Numerical simulation of spreading characteristics for nanofluids droplet impinging on the solid surface

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Introduction: The nanofluid is a class of fluids with high thermal conductivity and non-Newtonian flow behaviors. In order to better understand spreading phenomena during the impinging process, we present numerical simulations for nanofluids droplet impinging on the solid surface. The viscosity is measured at different shear rates and the shear-thinning behaviors of the nanofluids are incorporated to this study by employing the Carreau-Yasuda model.

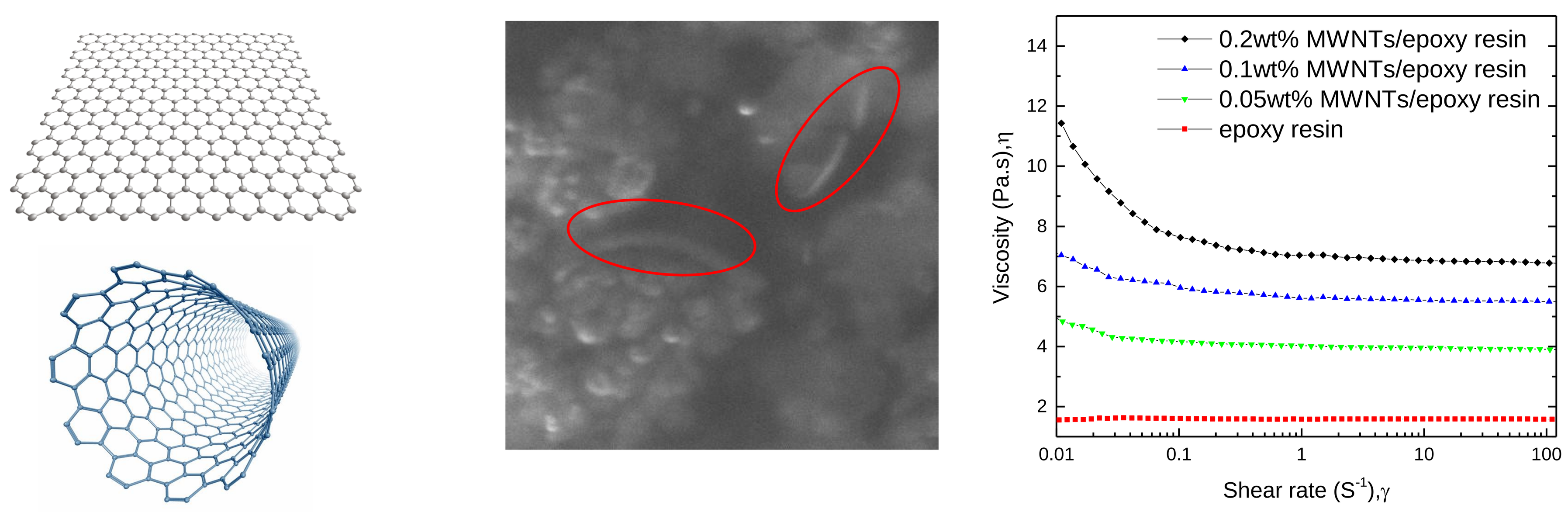

Figure 1. The structure of graphene and MWNTs (left), SEM image of MWNTS/resin(middle), viscosity of test MWNTs/resin nanofluids(right).

Computational Methods: The model described covers interface capture, fiber-orientation and laminar flow physics. The level-set method and Dinh-Armstrong model are carried about.

Continuity Equation $\nabla \cdot \boldsymbol{u} = 0$

Momentum conservation equation $\rho \frac{D\boldsymbol{u}}{Dt} = -\nabla p + \eta \nabla^2 \boldsymbol{u} + \nabla \cdot \boldsymbol{\tau}_f + \rho \boldsymbol{b}$

Dinh-Armstrong model $\boldsymbol{\sigma} = -p\boldsymbol{I} + 2\eta \boldsymbol{D} + \boldsymbol{\tau}_f, \quad \boldsymbol{\tau}_f = \eta N_p \boldsymbol{a}_4 : \boldsymbol{D}$

Level-Set Method $\frac{\partial \phi}{\partial t} + \boldsymbol{u} \cdot \nabla \phi = \lambda \nabla \cdot (\varepsilon \nabla \phi - \phi(1-\phi)\frac{\nabla \phi}{|\nabla \phi|})$

A 2D axisymmetric geometry is shown in Fig. 2, where the droplet is initially positioned above the solid surface with an initial velocity.

