

Pillar Density Modulation in a Semi-Packed MEMS Column



Ryan Chan

MEMS Lab, Virginia Tech



Masoud Agah

MEMS Lab, Virginia Tech

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Rundown

- Background information
- Breakdown of new design
- Experimental results
- Conclusion



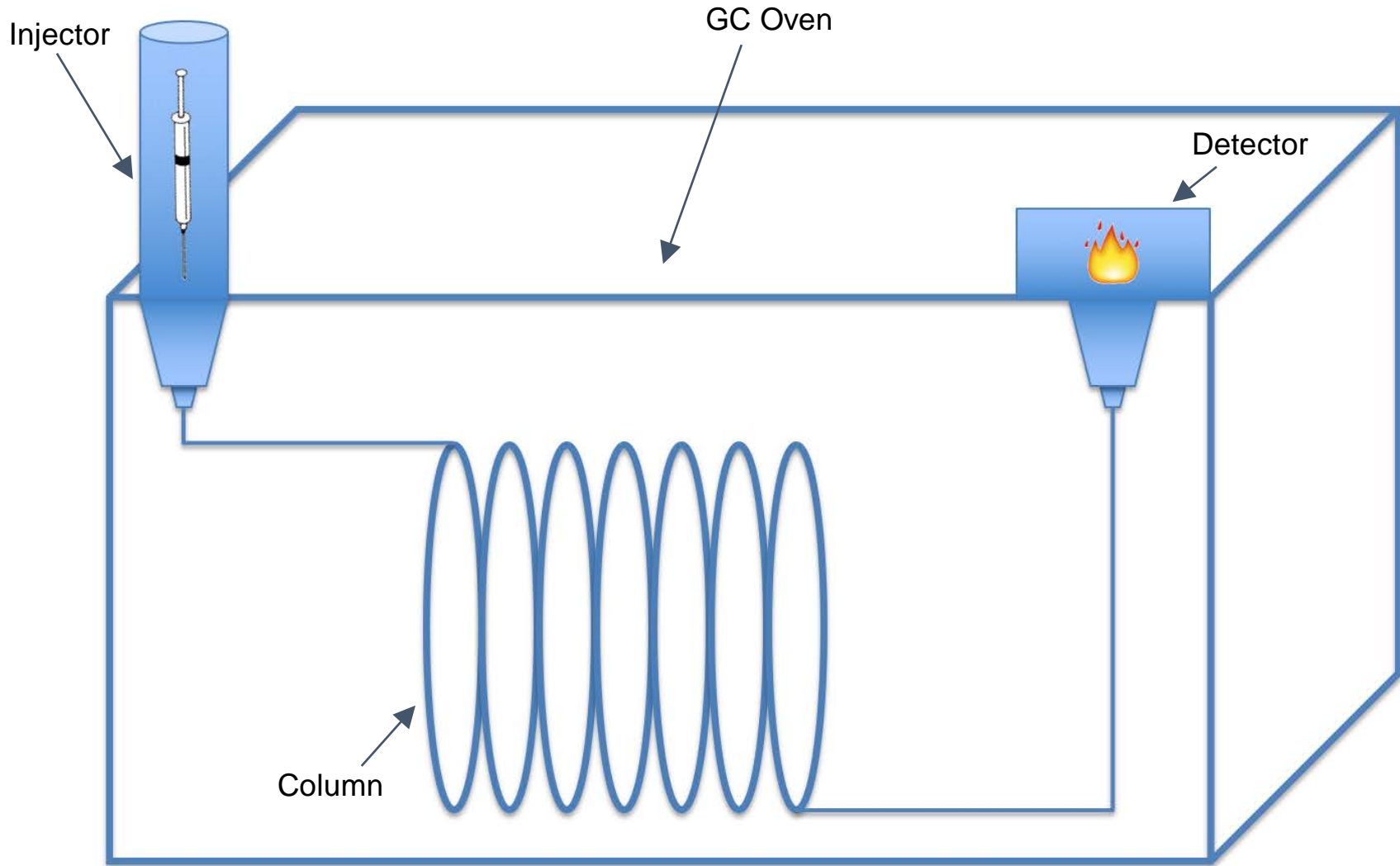
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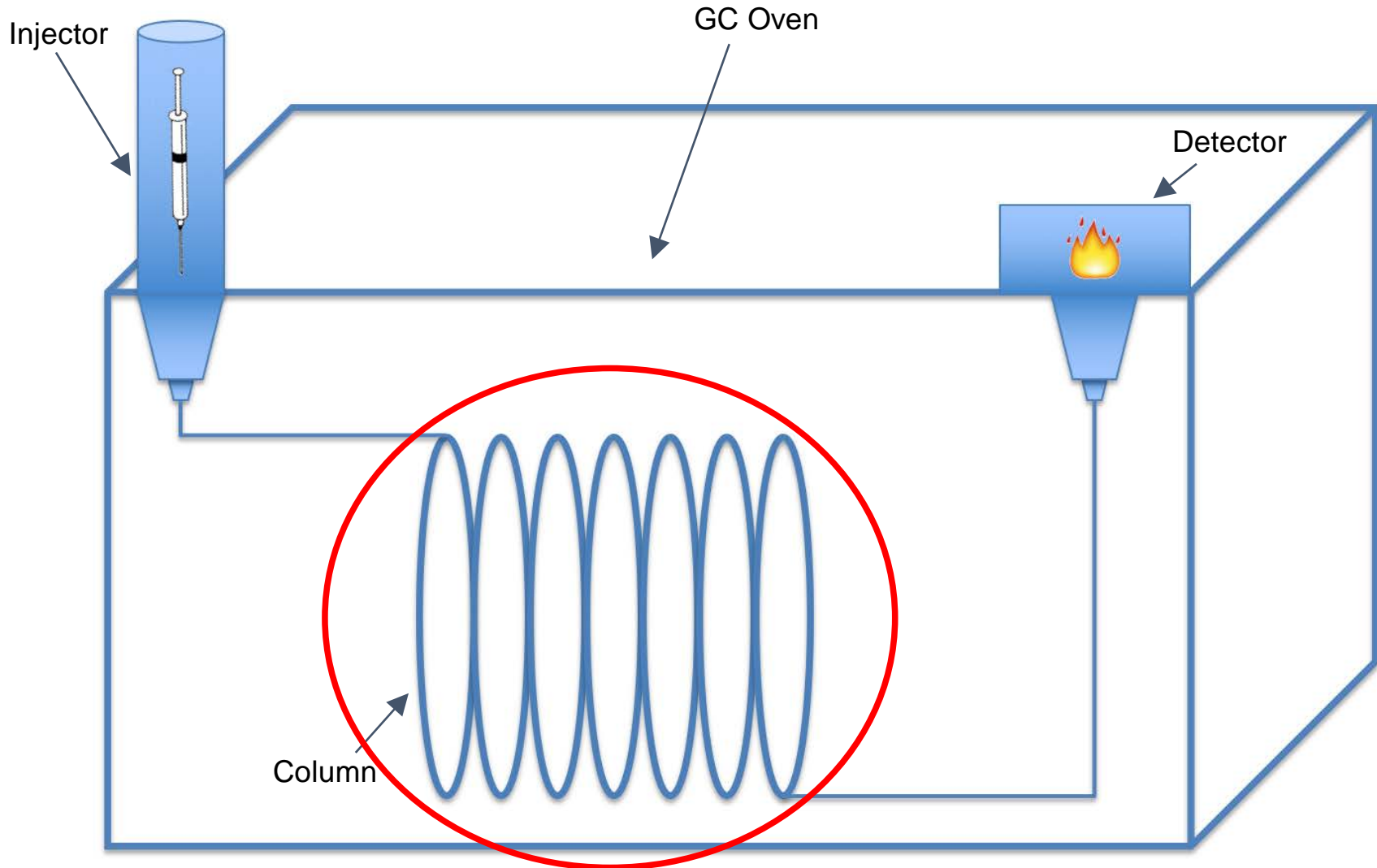
Why is gas chromatography important?

