Single-Phase Modeling in Microchannel with Piranha Pin Fin

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Introduction: This work aims at modeling single-phase heat transfer and fluid flow in microchannel. It's a preparation for further flow boiling research. To enhance the heat transfer between hot surface and working fluid, a novel pin fin design piranha pin fin (*PPF*) is proposed as shown in Fig.1. This *PPF* can be applied in flow boiling region for vapor venting.

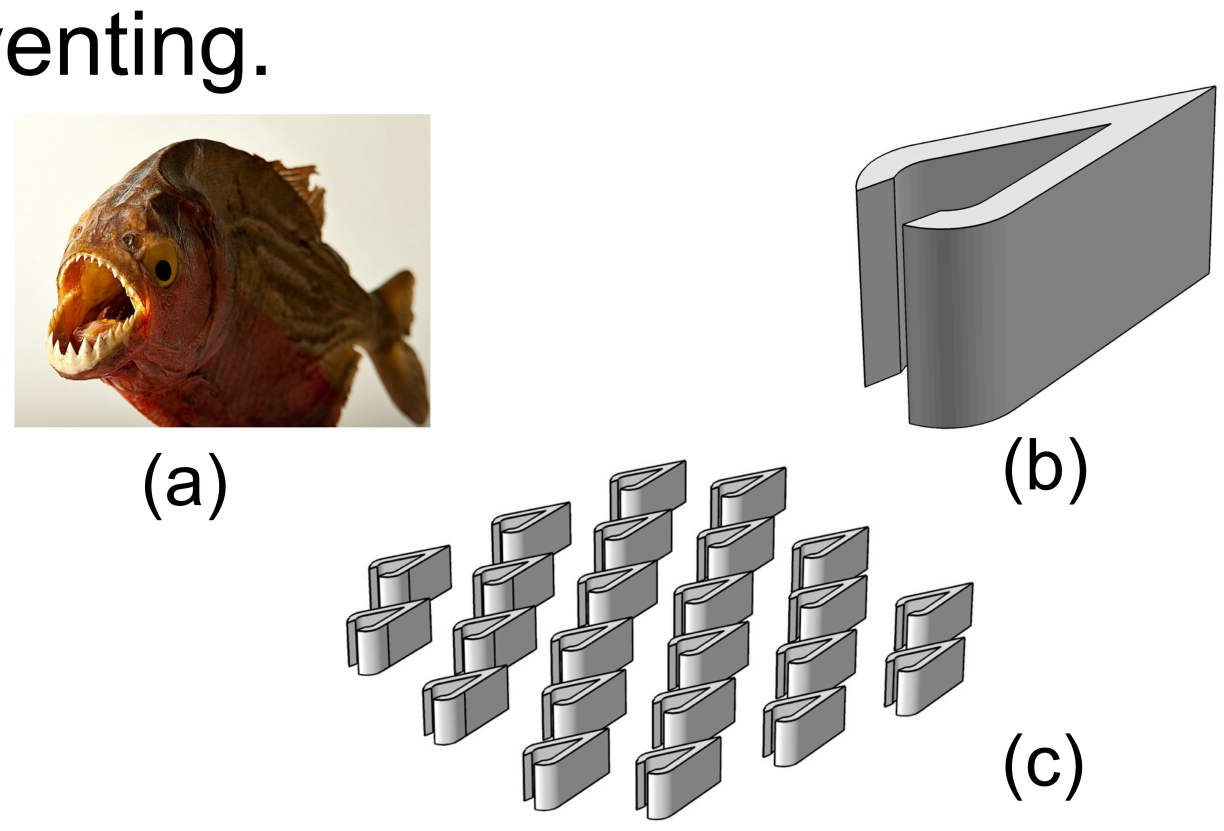

Figure 1. Piranha pin fin design (a) Piranha fish, (b) Piranha pin fin, (c) Pin fin arrays

Computational Methods: Laminar conjugate heat transfer module is applied for this study. Steady state is in interest here. The governing equation is shown as below.

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot\left[-p\boldsymbol{I} + \mu\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right) - \frac{2}{3}\mu(\nabla\cdot\mathbf{u})\boldsymbol{I}\right] + \boldsymbol{F}$$

$$\nabla\cdot(\rho\mathbf{u}) = 0$$

$$\rho c_p \mathbf{u}\cdot\nabla T + \nabla\cdot\boldsymbol{q} = Q + Q_{ted}$$

$$\boldsymbol{q} = -k\nabla T$$

Working fluid is customized as HFE7000. Microchannel is fabricated with silicon. Boundary conditions are set as follows.