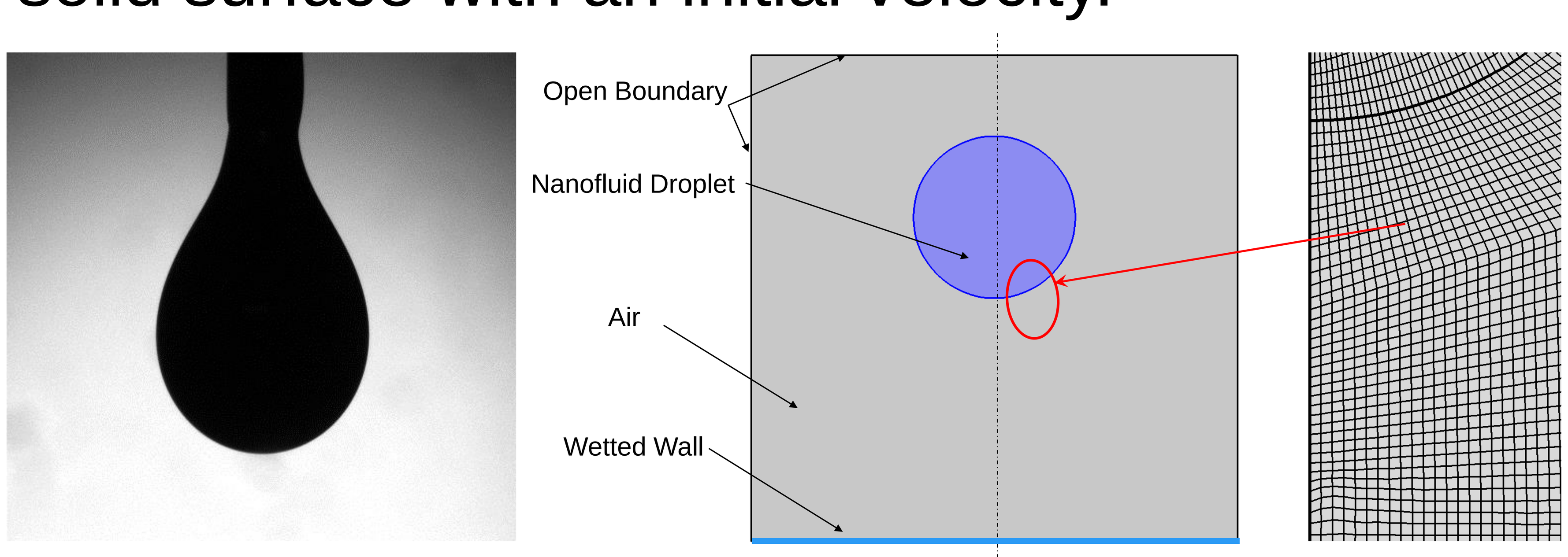

Figure 2. Experimental image(left), schematic of computational domain(middle), partial mapped mesh(right).