- Allows analyzation of individual analytes from a single sample
- Analysis of ambient environment in real time
 - Status of food
 - Medical applications

GC System

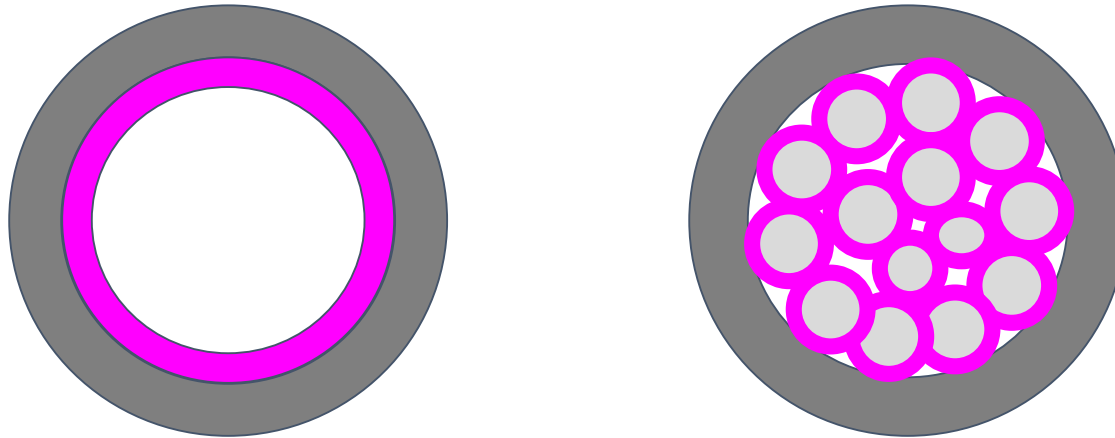


GC System



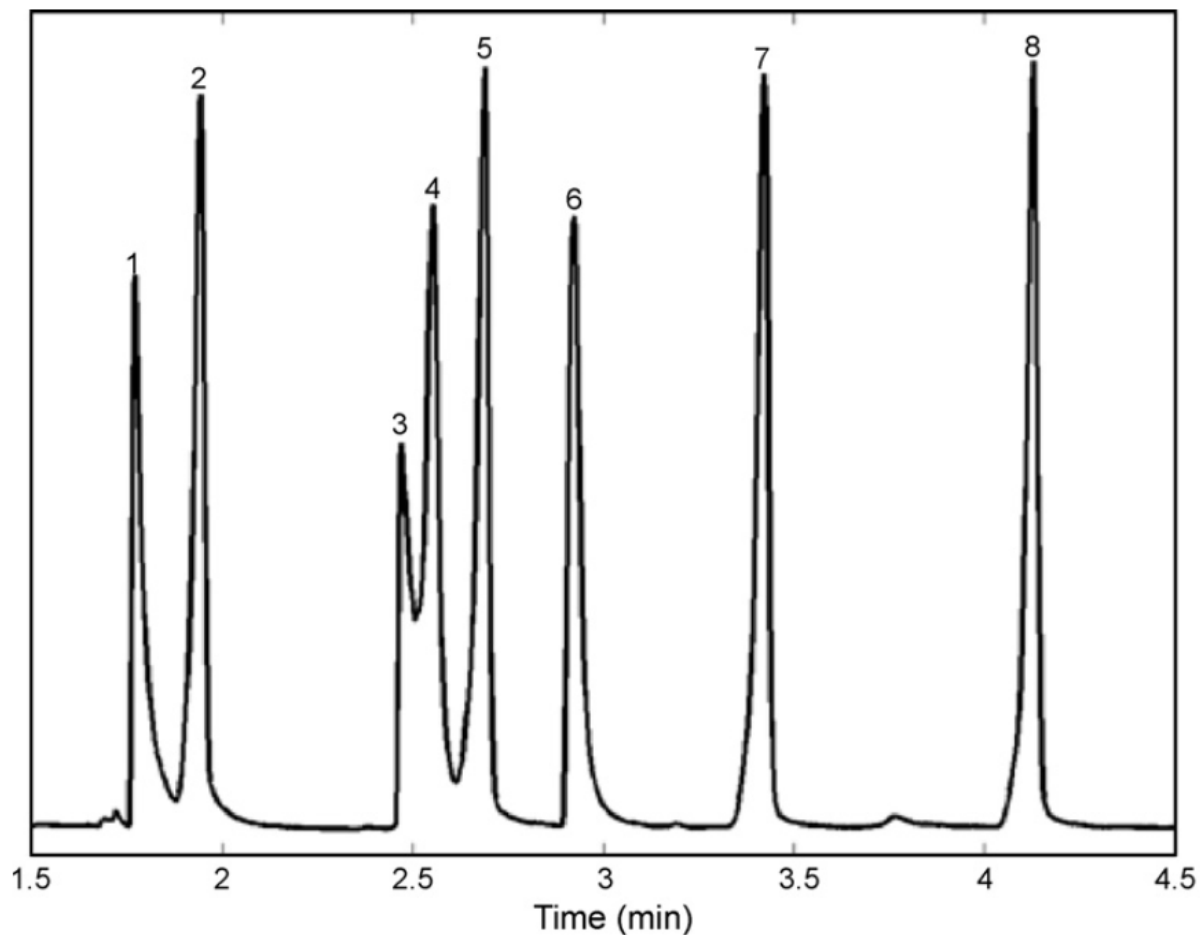
Column Characteristics

- Open vs. Packed



- Stationary Phase
 - Dictates the interaction between column and sample
 - Polarity
 - Film thickness

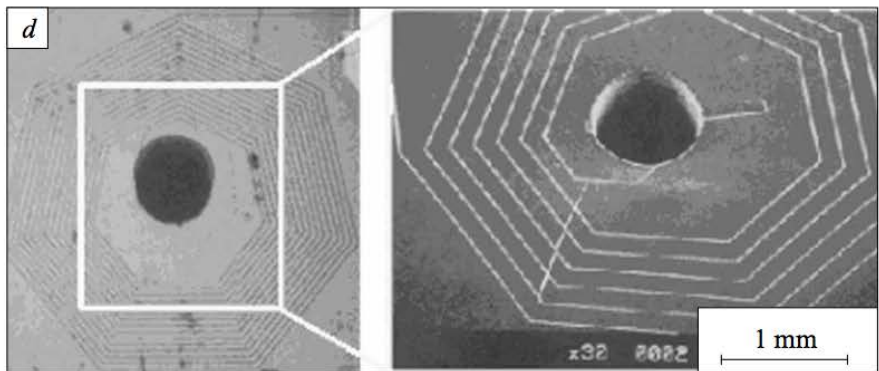
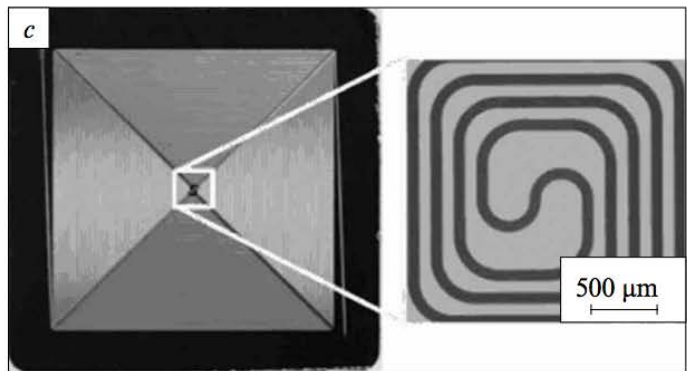
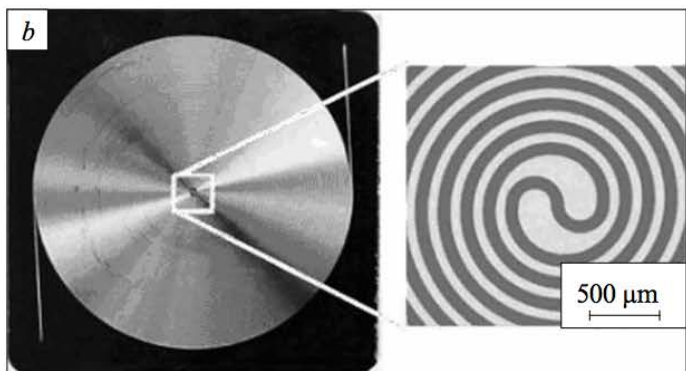
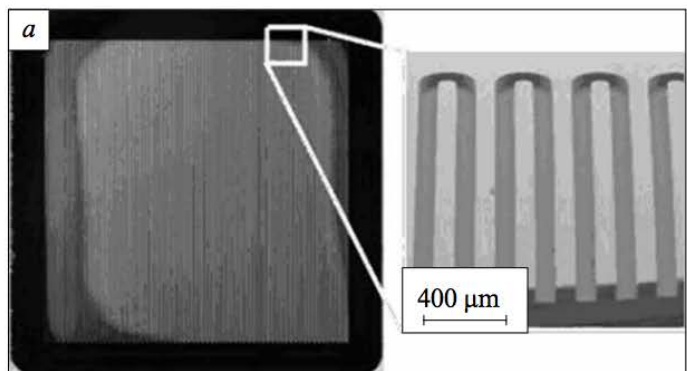
Separation Results