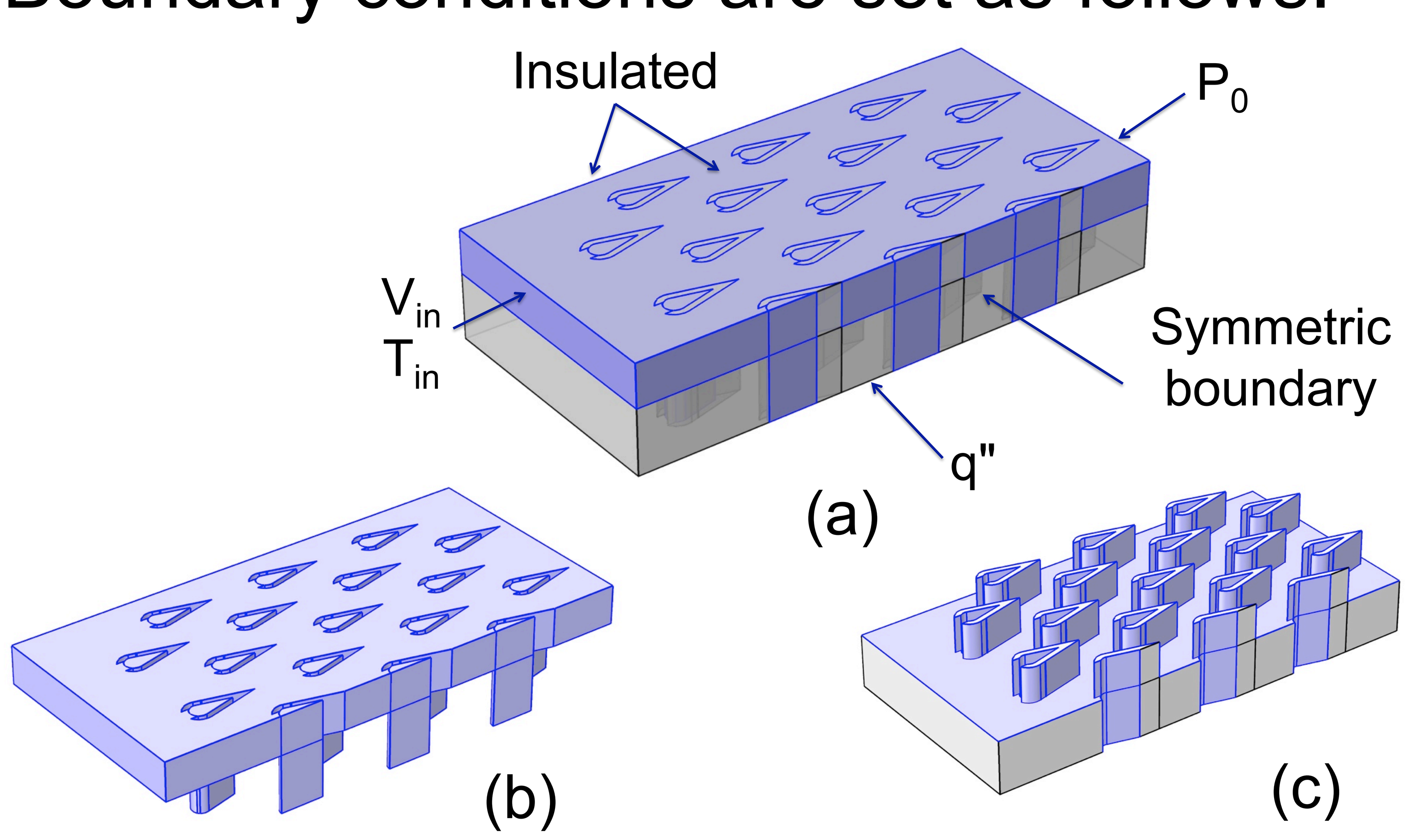

Figure 2. Model description (a) Model set up, (b) Fluid domain, (c) Solid domain

Results: Single-phase fluid flow and heat transfer analysis are shown in Fig. 3 and Fig.4.

