Experimental Investigation of Contact Angle Dynamics in Non-Isothermal Spreading

Elaheh Alizadeh-Birjandi and H. Pirouz Kavehpour

Department of Mechanical and Aerospace Engineering, University of California, Los Angeles

ISCST- 20180918AM-B-MD2

Presented at the 19th International Coating Science and Technology Symposium, September 16-19, 2018, Long Beach, CA, USA†.

Introduction

Understanding and accurate control of spreading and solidification of liquid droplets on solid substrate are the key aspects in improving the efficiency and performance of a wide range of industrial applications such as thermal spray coatings and 3D printing. Despite the previous efforts, the underlying mechanism is still lacking.

Our goal is to provide insight on the physics involved in the contact line arrest in non-isothermal spreading of liquid droplets under a variety of dynamic and thermal conditions. More specifically, we restrict our attention to the effect of sub-cooling on the advancing and receding contact angles as well as the subsequent solidification initiation mode at the vicinity of the contact line for both hydrophilic and hydrophobic substrates.

Experimental Method

The experimental investigations are performed using high-speed video camera for slow motion examination of droplet dynamics and high resolution Infrared thermography camera for thermal analysis. The results of our experimental observations help specify the governing factors involved in solidification arrest and verify the existence of two distinct regimes of solidification.

In order to examine the contact-line motion over a variety of dynamic and thermal conditions, we have devised spreading experiments using the injection needle. Tests were run at various combinations of the surface temperature and substrate material. KRÜSS DSA100 was used for recording the droplet spreading dynamics and subsequent evaluation of contact points and contact angles.

In principle, the DSA 100 machine consists of three main components (i) the specimen table with three manual knobs for accurate 3D positioning (ii) the video system with CCD camera, prism, light source and aperture (iii) a software-controlled multiple dosing unit. This state-of-the-art apparatus provides accurate measurement of the dynamic contact angle and base diameter of the spreading fluid. The intelligent dosing system of DSA 100 permits liquids to be dispensed without the risk of contaminating the sample. The bright light with extremely low radiated heat provides us with the illumination that is required for measuring drop's evolution. This new type of light guidance eliminates all interference by unrelated light making the drop shape recognizable by DSA 100 software. The drop is illuminated from one side and a camera at the opposite side records an image of the drop.

Temperature of the solid targets can be adjusted by a Peltier element situated in DSA100 machine from -30 °C to 160 °C. A Peltier element is a thermoelectric device, which transfers heat from one of its sides to the other when electricity is applied. The cold side is then brought in contact with the substrate and cools it to a chosen temperature before or after, depending on the experiment, the water droplet is placed on it. Cooling rate is kept fairly constant by circulation of coolant water with predetermined temperature around the hot side of the Peltier element. Temperature readings of the Peltier element were accurate to ±0.5 °C established by iDS uEye SE high speed camera and k-type thermocouple.

The advancing and receding contact angles are measured as shown in figure1 based on the arrest and movement of the contact line. The experiments were repeated for water droplet on three different substrates over a wide range of temperature.