	Component
1	2-Octanone
2	Decane
3	1-Octanol
4	2,6-Dimethylphenol
5	Undecane
6	2,6-Dimethylaniline
7	Dodecane
8	Tridecane

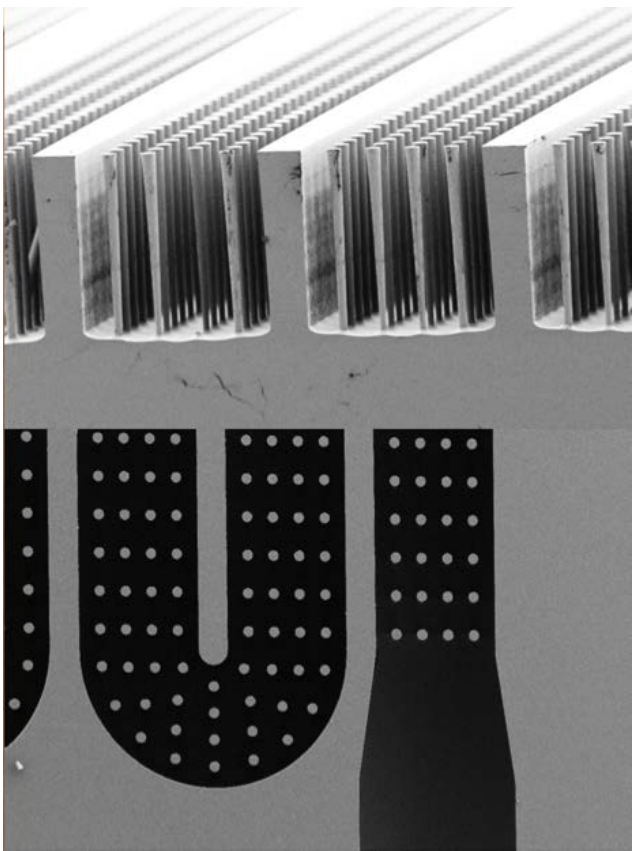
Ali, Syed, Mehdi Ashraf-Khorassani, Larry T. Taylor, and Masoud Agah. "MEMS-Based Semi-Packed Gas Chromatography Columns." *Sensors and Actuators B: Chemical* 141, no. 1 (August 18, 2009): 309–15. doi:10.1016/j.snb.2009.06.022.

MEMS GC Columns



Sidelnikov, Vladimir N., Olga A. Nikolaeva, Igor A. Platonov, and Valentin N. Parmon. "Gas Chromatography of the Future: Columns Whose Time Has Come." *Russian Chemical Reviews* 85, no. 10 (October 2016): 1033. doi:10.1070/RCR4627.

Different Column Variations



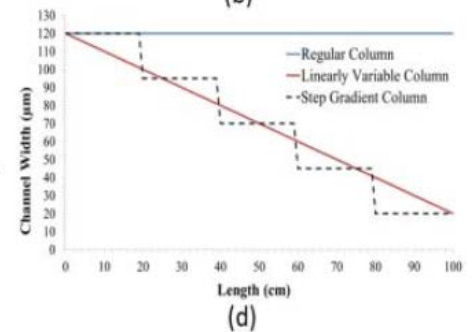
(a)



(b)

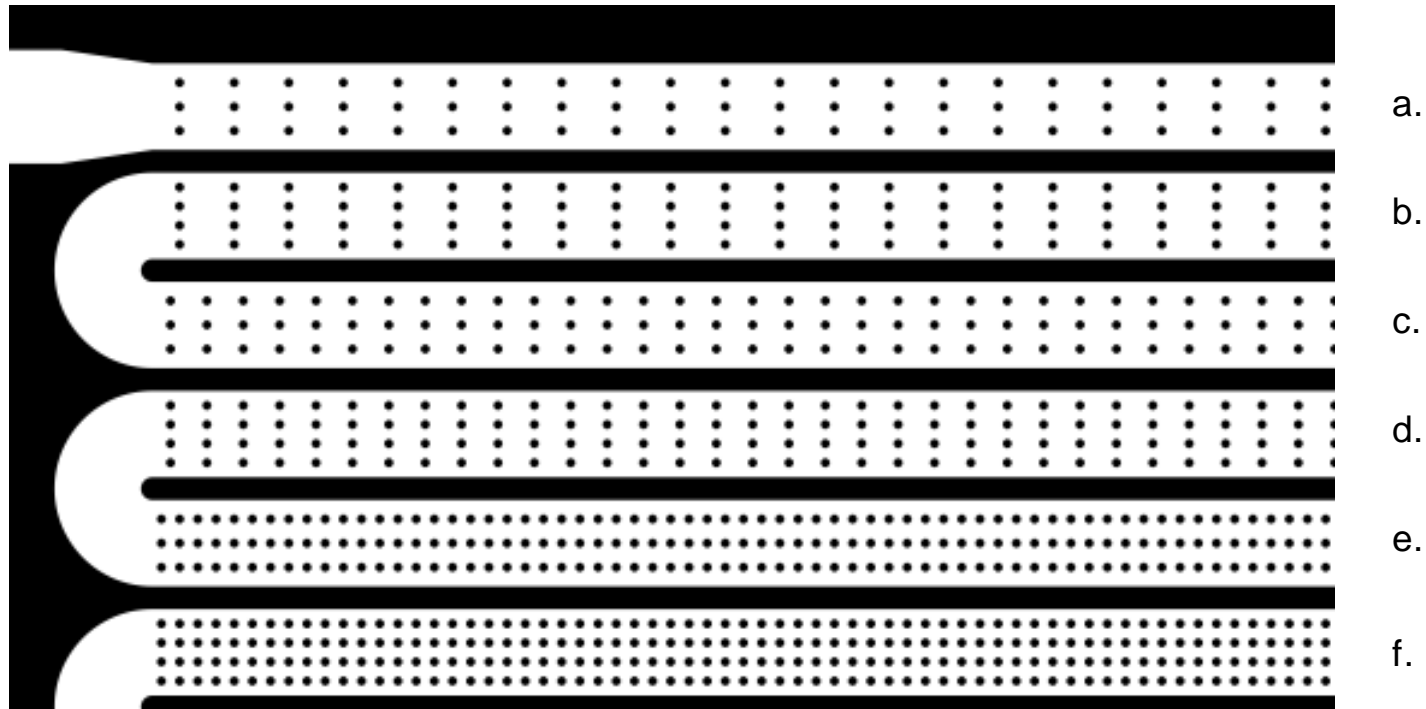


(c)



Shakeel, H., D. Wang, J. R. Heflin, and M. Agah. "Width-Modulated Microfluidic Columns for Gas Separations." *IEEE Sensors Journal* 14, no. 10 (October 2014): 3352–57. doi:10.1109/JSEN.2014.2326593.

