the surface and the condensing vapour and accurate pressure measurements in the vapour. The temperature will be measured directly underneath the condensing surface. The next step of the project will be to fabricate nanostructured surfaces for inducing superlyophobicity. Roughness is a key feature to achieve contact angles above 150° (limit for superlyophobicity) and controlled, and periodical roughness on the nanoscale is beneficial. Surfaces that are non- wetting towards organic non-polar liquids are candidates surface structures for dropwise condensation of CO_2.

Keywords : CCS, dropwise condensation, low surface tension liquid, superlyophobic surfaces
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