Semiconductor Sensors:

Ch6: Gas Sensors cont.

Electronic Nose


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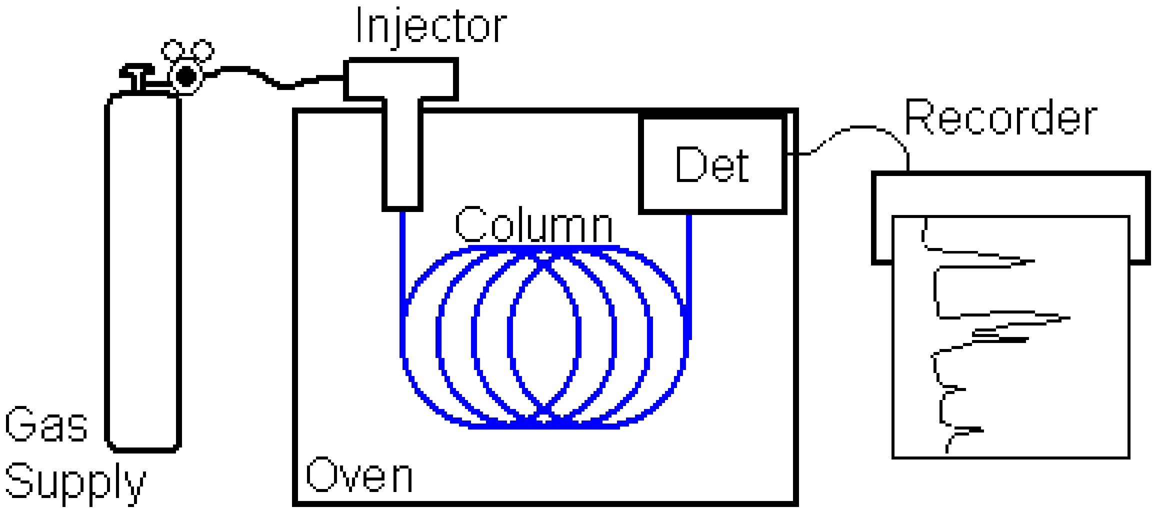
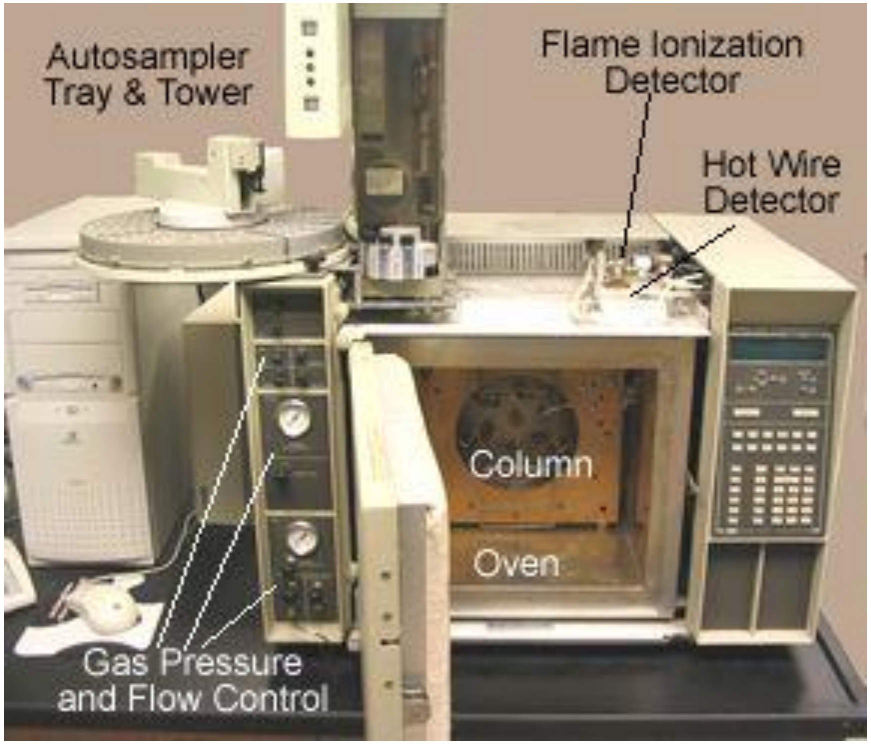
The human nose has been used as an analytical tool in many industries to measure the quality of food, drinks, perfumes and also cosmetic and chemical products.
For this reason, gas chromatography and mass spectrometry have been employed to aid human panels to assess the quality of products through odour evaluation and identification and also to obtain more consistent results. However, these assistive techniques are not portable, they tend to be expensive and their performance is relatively slow.

E-nose systems utilize an array of sensors to give a fingerprint response to a given odour, and pattern recognition software then performs odour identification and discrimination. The e-nose is a cost-effective solution to the problems associated with sensory panels and with chromatographic and mass-spectrometric techniques and can accommodate real time performance in the field when implemented in portable form.