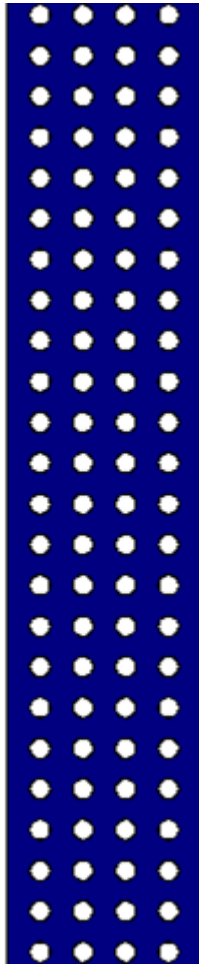
Pillar Density Modulation



- a. 3 pillars, 120 μ m pitch
- b. 4 pillars, 120 μ m pitch
- c. 3 pillars, 80 μ m pitch
- d. 4 pillars, 80 μ m pitch
- e. 3 pillars, 40 μ m pitch
- f. 4 pillars, 40 μ m pitch

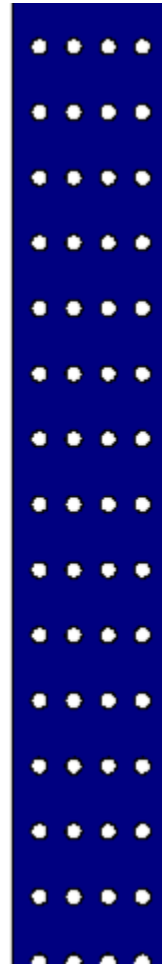
Simulations of pillar pitches

a.



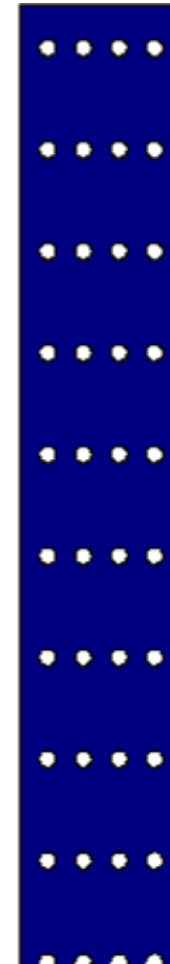
40µm pitch

b.



80µm pitch

c.



120µm pitch



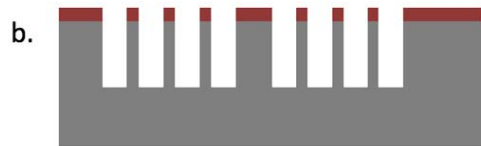
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Fabrication Process Flow



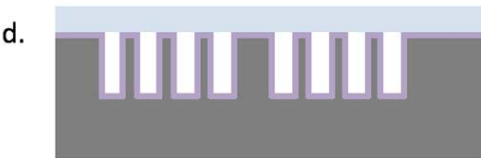
a. Spin photoresist and perform photolithography



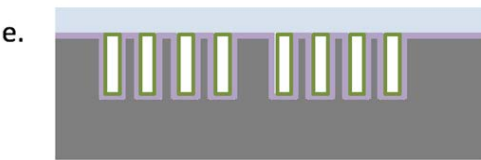
a. Etch the channel for the column utilizing deep reactive ion etching (DRIE)



a. Grow thin film of alumina using atomic layer deposition (ALD)



a. Bond Pyrex wafer to silicon substrate to create airtight seal



a. Functionalize column with stationary phase

■ Silicon ■ Alumina ■ Stationary phase
■ PR 9260 ■ Pyrex

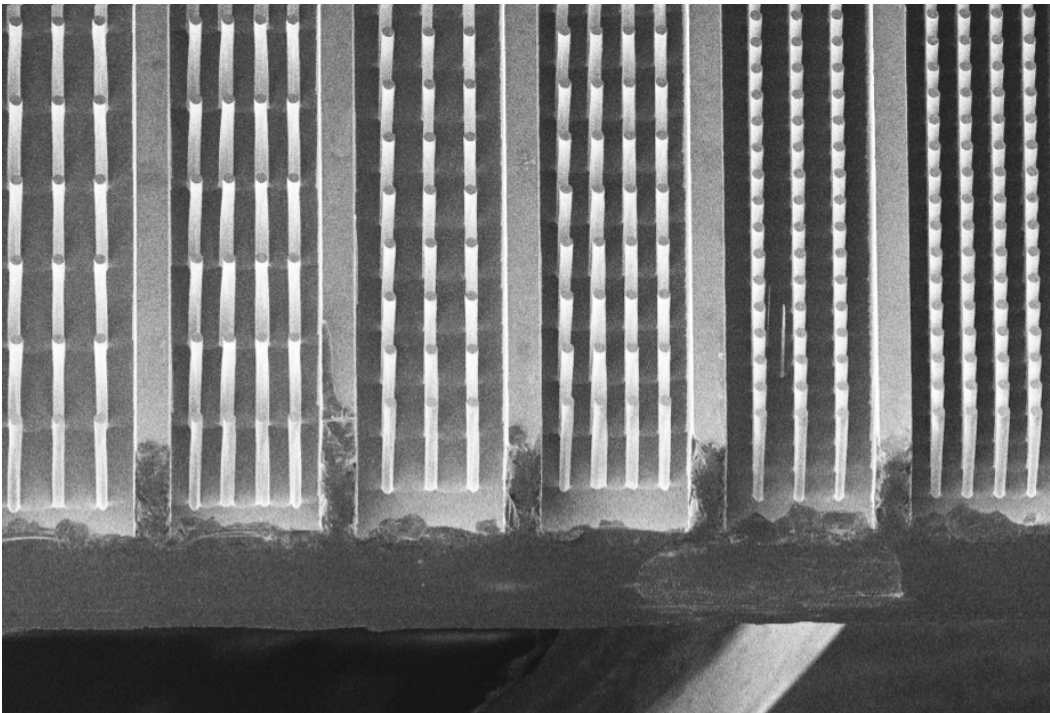


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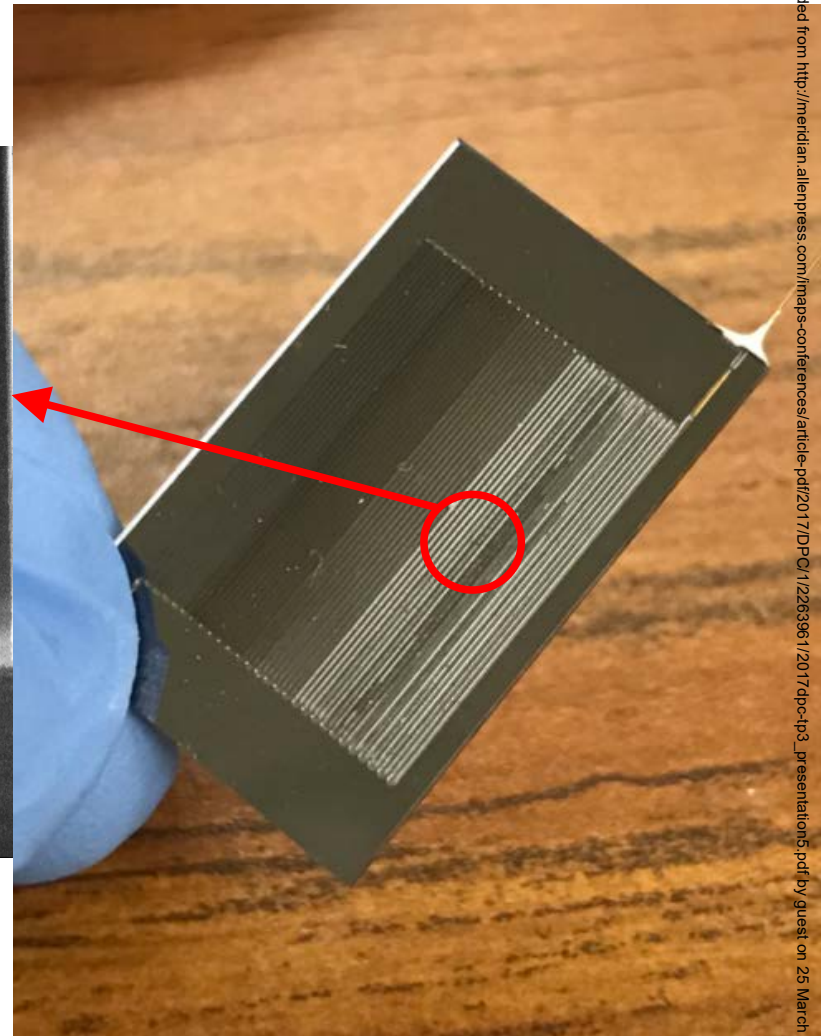
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Images of Device