Results:

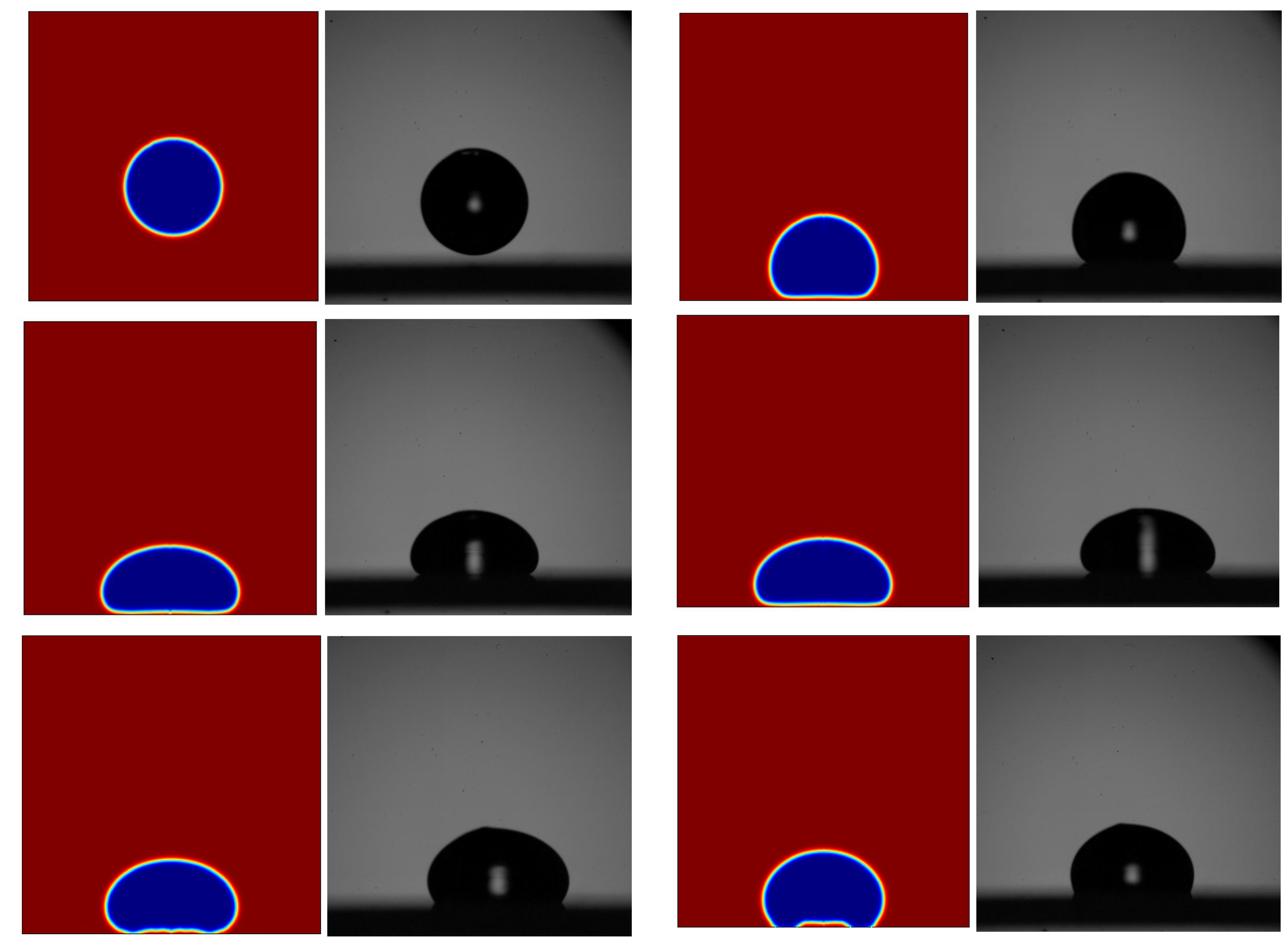

Figure 3. Impingement process of pure resin: t=1,2,3,4,10,30ms.