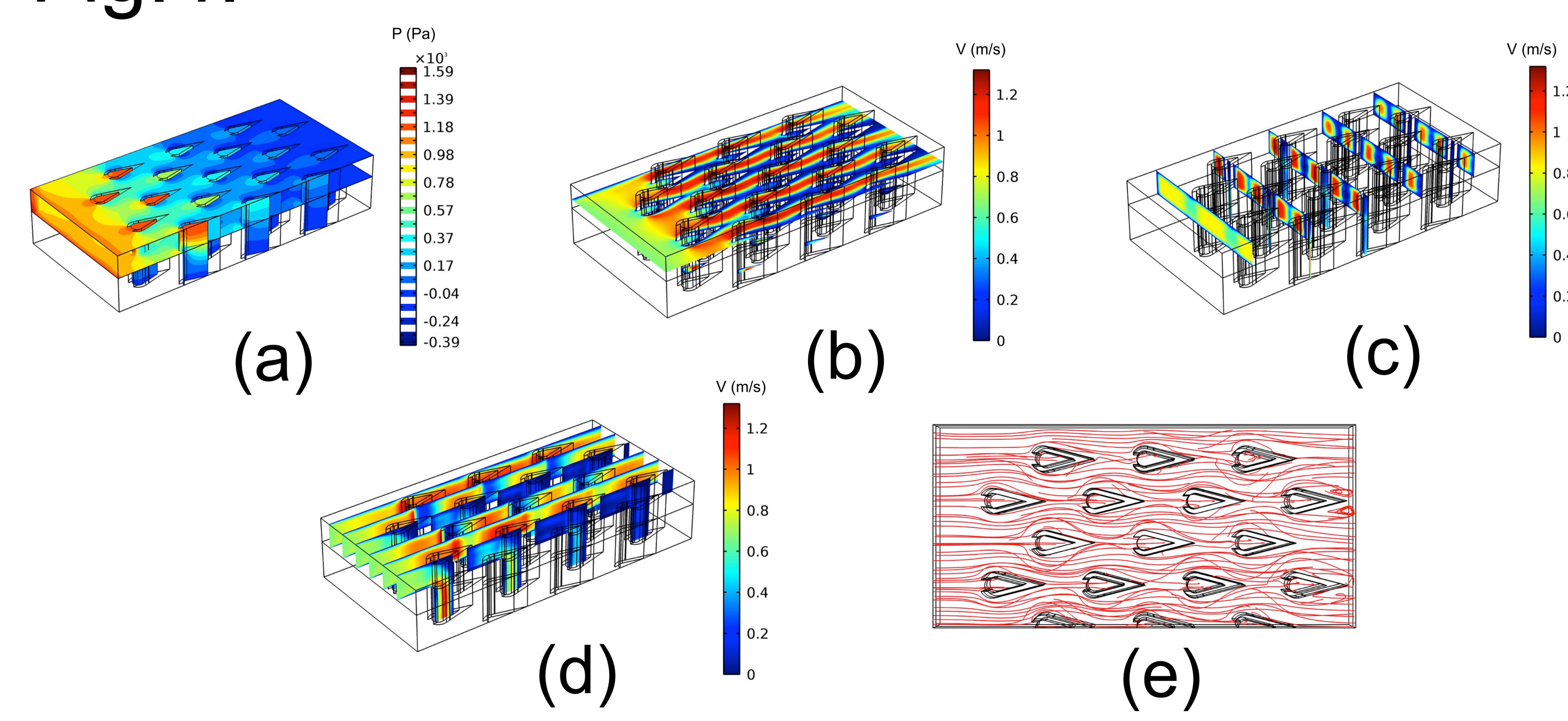

Figure 3. Fluid flow analysis G_{in}=948 kg/m^{2}s (a) Pressure distribution, (b) XY plane velocity, (c) XZ plane velocity, (d) ZY plane velocity, (e) Streamlines from XY view