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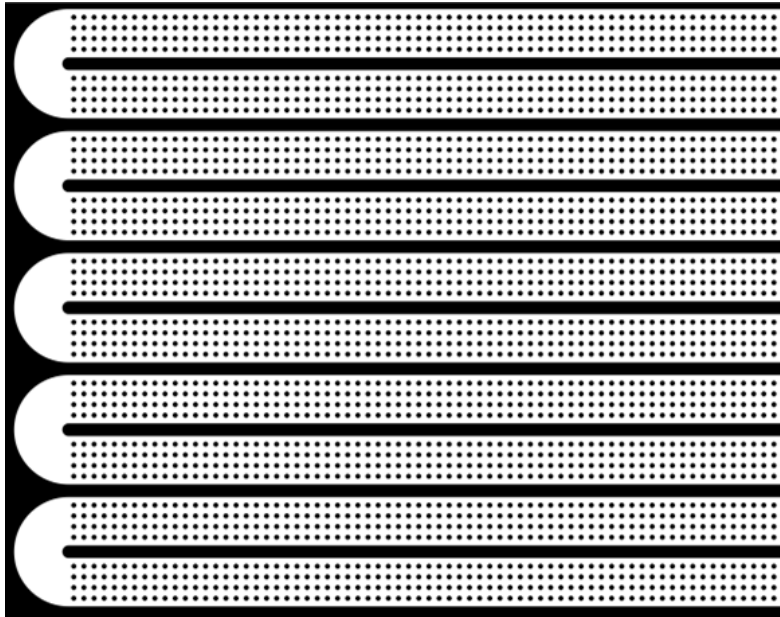
SEM image of uncoated column



