Imbibition, evaporation and particles transport on textured substrates and in porous layers

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Imbibition of volatile liquids on textured surfaces and in porous layers governs heat and mass transport in natural phenomena and in technological applications, including thermal management of electronic devices and ink-jet printing. These processes are responsible for significant improvement of cooling efficiency during drop impact cooling [1] and flow boiling [2] if the hot surfaces are covered by highly porous nanofiber layers.

Prediction of imbibition rate in textured substrates and porous layers, especially in the presence of evaporation, is a very complicated task. The existent imbibition theory for porous media relies on the known capillary pressure and the material permeability and is only applicable for the cases where the imbibition front separates a completely saturated region from a completely dry region. The hydrodynamics and transport processes during imbibition on textured surfaces and porous layers are substantially more complicated and are not completely understood.

A simultaneous imbibition and evaporation in a model textured substrate are described theoretically and numerically. A typical element of the model system is a single groove, along which the liquid flows under the action of capillary pressure gradient. The cross-section area occupied by the liquid varies along the groove. The shape of the liquid-gas interface and the imbibition rate are determined by the groove geometry, the properties of the liquid, the substrate wettability and the thermal conditions. The predicted maximal imbibed length decreases with increasing of substrate temperature and with decreasing of relative humidity. This trend agrees with the available experimental results on imbibition into porous layers. The developed model is a new step towards development of a general model for prediction of simultaneous imbibition and evaporation on real textured surfaces and porous layers.

Flow of particles-laden liquids in porous layers and deposition of particles on elements of porous structure has not been sufficiently investigated. The first results of our group in the framework of the EU ITN project “Complex wetting phenomena” (www.cowet.eu) are presented.

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