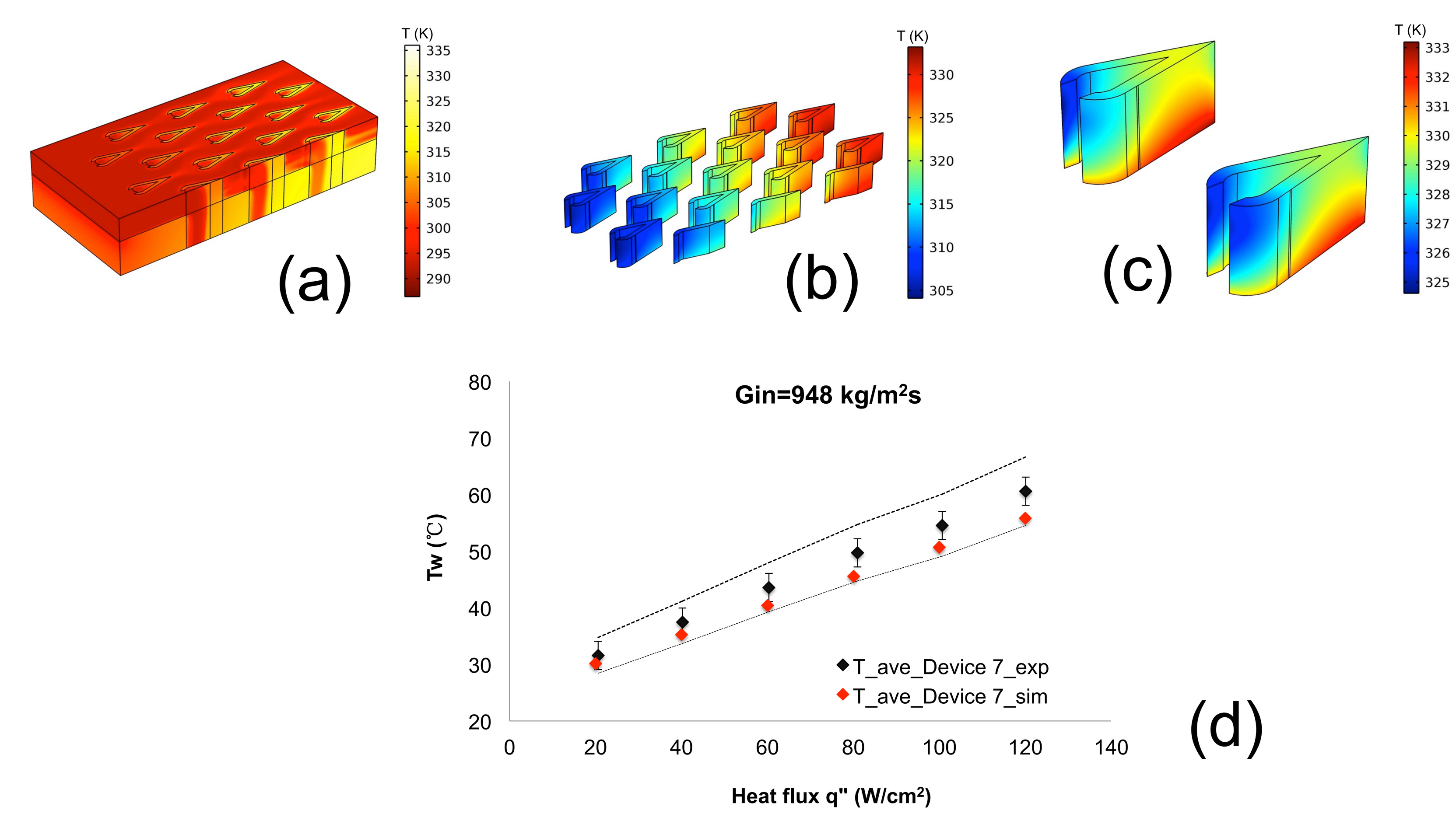

Figure 4. Heat transfer analysis (a) Device level temperature distribution (G_{in}=948 kg/m^{2}s, q"=80 w/cm^2), (b)*PPF* array temperature, (c) *PPF* temperature, (d) Experimental validation