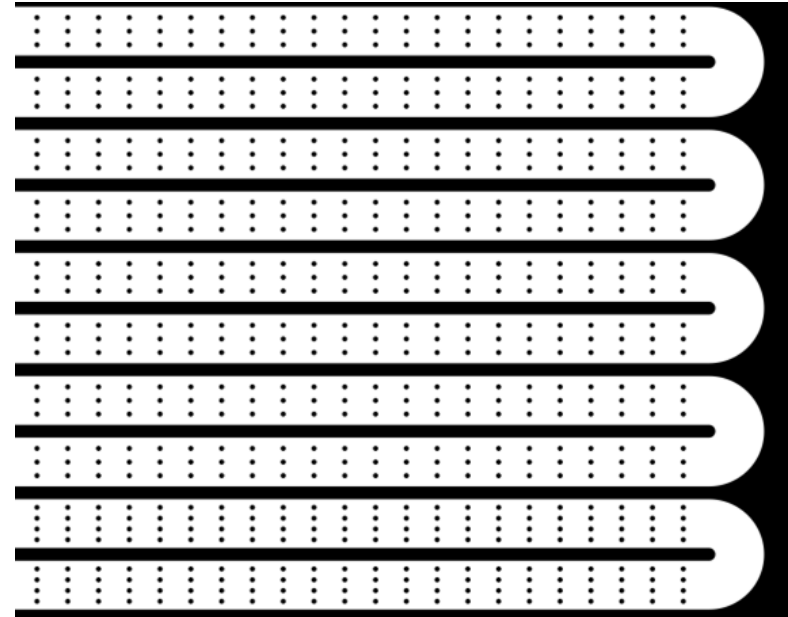
Optical image of finished device

Control Designs

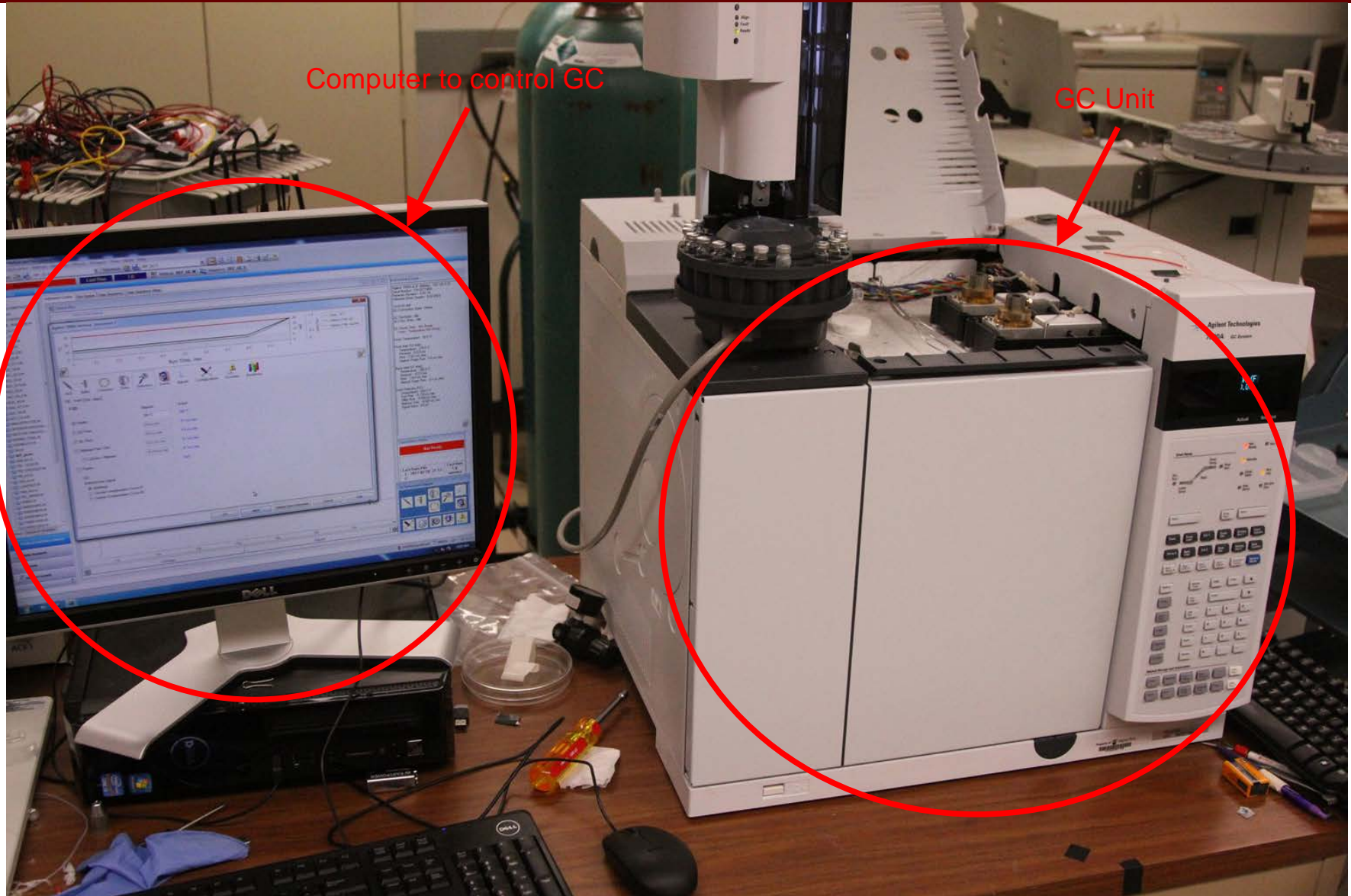
Max Density



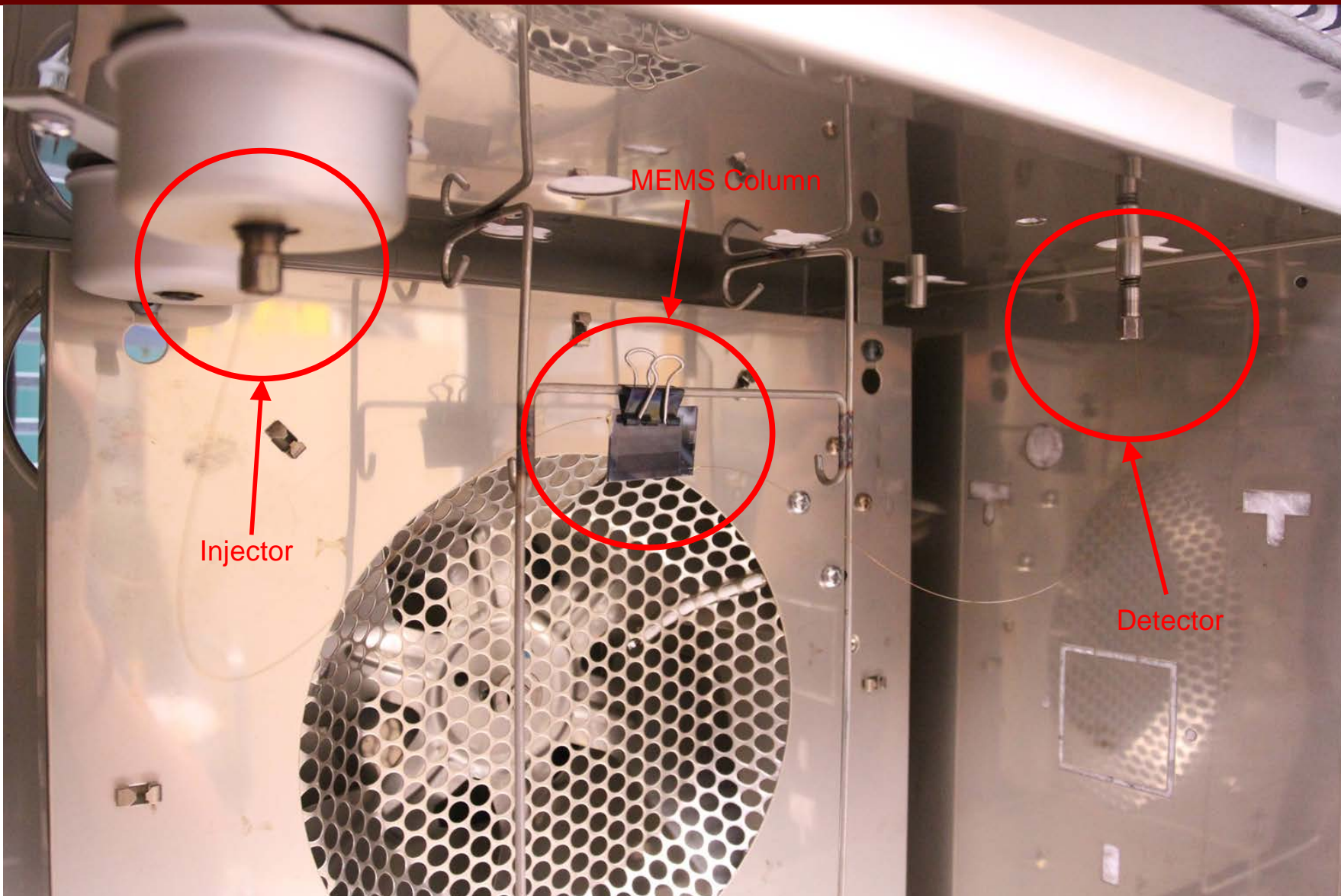
Minimum Density



Experimental Setup



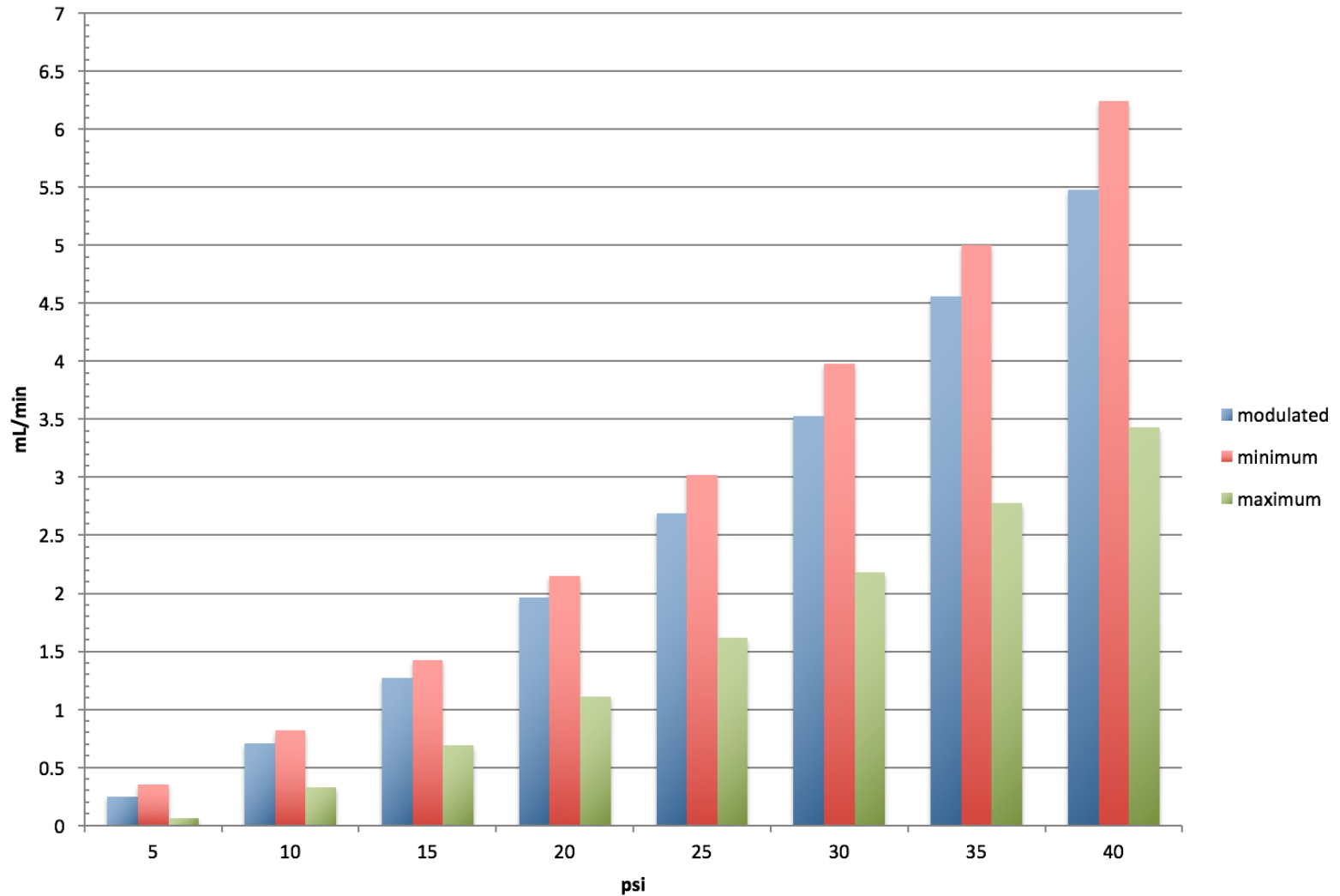