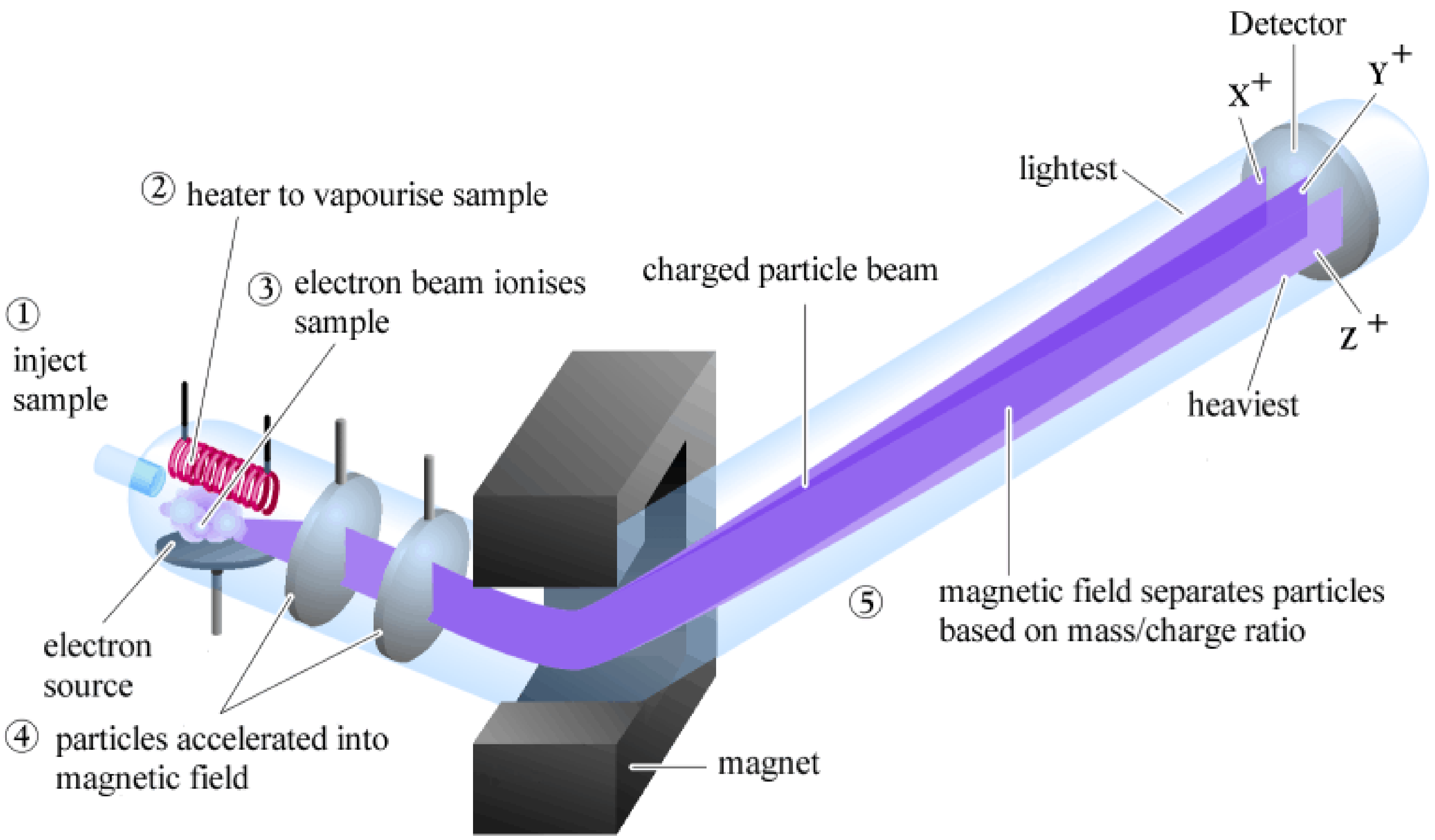
Arshak, K., et al. "A review of gas sensors employed in electronic nose applications.“ *Sensor review* 24.2 (2004): 181-198.

سیستم طیف سنجی گازی





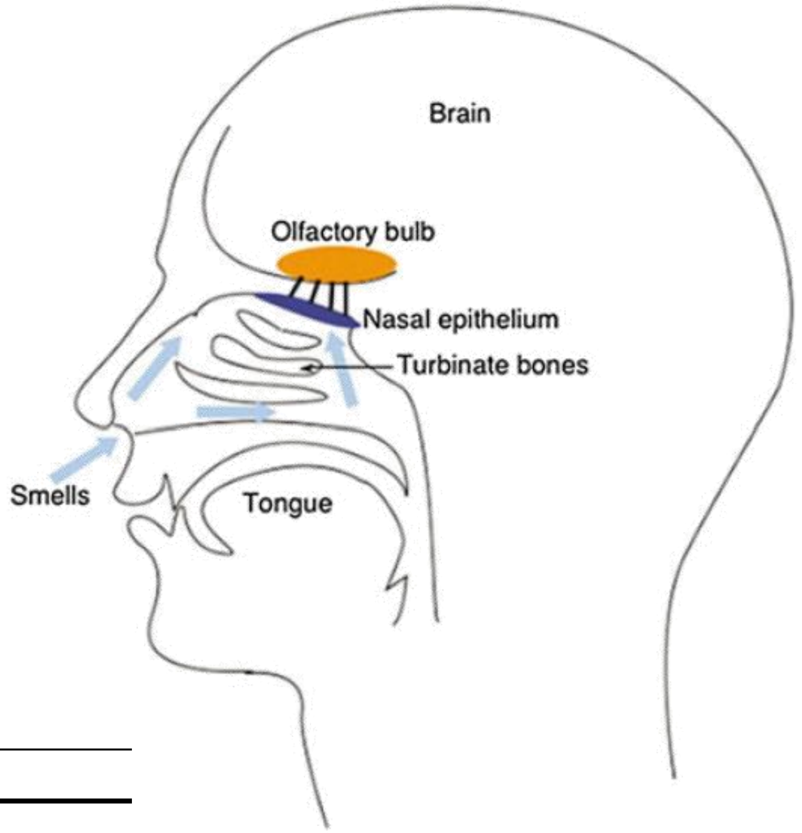
سیستم طیف سنجی جرمی



http://www.chem.ucalgary.ca/courses/351/Carey5th/Ch13/ch13-ms.html

The fundamental processes that must occur for a mammalian nose to detect and identify an odor can be summarized as follows:

1. Sniffing
2. reception and binding
3. stimulus
4. transmission
5. recognition
6. action
7. cleansing

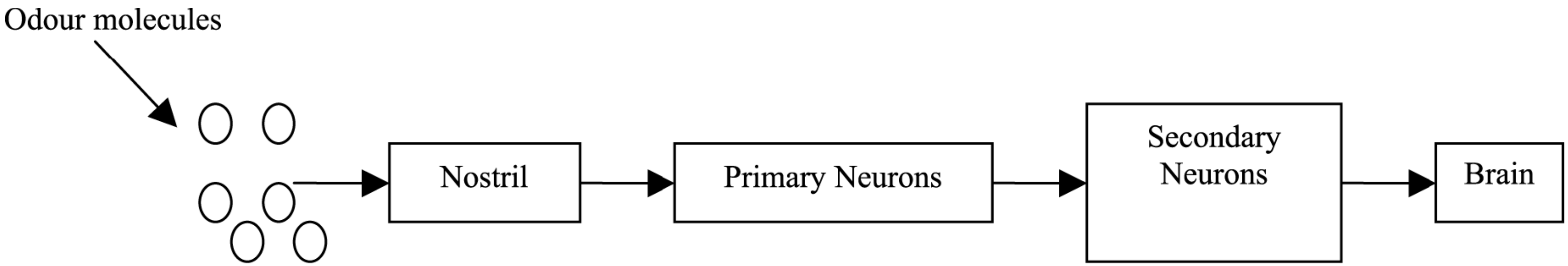


Primary odorant

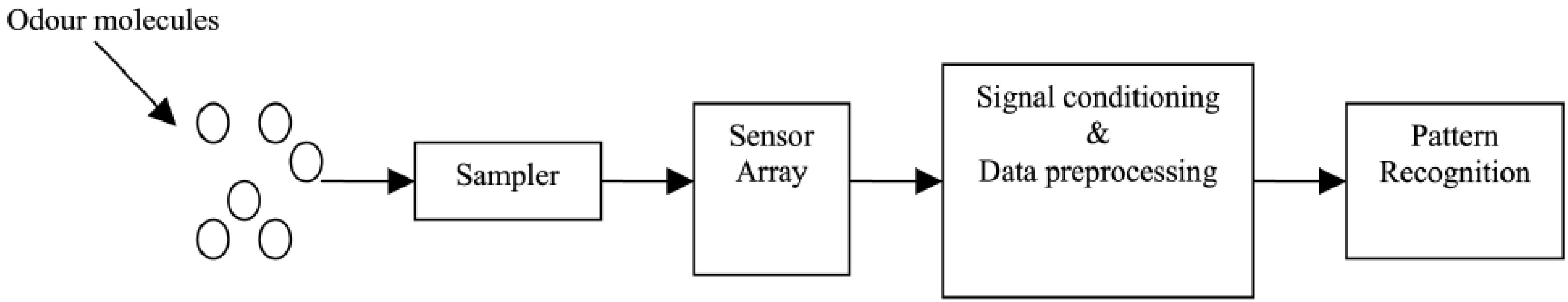
Odor	Example
Camphoric	Mothballs
Musky	Perfume/Aftershave
Roses	Floral
Peppermint	Mint gum
Ethereal	Dry cleaning fluid
Pungent	Vinegar
Putrid	Rotten Eggs

Patel, Himanshu K. *The electronic nose: artificial olfaction technology*. Springer, 2016.

بینی انسان و بینی الکترونیکی



Mammalian olfaction system

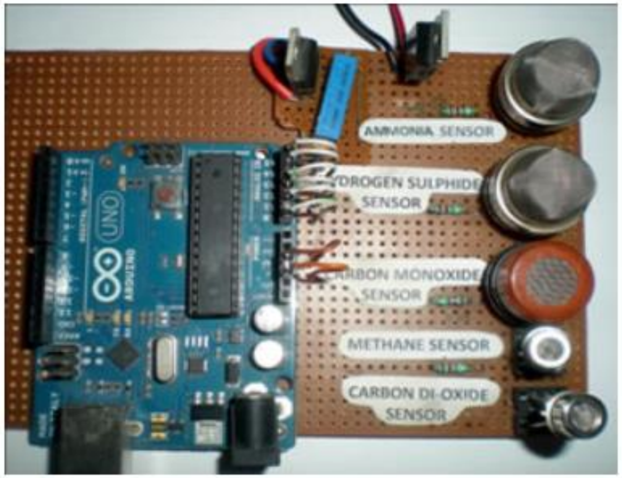


Electronic nose system

Arshak, K., et al. "A review of gas sensors employed in electronic nose applications.“ *Sensor review* 24.2 (2004): 181-198.