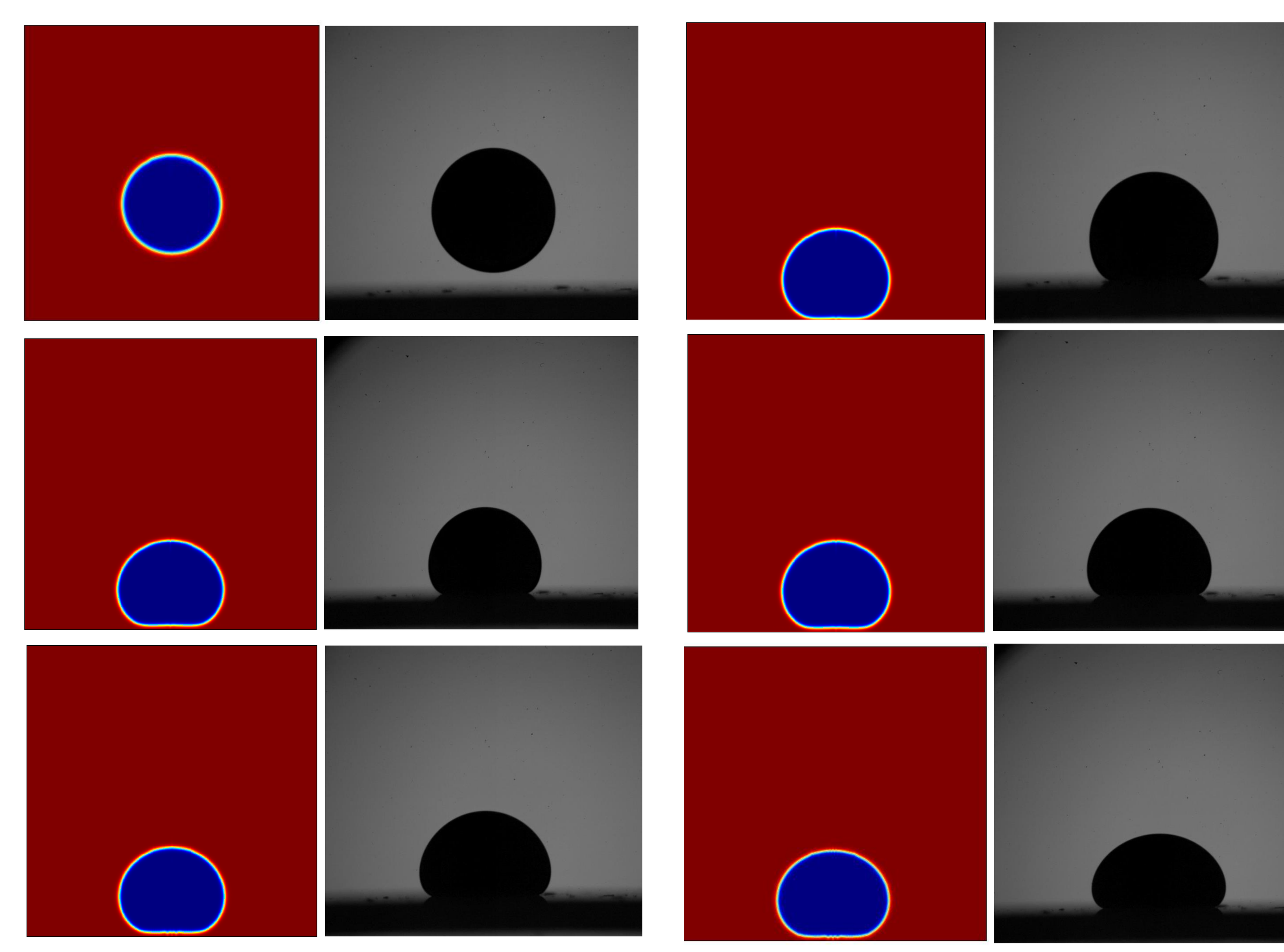

Figure 4. Impingement process of 0.2wt% MWNTs/epoxy resin: t=1,2,3,4,10,30ms.

Conclusions: Both the simulations and experiments show that the spreading and receding process of epoxy resin droplets are inhibited because of the shear thinning phenomenon caused by the addition of nano-dispersed phase.

References:

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2. AMIT GUPTA and RANGANATHAN KUMAR, "Droplet impingement and breakup on a dry surface", Computers and Fluids, 39,1696-1703 (2010).