Experimental Setup



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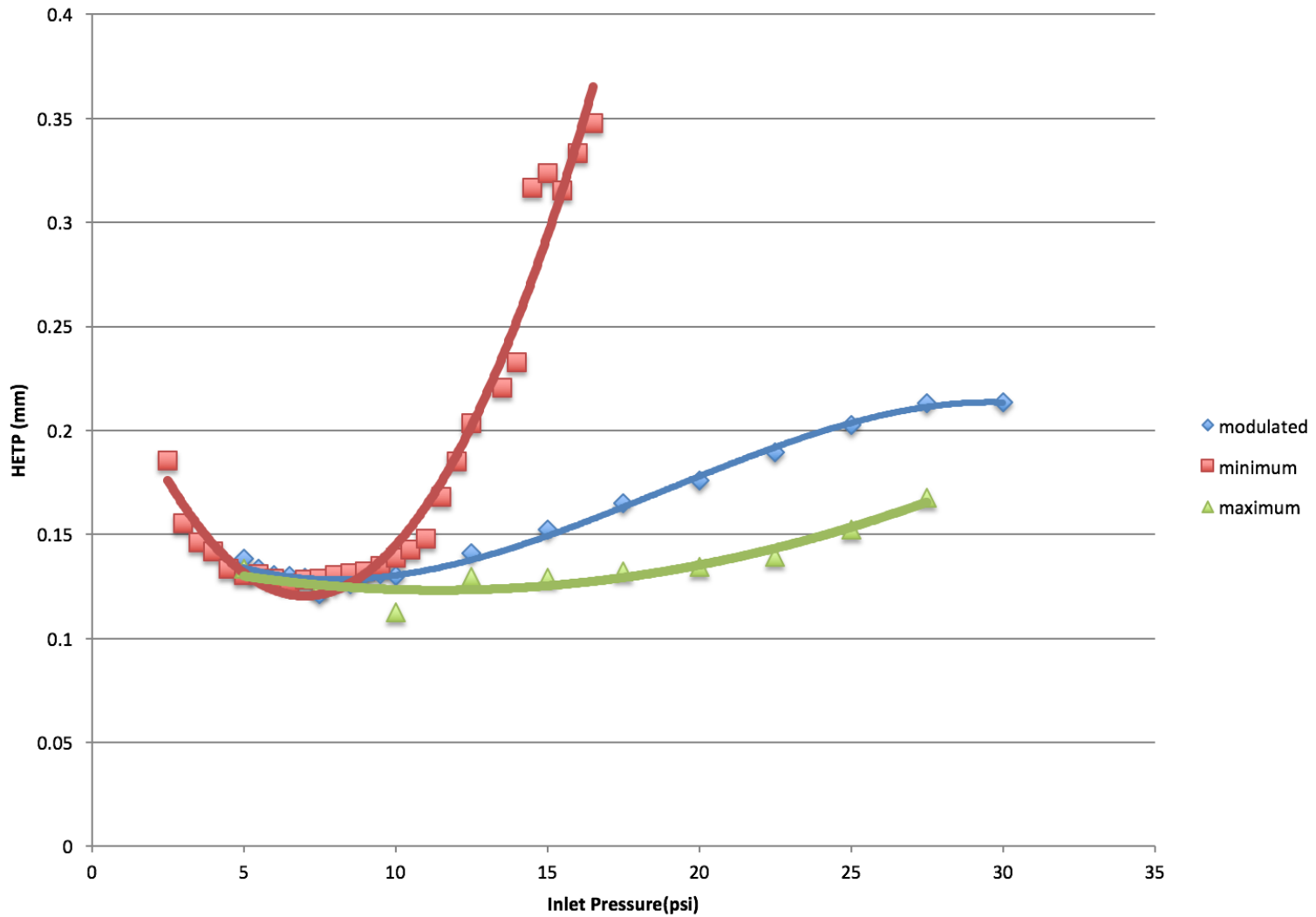


Flow Rate through Columns



Results

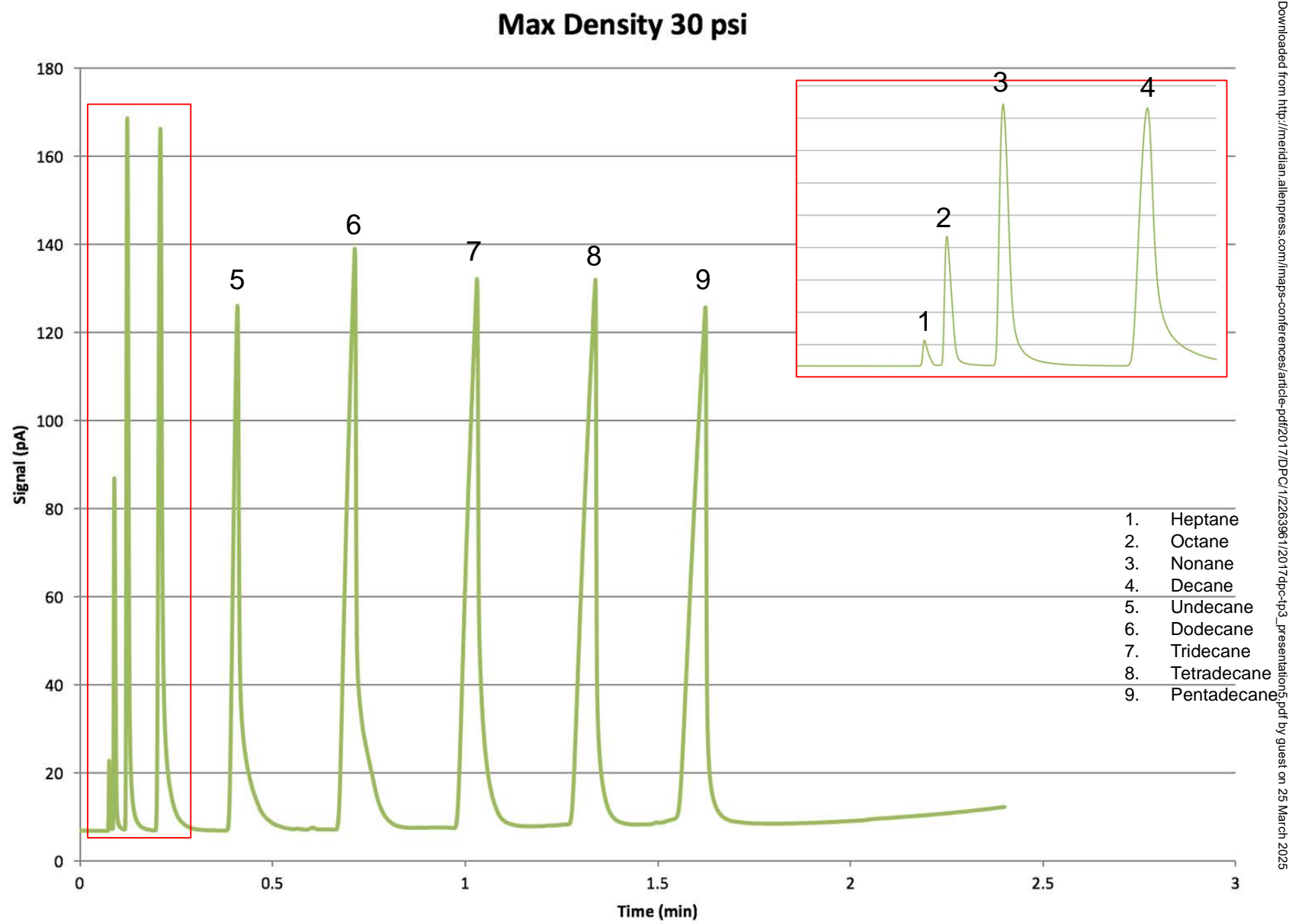
Height Equivalent to a Theoretical Plate (HETP) Graph



