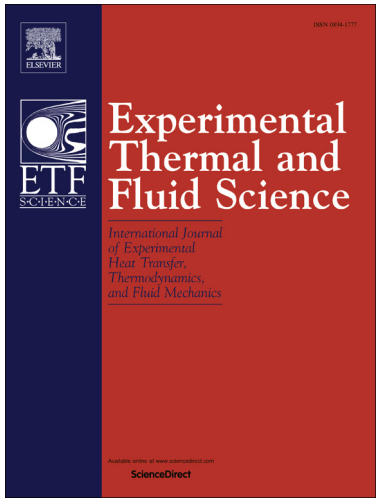

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Discontinuous Pinning Effect by a Hole Row to the Gas-Liquid Interface in a Parallel Gap

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Abstract:

Discontinuous contact line pinning phenomenon appears when liquid wets discontinuous sharp features. It provides additional resistance to the gas-liquid interface and sometimes can be used as an effective approach for liquid control, such as avoiding liquid leakage by extraction holes in immersion lithography and other microfluidic devices. The discontinuous pinning effect by a hole row to the gas-liquid interface in a parallel gap was investigated in this study. We designed an experiment to investigate the behavior and the maximum resistance pressure of a hole row blocking the air-water interface in the gap. It was observed that the interface was partially pinned by the hole edges, while the unpinned parts was also stopped by the interface stretching. The pinning effect caused the interface distorted and produced additive Laplace pressure to resist the water pressure. Three failure types of the discontinuous pinning system were found, which were related to not only the hole edge pinning effect, but also the shape and position of the contact line. By analyzing the experimental results, analytical models based on the Laplace equation were built to formulate the pinning effects in the paper. The resistance pressure can be determined dependent on the developed analytical method. The experimental results agreed with the models in the failure types and maximum resistance pressure estimations.

Keywords:

Contact line pinning; Discontinuous pinning effect; Gas-liquid interface; Liquid control; Immersion lithography.

1. Introduction

Contact line pinning refers to the natural phenomenon that the contact line is stopped by a physical or chemical inhomogeneous feature in wetting, which may be a sharp edge in physics or an intersection line between the hydrophilic and hydrophobic surfaces in chemistry etc. It is common in daily life such as water being trapped at the end of a capillary tube [1]. What is more, it is also a basic behavior in a variety of fields, including microfluidic systems [2, 3], coating [4, 5], and microfabrication [6, 7]. The reason of contact line pinning is that the contact line do not move forward until the contact angle relative to the next feature surface reaches to the advancing value, which is called the advancing angle θ_a [8]. During the pinning process, the gas-liquid interface curvature changes as the contact angle varies, resulting in the capillary force changing. Therefore, contact line pinning is essentially an interfacial effect, especially in systems with smaller size.

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