روشهای استفاده از حسگرهای گاز در بینی الکترونیکی

۱- آرایه واقعی



Lab scale design of portable gas mixture analysis system with Sensor array

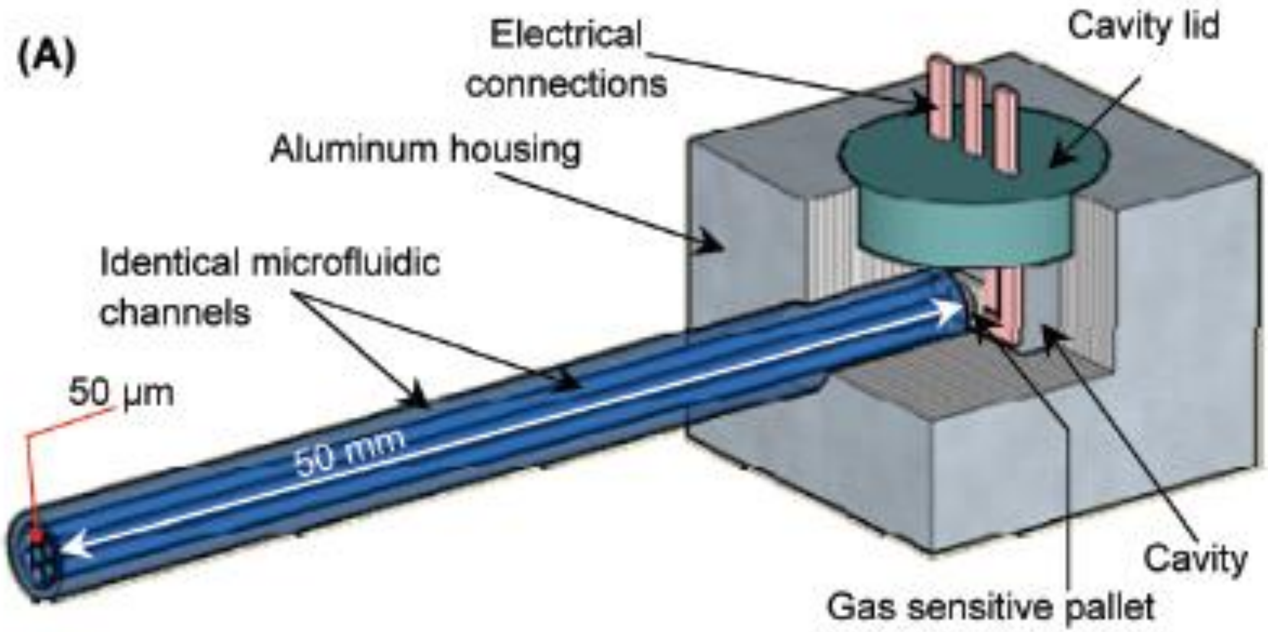
http://dst.gov.in/instrumentation-development-programme

عیب: رانش غیر همسان حسگرها به مرور زمان

۲- استفاده از یک حسگر با مسیر نفوذ گاز

۳- استفاده از یک حسگر با دماهای سطح مختلف (آرایه مجازی با روش دمایی)

بینی الکترونیکی- نوع ۲ (استفاده از یک حسگر با مسیر نفوذ گاز)



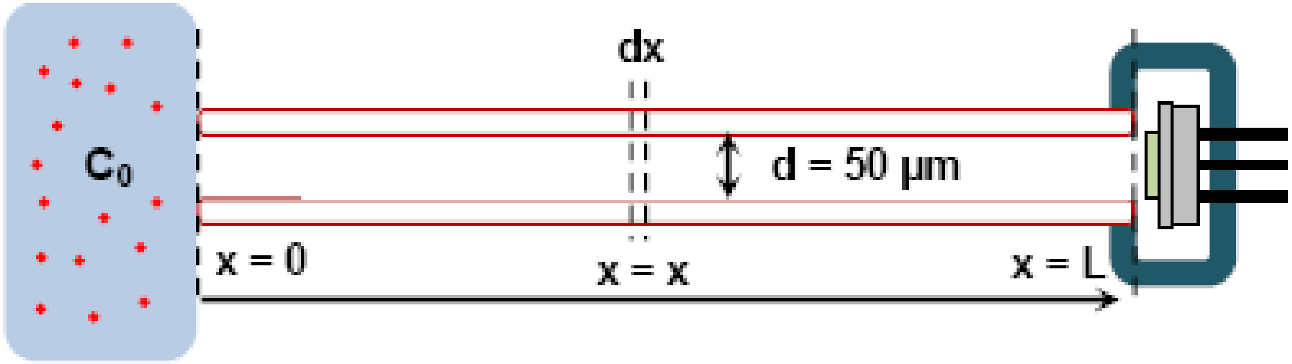
Hossein-Babaei, Faramarz, and Vahid Ghafarinia. "Gas analysis by monitoring molecular diffusion in a microfluidic channel." *Analytical chemistry* (2010).

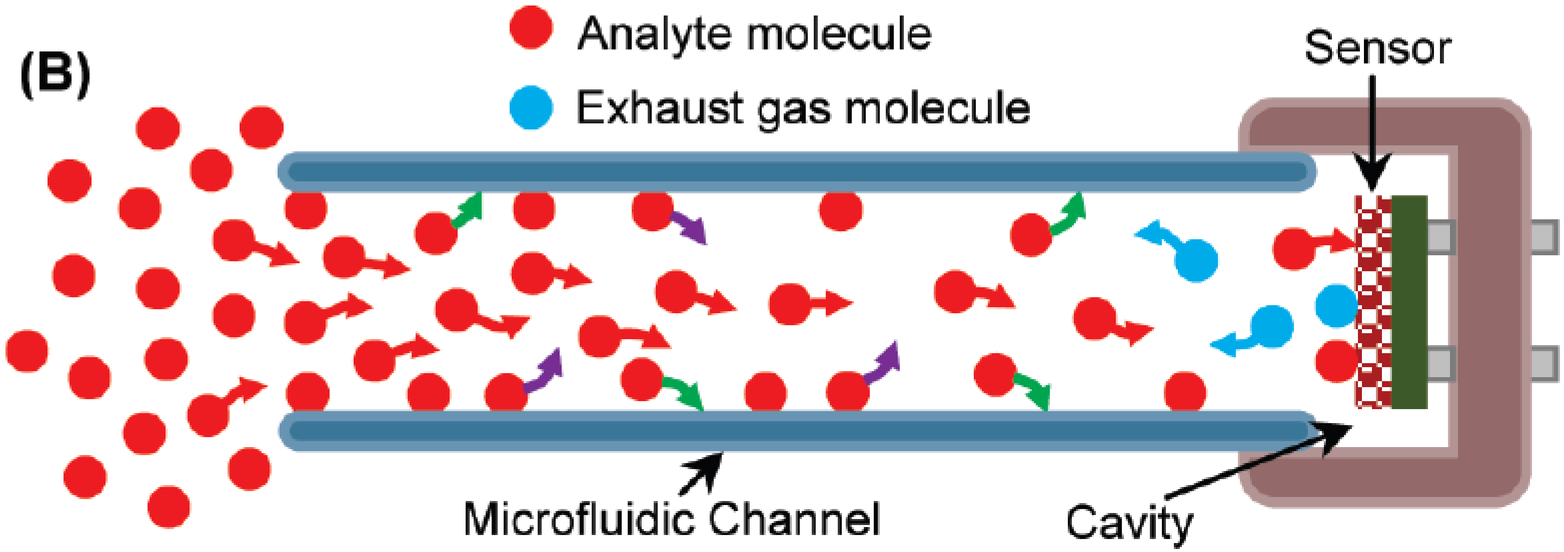
بینی الکترونیکی- نوع ۲ (استفاده از یک حسگر با مسیر نفوذ گاز)