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Results

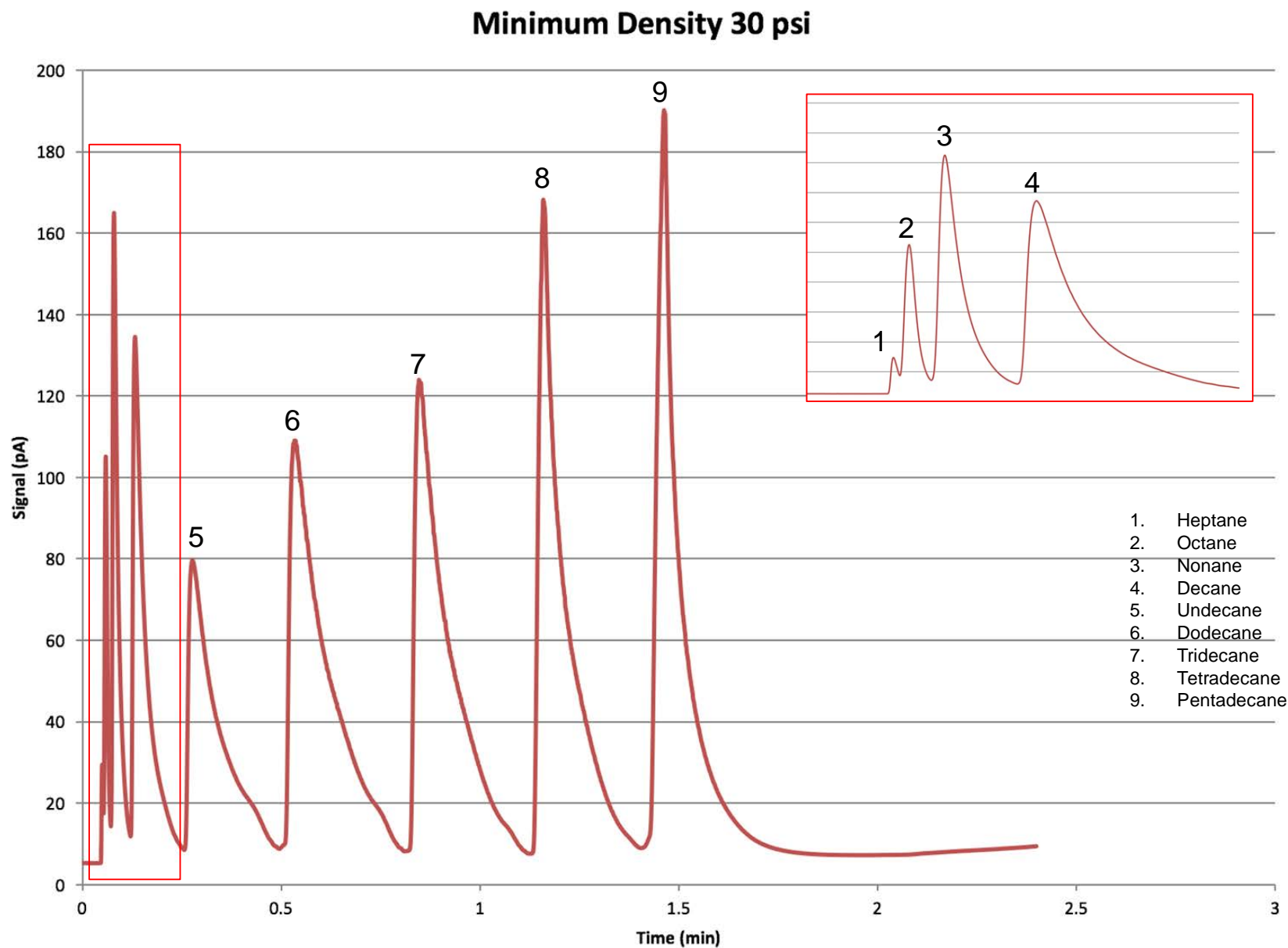


- 1. Heptane
- 2. Octane
- 3. Nonane
- 4. Decane
- 5. Undecane
- 6. Dodecane
- 7. Tridecane
- 8. Tetradecane
- 9. Pentadecane

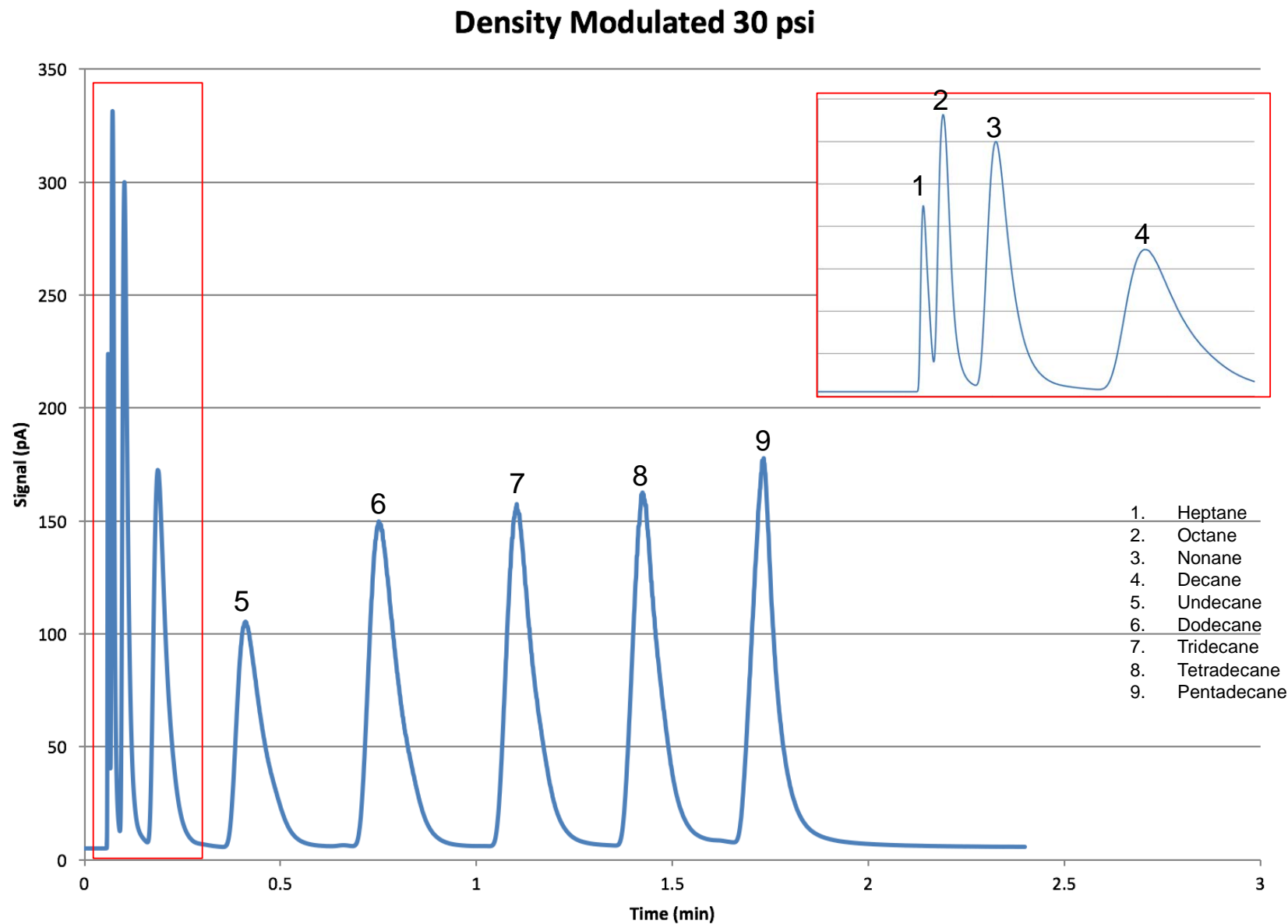
30 psi inlet pressure with temperature programming of 30-120C at 40C/min



Results



Results



Conclusions

- Density Modulated design has a lower pressure drop across the column than the maximum design
- However, it does not lose out on separation efficiency like the minimum design (HETP)
- Separation results show that further optimization is possible
- Could lead to improvements in high speed separations (less than a minute)