Department of Chemical Engineering, IIT Kharagpur

Microscale Transport Process (CH 62039) Mid-Semester Examination, Autumn 2015-16

B.Tech/Dual 4th year, M.Tech 1st year, R.S. (Total students 68), Total marks 30, Duration 2 hours

Q1. A major recent research effort is directed towards cooling of hot spots utilizing change-of-phase heat transfer from microgrooved surfaces.

- Mention very briefly the pertinent issue in the selection of channel dimensions for a specific process and what strategy can be used to increase the flow rate and to distribute it properly in a compact device.
- Sketch the variation of pressure drop with volumetric flow rate in a microchannel citing proper reasons.
- Two liquids are being pumped through a micrchannel at the same volumetric rate with many bends and obstructions in the flow-path. The viscosity of the second liquid is 2.5 times that of the first liquid. State with reasons the difference in the readings of a pressure drop measuring device attached to the microchannel for these two liquids.
- Can you suggest (with proper reasons) any surface modification strategy to reduce the problem of higher pressure drop in such devices? **2+1+1+1 = 5 Marks**

Q2. Starting with the Augmented Young-Laplace equation, prove that for an evaporating, curved thin film the flow towards the contact line (from the capillary meniscus region) is sustained by capillary pressure gradient and disjoining pressure. **2 Marks**

Q3. Based on a differential volume element of a liquid in a triangular grove, derive the governing equation of flow and cite the significances of each term. **3 Marks**

Q4.

i) Mention the basic steps involved in converting a laboratory scale process to microstructured devices.

ii) State how dilute and dense gases behave when the system size is reduced gradually.

2+1 = 3 Marks

Q5. Write **within two sentences** the difference between

i) anodic bonding and fusion bonding
ii) μ-stereolithography and photolithography
iii) casting and molding
iv) molding and microinjection
v) cytotoxic and biocompatible
vi) press-fit interconnect and glued interconnect
vii) plastic coupler and integrated 'O' ring
viii) silicon and glass in connection with crystalinity
ix) silicon wet etching and glass wet etching
x) positive resist and negative resist
xi) physical dry etching and chemical dry etching
xii) isotropic and anisotropic etching
xiii) reactive ion etching and DRIE
xiv) thermal evaporation and sputtering
xv) film-dewetting and post-exposure baking of resist film
xvi) molding in closed capillary and in open capillary
xvii) use of PDMS and PMMA in microfabrication
xviii) diffusion and dispersion
xix) use of vacuum in spin coater chuck and in plasma chamber
xx) T sensor and H filter
xxi) valve action through hydrophoblic layer and hydrogel layer
xxii) capillary pumping and pressure driven pumping **22×0.5=11 Marks**

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Q6. A horizontal capillary of internal diameter *d* is to be filled by a liquid of viscosity μ solely by capillary force. Do you expect the velocity of the liquid front in the tube to increase or decrease with time / progression? Write down the Poiseuille's equation for fully developed flow, where pressure gradient is expressed in terms of surface tension force. Assume the surface tension and contact angle as σ and θ respectively. Consider the initial liquid meniscus position in the channel as L_0. Obtain the distance traveled by the liquid meniscus as function of time, and σ, θ, μ, d. **2 Marks**

Q7. Write down the assumptions, governing equations, and initial and boundary conditions employed in theorizing Taylor dispersion. **2 Marks**

Q8. Define mixing quality and mixing effectiveness in a passive mixer. **2 Marks**

Useful relations

$$\sigma=\pi d^2 \qquad \Lambda=\frac{1}{\sqrt{2}n\sigma} \qquad Kn=\frac{\Lambda}{L} \qquad \Delta p=\left(C_f\frac{l}{d_h}+\zeta\,\text{Re}\right)\frac{\rho v^2}{2}\frac{\text{Re}}{d_h^2}$$

$$\Pi=\frac{-\bar{A}}{\delta^3}\ ;\ \delta<50nm \qquad \Delta p=\left(C_f\eta l+\zeta\frac{V}{N}\right)\frac{\rho}{2}\frac{V}{N d_h^4}$$

$$=-\frac{B}{\delta^4}\ ;\ \delta>50nm$$

$$\Delta p=\left(C_f\nu\frac{l}{d_h}+\zeta d_h\bar{w}\right)\frac{\rho}{2}\frac{\bar{w}}{d_h}=C_f\frac{\eta l}{2d_h}\bar{w}+\zeta\frac{\rho}{2}\bar{w}^2$$

$$\Delta P = P_l - P_V = -\sigma K - \Pi$$

$$\omega=\frac{1}{\lambda_D}=\sqrt{\frac{e^2\sum_i n_i z_i^2}{\epsilon\epsilon_o k_B T}}$$