In a microfluidic channel, by definition in the 1 mm to 1 μm diameter range, the only processes of significance at isothermal and isobar conditions are the concentration gradient caused molecular diffusion and the molecular interactions with the channel walls. Then, *C(x,t)* is determined by the following “diffusion-physisorption equation”:

$$\frac{\partial C(x,t)}{\partial t} = D\frac{\partial^2 C(x,t)}{\partial x^2} - \frac{\partial C_S(x,t)}{\partial t}$$

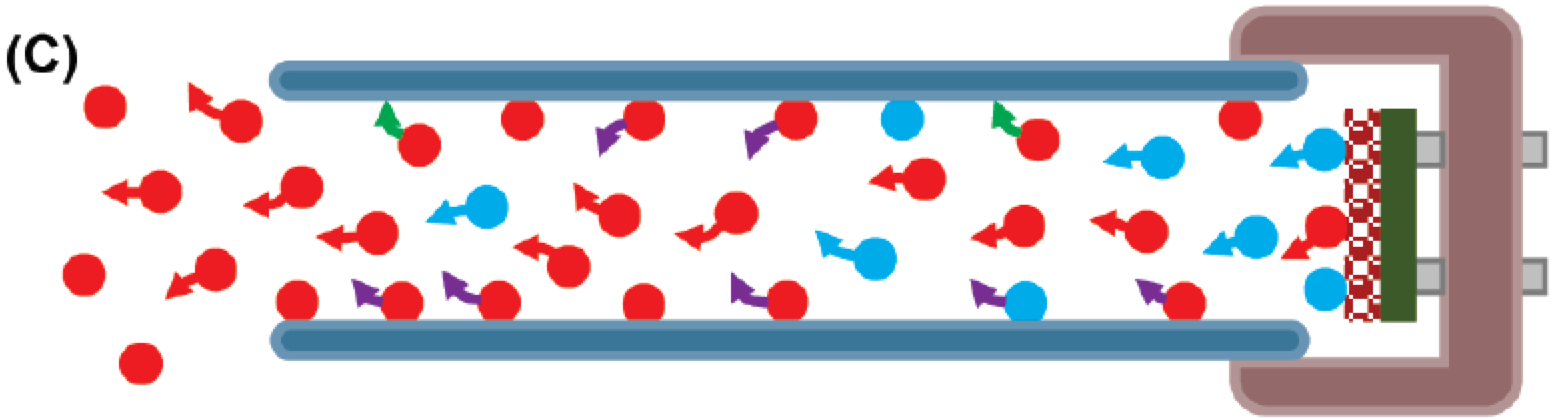
wherein, D is the diffusivity of the target molecule (TM) in the background gas, and $C_S(x, t)$ is the amount of TMs physisorbed to the channel wall per unit volume of the channel.