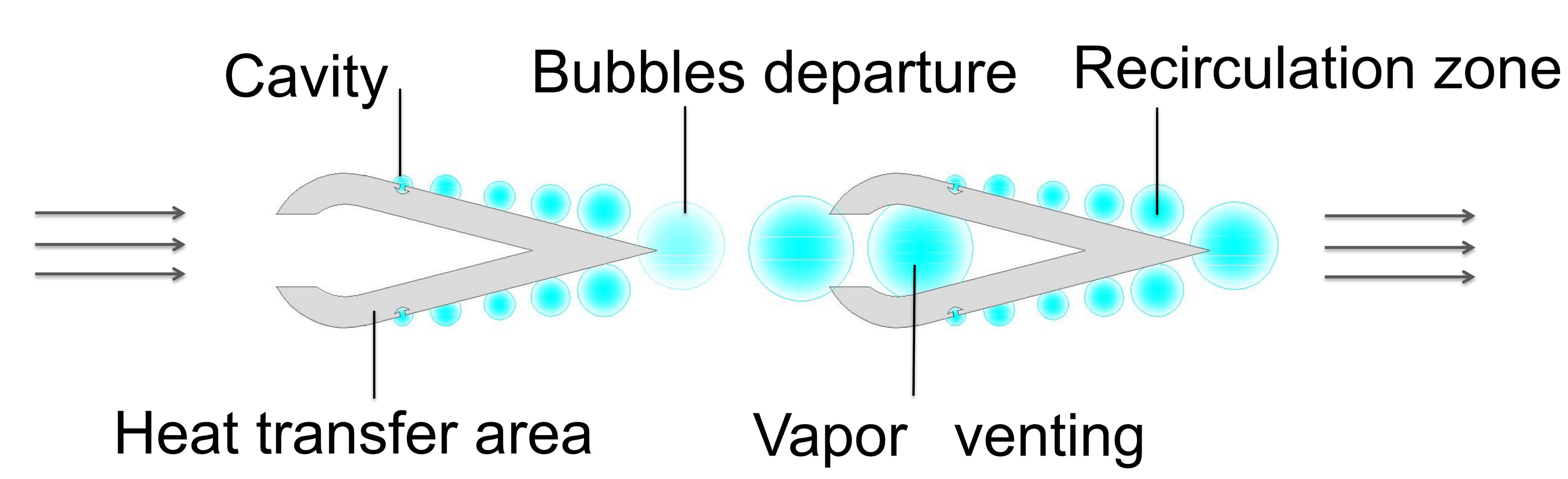

Figure 5. Schematic diagram for *PPF*'s vapor venting

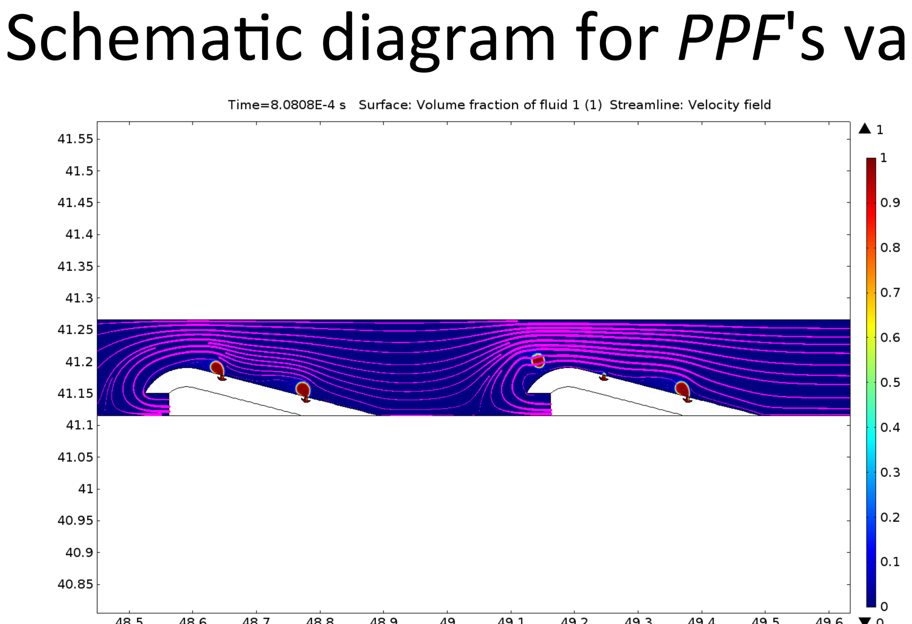

Figure 6. Flow boiling in microchannel with *PPF*

Conclusions: *PPFs* in microchannel are capable of enhancing heat transfer between cold fluid and hot surface. This modeling provides insightful view of *PPF* and favors further research of flow boiling.