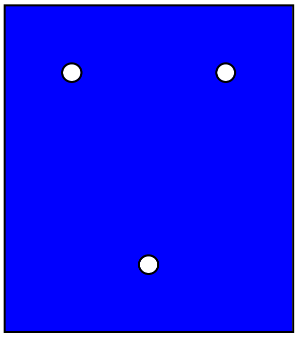
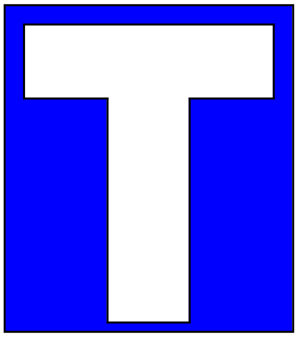
a.

Step 1: 1st Silicon wafer
MASK 1



1. Positive photoresist
2. DRIE

Step 2: 2nd Silicon wafer
MASK 2:

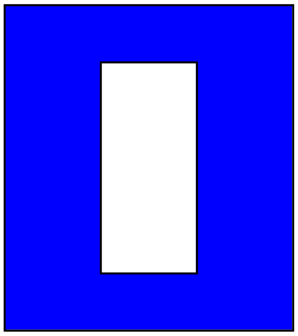


1.Positive photoresist
2. DRIE

Step 3: Fusion bond silicon wafers at >1000 C

Step 4:

MASK 3:

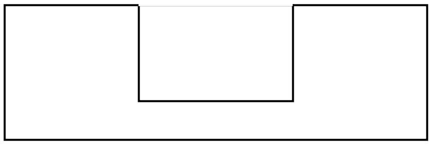


1. Apply Ti or Cromium
'glue' layer using mask
2. Apply Pt by evaporation

Step 5: Bond wafers to pyrex

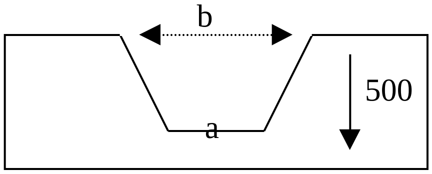
NOTE: It is not possible to bond the silicon wafers after depositing the catalyst as the high temperatures will lead to reactions of the catalyst metal with the silicon support and to evaporation of the metal catalyst which will contaminate the furnace and inhibit binding. Points were not deducted for schemes which had deposition before bonding since this was not explicitly explained in class.

b.



500 microns x 500 microns

with KOH: anisotropic etching



etching angle = 54.7 degrees

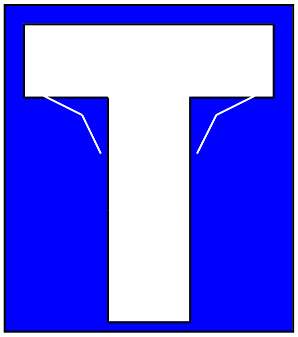
$\tan 54.7 = 500\,(2)/(b-a)$

cross section area must be equal: $500 \times 500 = 500\,(a+b)/2$ → $a+b=1000$ microns

$a=146$

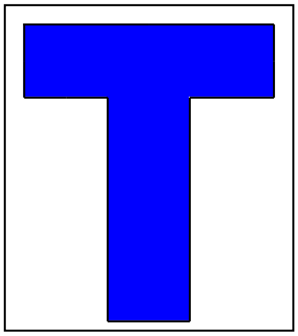
$b=854$

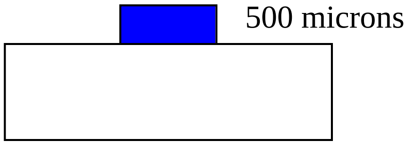
Corners may be undercut



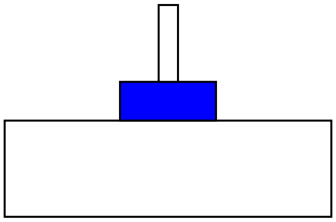
c. Use SU-8 negative resist photopolymer (high aspect ratio photoresist)

Step 2: Negative photoresist on silicon

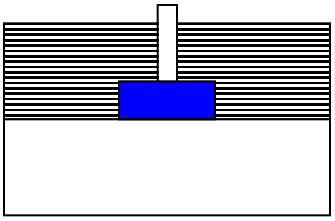




Step 3: Place posts on master for inlet and outlet ports



Step 4: Cast PDMS to 500 microns above photoresist



Step 5: Peel off PDMS
Step 6: Apply catalyst to pyrex by evaporation using T-shaped mask . Bond glass to PDMS
There are many ways this can be done, this is just one example.

d. $D=10^{-5}$ cm^2/s
The approximate evaluation of the extent of mixing can be described by:

Mixing length (l) = $(Dt)^{0.5}$

Assume the reactants are introduced in equal amounts with equal flow rates ($V_a = V_b$) then $t = L/v$ where L is the length of the channel (2 cm) and we want complete mixing so $l = W/2$ where W is the width of the channel. $W/2 = (DL/v)^{0.5}$

For these constraints, the fluid velocity required is 0.032 cm/s. However, we must also consider that once the reactants are mixed, they must also diffuse the depth of the channel to contact the catalytic surface. Therefore we have the additional constraint that the depth of the channel (H) = $(DL/v)^{0.5}$. The velocity calculated above must be quartered to meet our requirement of complete mixing and reaction at the outlet. V = 0.008 cm/s. This is VERY slow and not realistic from a yield vs. time consideration.

If the reactants were gases, the mixer would be much more effective since $D_{gas} \sim 10^{-1}$ cm^2/s, much higher than for liquids. Even for reasonable velocities, diffusion would be fast enough to achieve mixing. Using the equations above, v=320 cm/s.

Chemical limitations: Most organic solvents are incompatible with PDMS. Limited to aqueous reactions. Silicon/glass reactor can handle most solvents but will be damaged by highly basic solutions such as KOH or systems with Cl_2, HF etc…

(GRADING: 3pts for 1st diffusion calculation, 3pts for diffusion to catalyst, 1pt for statement about gas reaction, 1pt for statement about catalyst contact, 1pt for statement about silicon chemical limitations and 1pt for statement about PDMS chemical limitations.)

e. Answers will vary but should address the issues of poor mixing and low contact area with the catalyst.