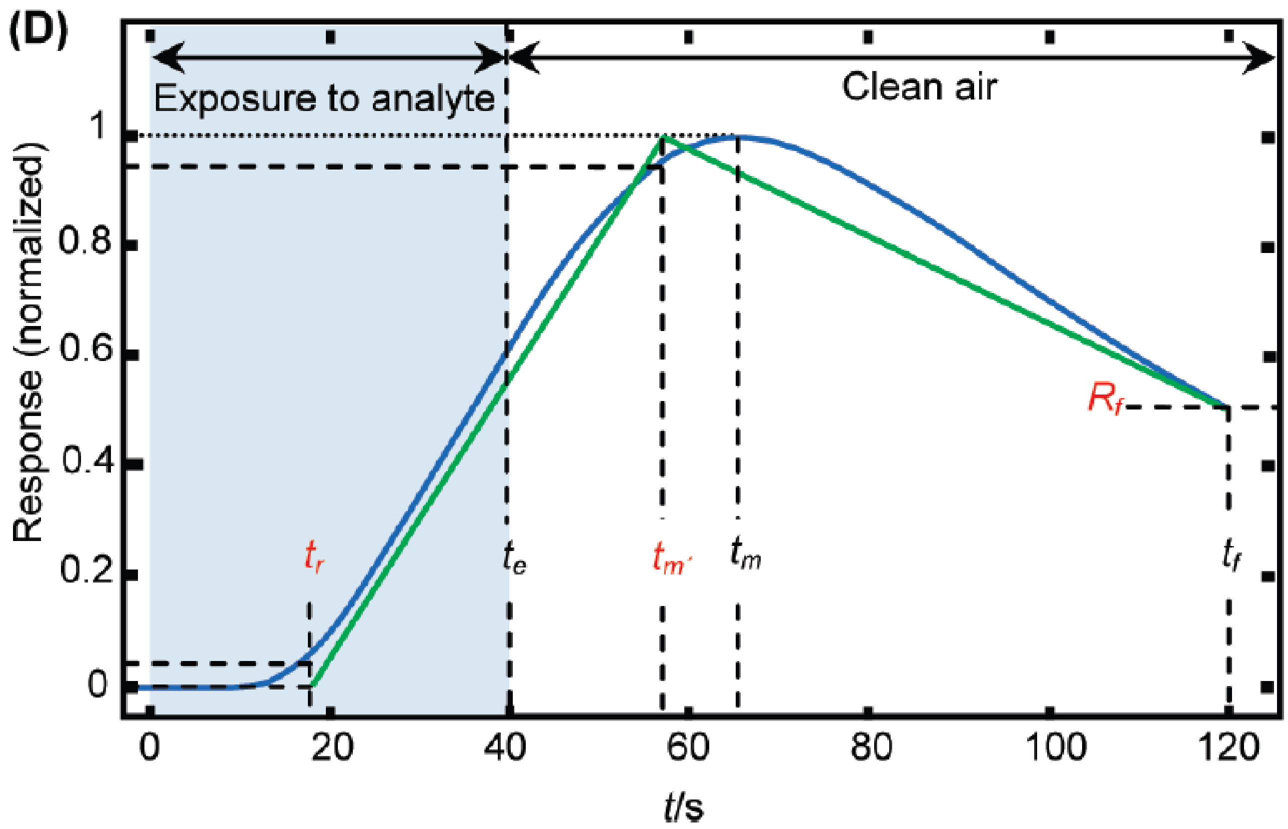


Analyte diffusion along one channel. Physisorption to the walls reduces the effective diffusion rate. The red, green, violet, and blue arrows illustrate the diffuse-in, physisorption, desorption, and diffuse out processes, respectively.

Hossein-Babaei, Faramarz, and Vahid Ghafarinia. "Gas analysis by monitoring molecular diffusion in a microfluidic channel." *Analytical chemistry* (2010).

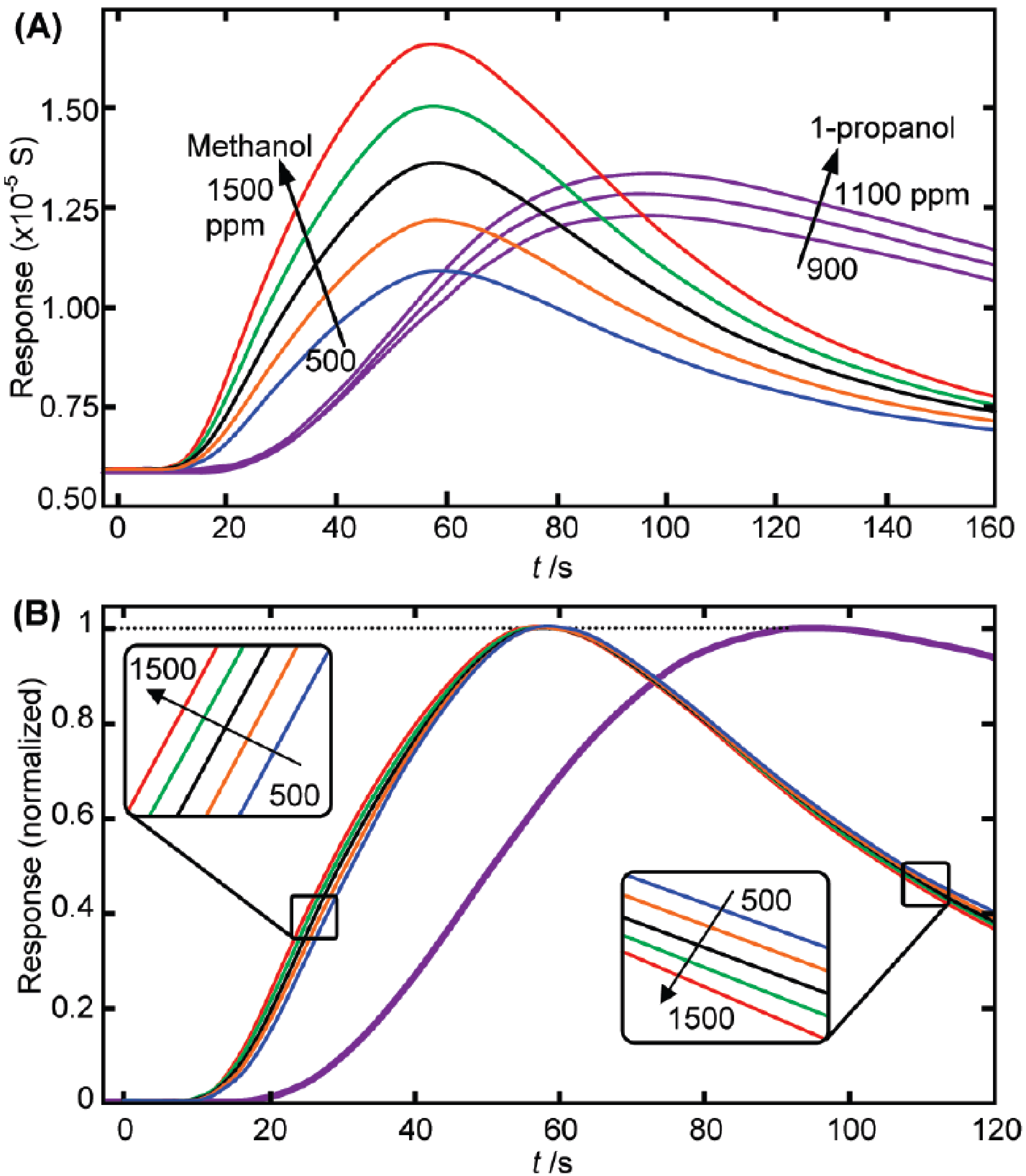


The same as in part B when the channel is reconnected to the clean air reservoir. The pace of analyte depletion is determined by the desorption rate of the molecules and its diffusivity in air.



