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Use of diffusion controlled drop evaporation equations for dropwise condensation during dew formation and effect of neighboring droplets

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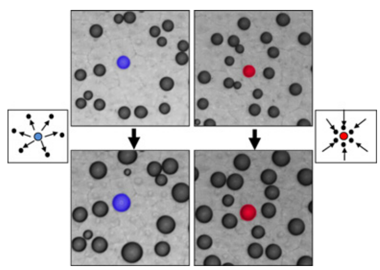
HIGHLIGHTS

- ▶ Drop evaporation equations were applied to estimate rate of slow drop condensation.
- ▶ Polyolefin surfaces having close surface tension but large *CAH* values were used.
- ▶ Effect of water θ_e and *CAH* on single drop condensation rate was investigated.
- ▶ Isolated droplets grow according a power law with exponent 1/3 on polymer surfaces.
- ▶ Condensation rate for a surrounded droplet was 14–40% lower than an isolated one.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, we determined that the equations derived for the diffusion controlled drop evaporation processes can be successfully applied to the condensation rate of water droplets on polymer surfaces having a surface temperature just below the dew point. The differences between the growth rates of condensed isolated droplets on five different polyolefin surfaces, whose surface free energies were in a close range of 30–37 mJ/m^2, were attributed to the difference in surface roughness which alters the droplet nucleation rate, drop pinning effect and initial contact angles. The condensation rate of isolated droplets decreased with the increase of surface roughness, water contact angle and contact angle hysteresis in the order of ethylene–vinyl acetate copolymer (EVA) > low density polyethylene (LDPE) > high density polyethylene (HDPE) > polypropylene–polyethylene copolymer (PPPE) > polypropylene (PP). The drop radius of the individual isolated droplets was found to grow according a power law with exponent 1/3 except PP similar to previous reports. We also compared the volume increase of an isolated single droplet with the volume increase of another similar sized single droplet which was surrounded by neighboring droplets and found that when neighboring droplets are present in close proximity, the condensation rate was 14–40% lower than that of a single isolated droplet due to blocking of lateral water vapor diffusion. This effect was more pronounced on substrates having high surface roughness.

1. Introduction

A water droplet nucleates on a surface whose temperature is below the saturation temperature because of the condensation of the supersaturated water vapor. Later, it grows by direct condensation of the supersaturated vapor which was present in the surrounding atmosphere and was carried to the droplet by a constant gas flux. This type of growth indicates the similar characteristics as formation of dew [1–10]. In principle, dew formation is a problem of phase transition and a bulk homogeneous phase, characterized by its temperature and pressure, transforms in a liquid phase on a substrate held at a lower temperature. During the

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