Characterization of Flow Regimes in T-Junction Microfluidic Devices

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Introduction:

Microfluidic devices hold a ginormous share in the future point-of-care devices and biotechnology market. Hence, good amount of knowledge is necessary to tune flow parameters to get precise control in the flow behavior inside microchannel. This type is controlled flow is necessary for cell sorting, bio assay preparation and DNA sequestration processes, etc. In this work, we have studied the different flow behavior due to variation in continuous and dispersed phase Reynolds number. The results have been obtained for a constant Capillary Number (Ca) = 0.01 and Continuous phase Reynolds Number (Re_C) carried from 0.001 to 0.1 and Dispersed Phase Reynolds Number(Re_D) varied from 0.001 to 10.

Computational Models and Methods:

$$\rho\frac{\partial u}{\partial t} + \rho(u.\nabla)u = \nabla.[-pI + \mu(\nabla u + (\nabla u)^T)] + \rho g + F_{st}$$

$$\nabla.u = 0$$

$$\frac{\partial \phi}{\partial t} + u.\nabla\phi = \gamma\nabla.\left(\epsilon_{ls}\nabla\phi - \phi(1-\phi)\frac{\nabla\phi}{|\nabla\phi|}\right), \phi = phils$$

PARDISO solver in COMSOL Multiphysics® (version 5.4) is used to solve the conservative naiver strokes equation and level set equation. The effective droplet diameter

$$d_{eff} = 2\sqrt{\frac{1}{\pi}\int(\phi > 0.5)d\Omega}$$

Computational Parameters:

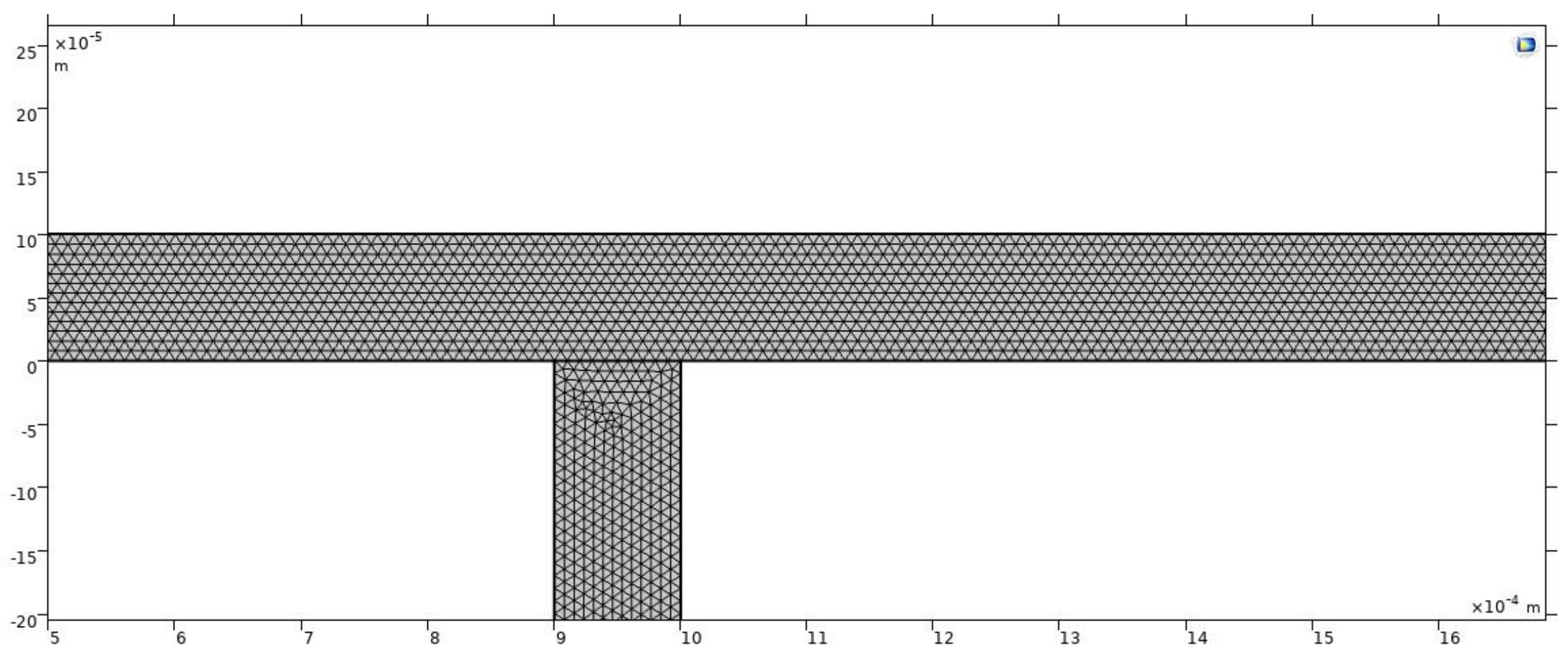

Figure 1. 2-D Free Triangular Meshed Section of T-junction Microfluidic Channel

The computation domain (L=4000 µm, w=100µm, upstream length=900 µm) has been meshed with fine sized free triangular Mesh with a custom defined maximum element size of 10µm.