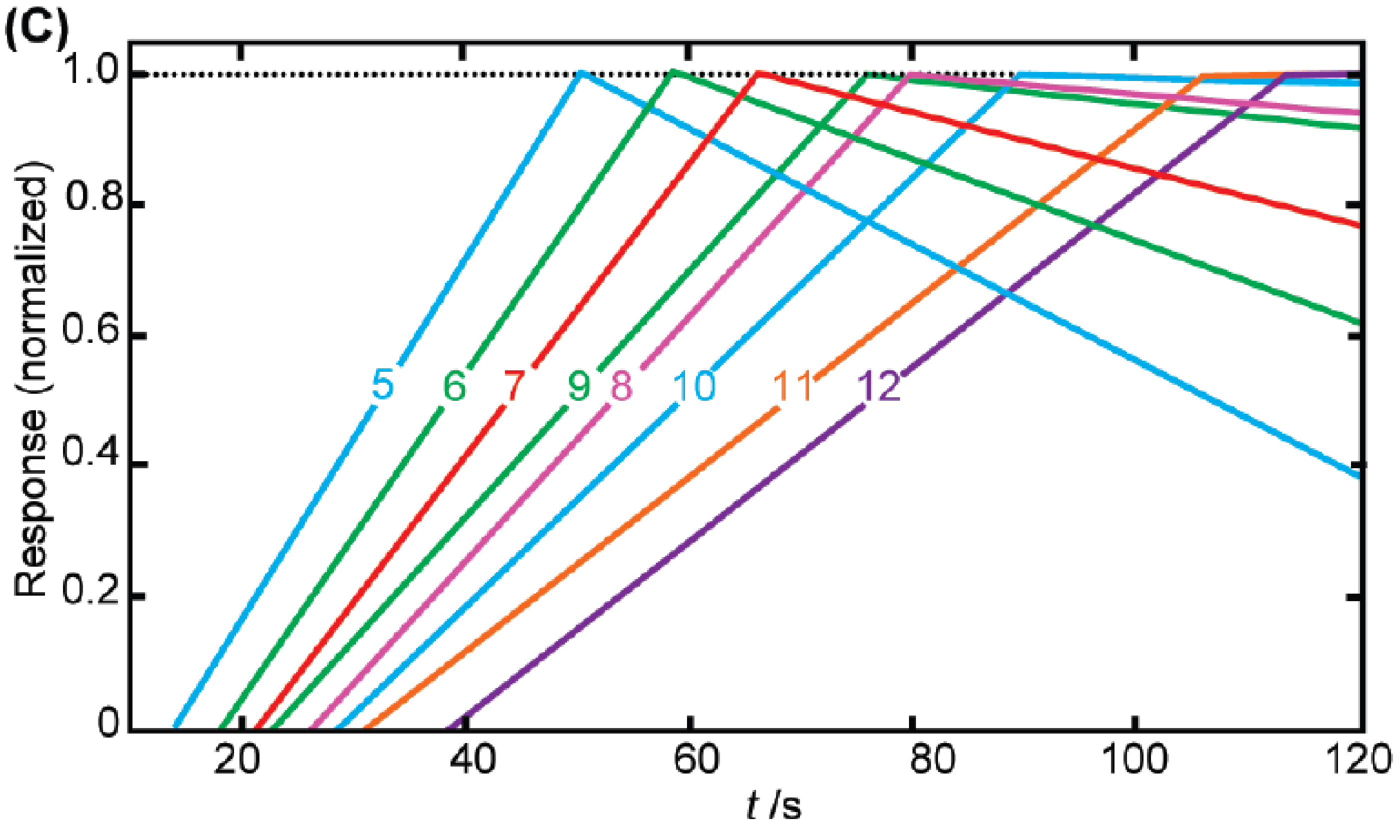
An experimental normalized response profile and its “line diagram”. The line diagram is specified by determining t_r and $t_{m'}$, moments where the response profile reaches 5% and 95% of its maximum level, respectively, and R_f, the dimensionless magnitude of the profile at t_f.