Total elements = 13766

Degrees of freedom = 86420

Contact Angle = 135°

Time Step (△t) = 0.001 sec

Relative Tolerance = 0.0001

Results and Discussions:

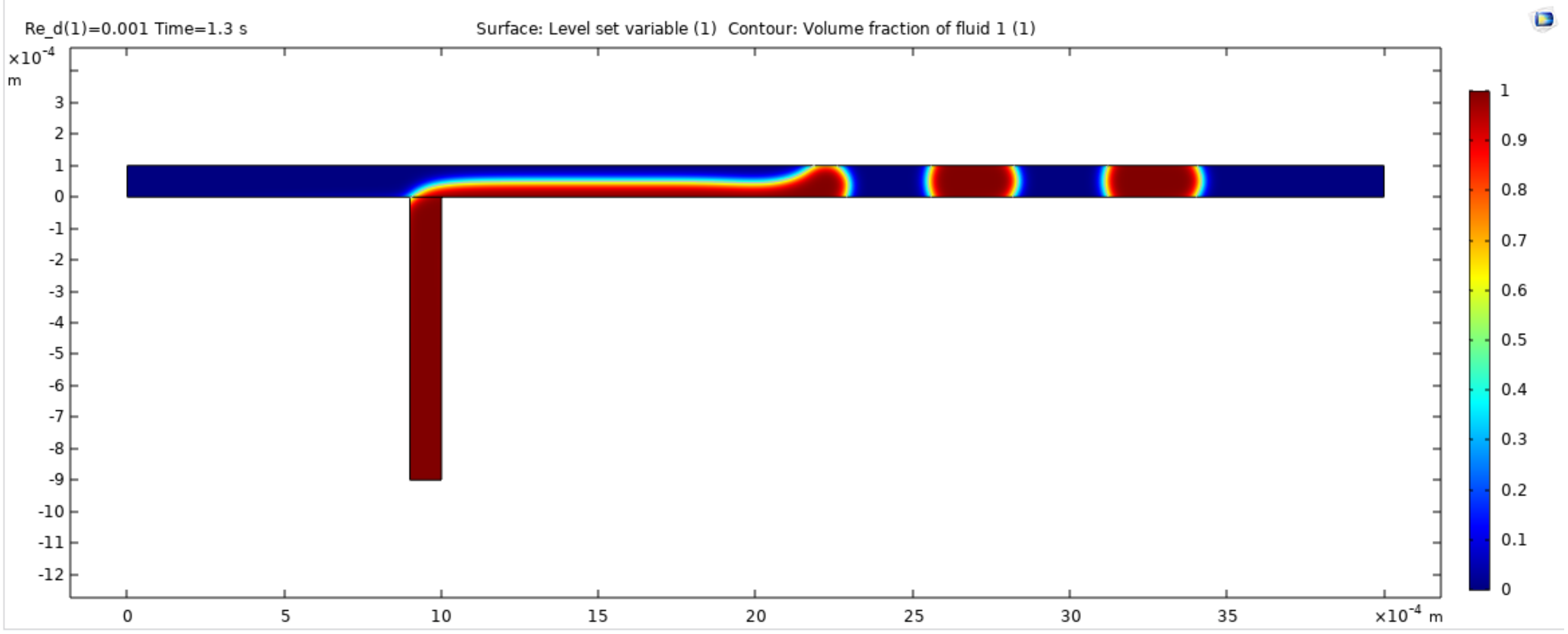

Figure 2. Regime for Ca=0.01, Re_C=0.001, Re_D = 0.001

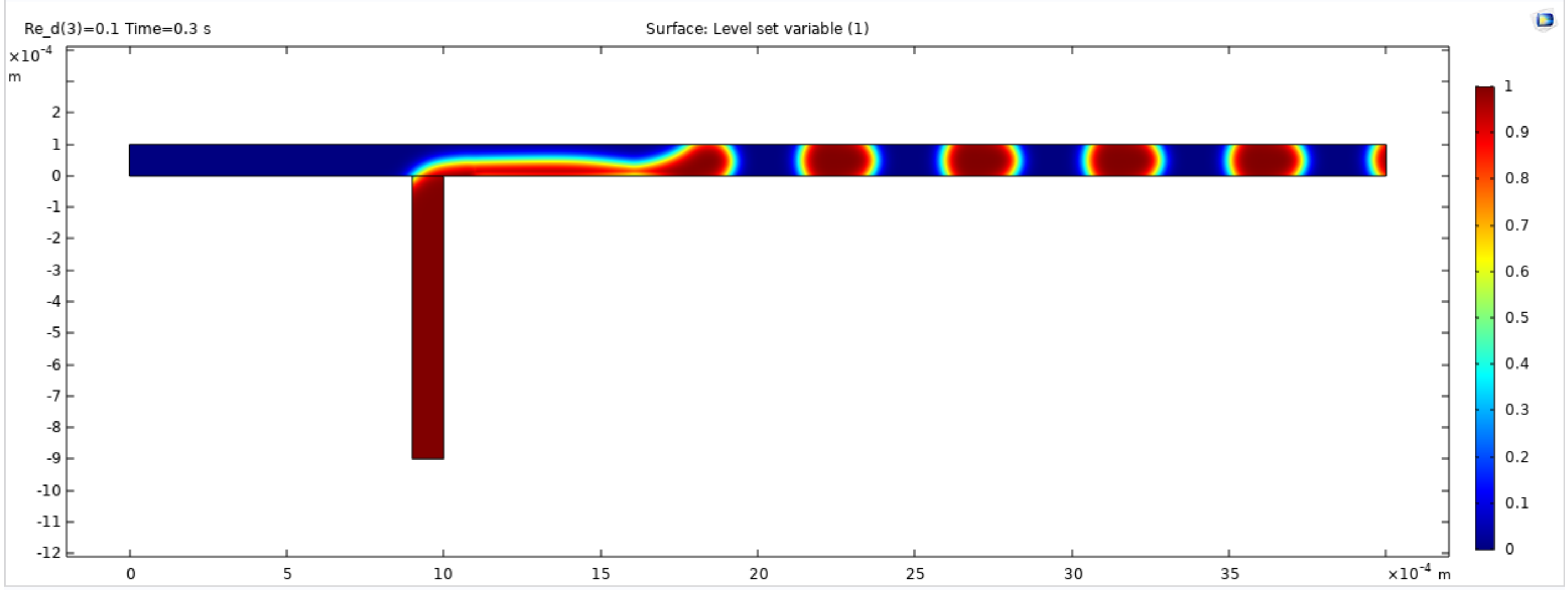

Figure 3. Regime for Ca=0.01, Re_C = 0.1, Re_D=0.1

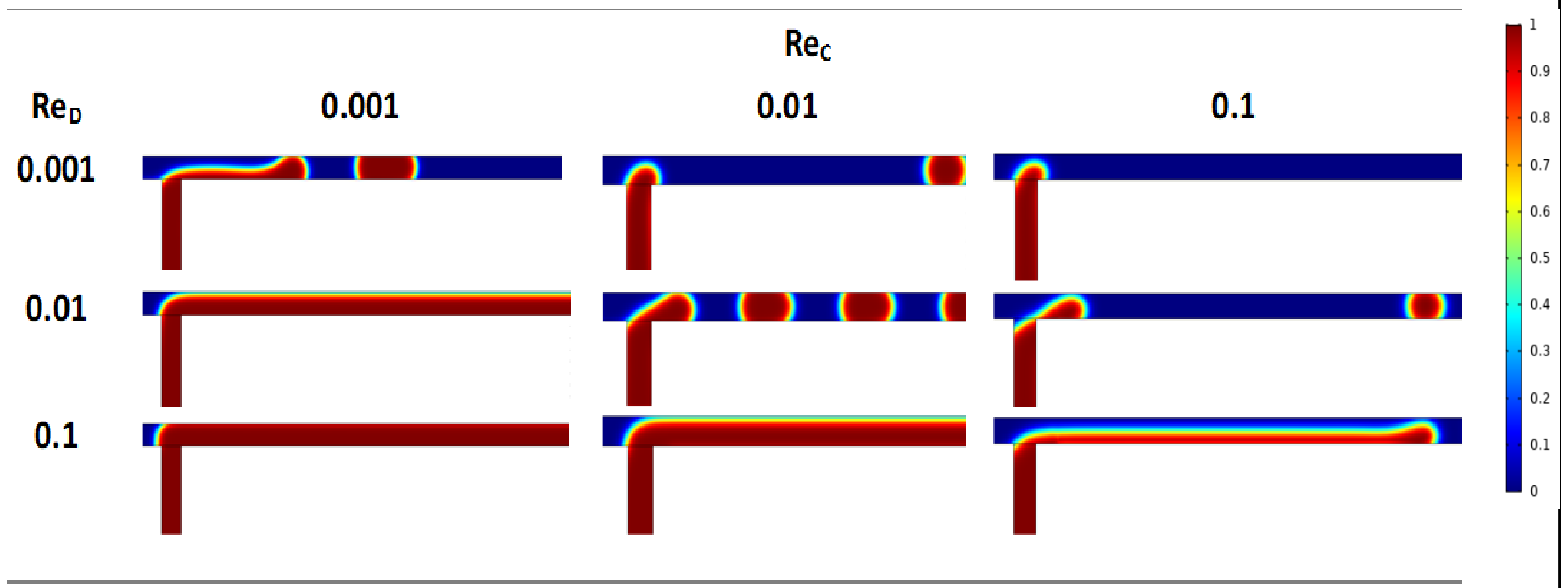

Figure 4. Flow regimes for different Re_C and Re_D for Ca = 0.01

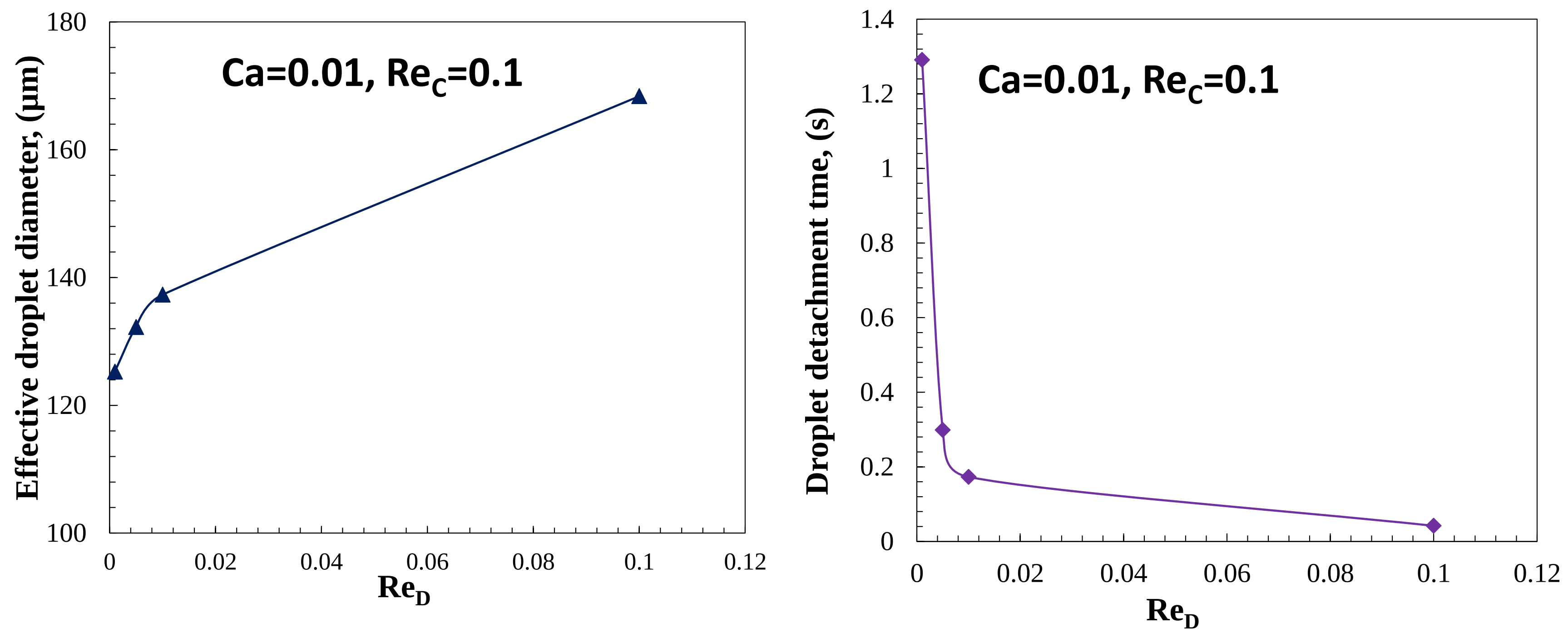

Figure 5. Effective droplet diameter and detachment time comparison plot at Re_C = 0.1 and Ca = 0.01

Conclusions:

- It is noticeable that the monodispersity increases with the increase of continuous phase Reynolds number
- Effective droplet diameter increases with increasing dispersed phase flow rate, keeping rest constant.
- Droplet Breakup time keeps reducing with increasing Re_D value.

References:

1. Jullien, M.-C., Tsang Mui Ching, M.-J., Cohen, C., Menetrier, L., Tabeling, P., 2009. Droplet breakup in microfluidic T-junctions at small capillary numbers. Phys. Fluids 21, 072001.
2. Xu, J. & Li, Shaowei & Tan, Jing & Luo, Guangsheng., 2008. Correlations of droplet formation in T-junction microfluidic devices: From squeezing to dripping. Microfluidics and Nanofluidics 5, pp 711–717 .