بینی الکترونیکی- نوع ۲

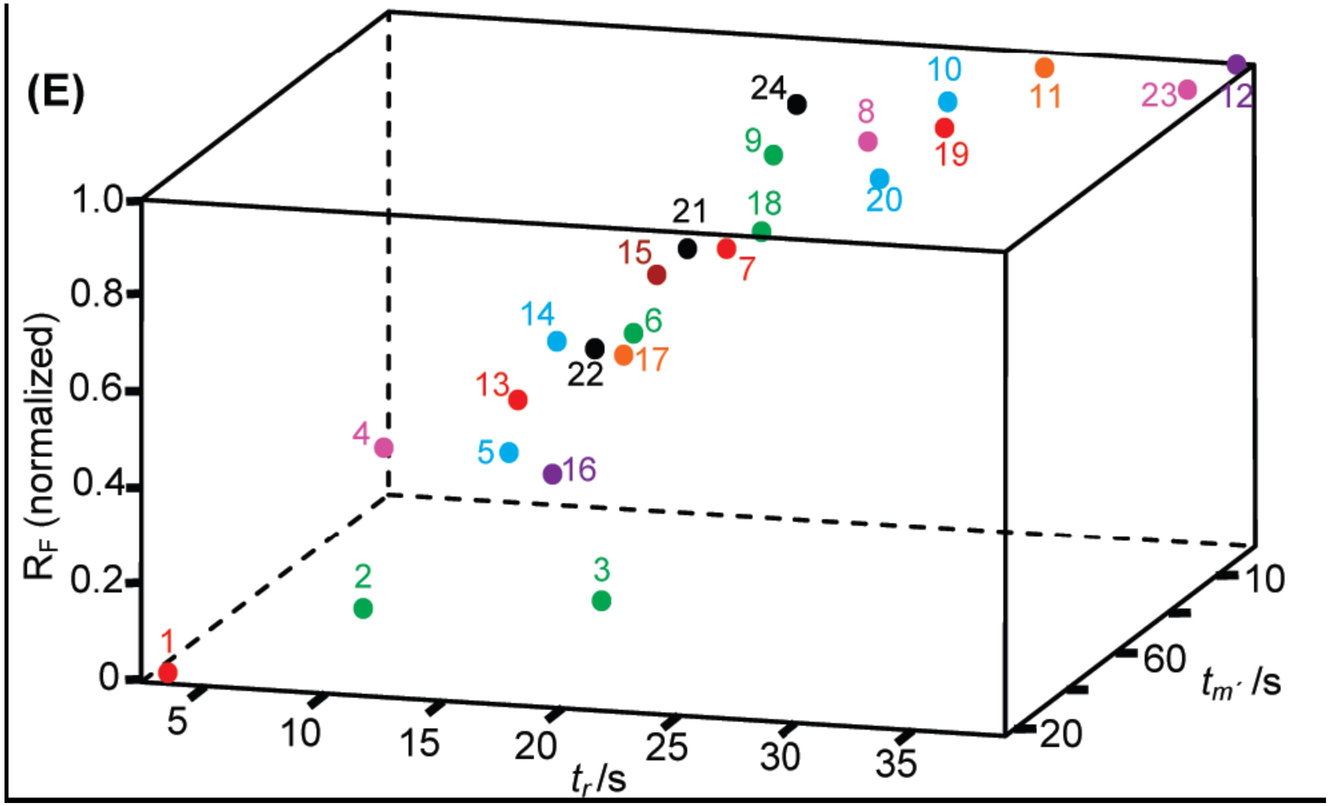


نتایج آزمایش گازهای مختلف در غلظتهای متفاوت و اثر نرمالیزاسیون

Hossein-Babaei, Faramarz, and Vahid Ghafarinia. "Gas analysis by monitoring molecular diffusion in a microfluidic channel." *Analytical chemistry* (2010).

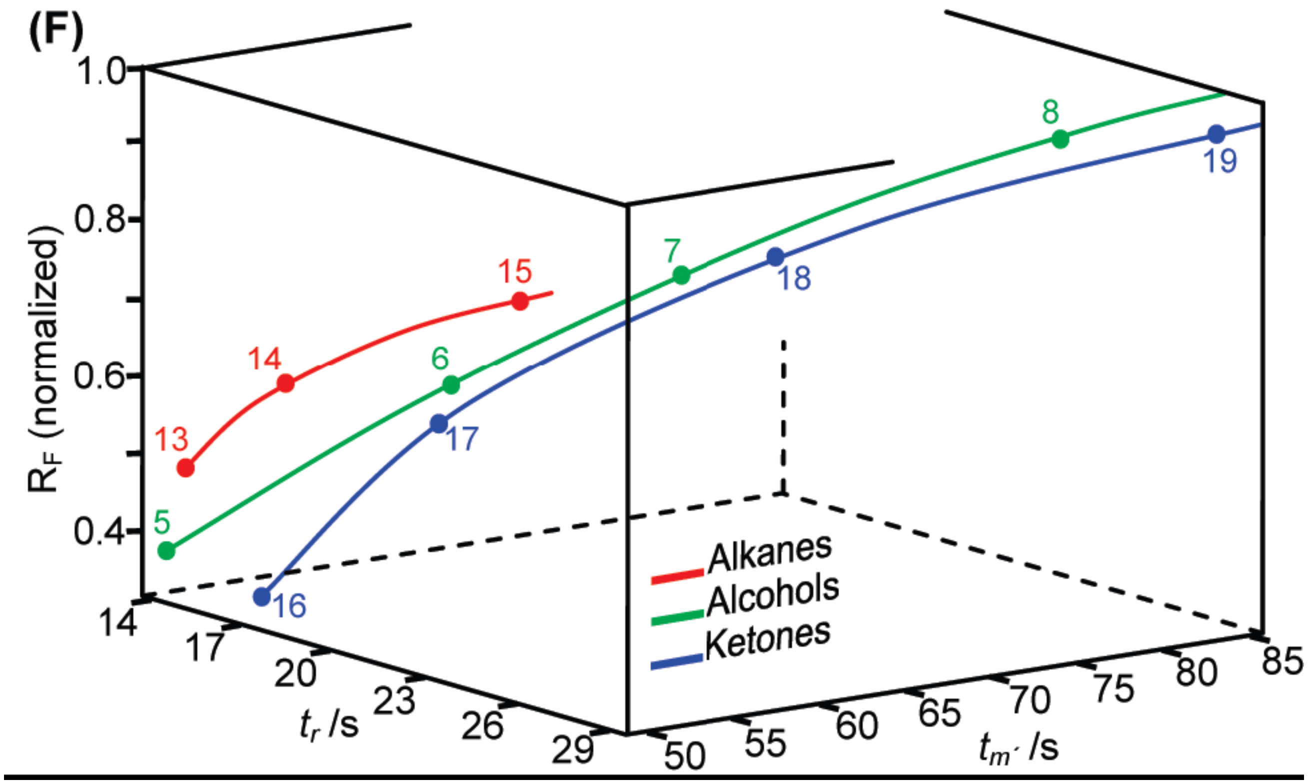


hydrogen (1), carbon monoxide (2), argon (3), oxygen (4), methanol (5), ethanol (6), isopropanol (7), 1-propanol (8), *tert*-butanol (9), 2-butanol (10), iso-butanol (11), 1-butanol (12), methane (13), *n*-butane (14), *n*-pentane (15), acetone (16), butanone (17), 2-pentanone (18), methyl isobutyl ketone (19), chloroform (20), toluene (21), benzene (22), carbon tetrachloride (23), and ammonia (24).



hydrogen (1), carbon monoxide (2), argon (3), oxygen (4), methanol (5), ethanol (6), isopropanol (7), 1-propanol (8), *tert*-butanol (9), 2-butanol (10), iso-butanol (11), 1-butanol (12), methane (13), *n*-butane (14), *n*-pentane (15), acetone (16), butanone (17), 2-pentanone (18), methyl isobutyl ketone (19), chloroform (20), toluene (21), benzene (22), carbon tetrachloride (23), and ammonia (24).

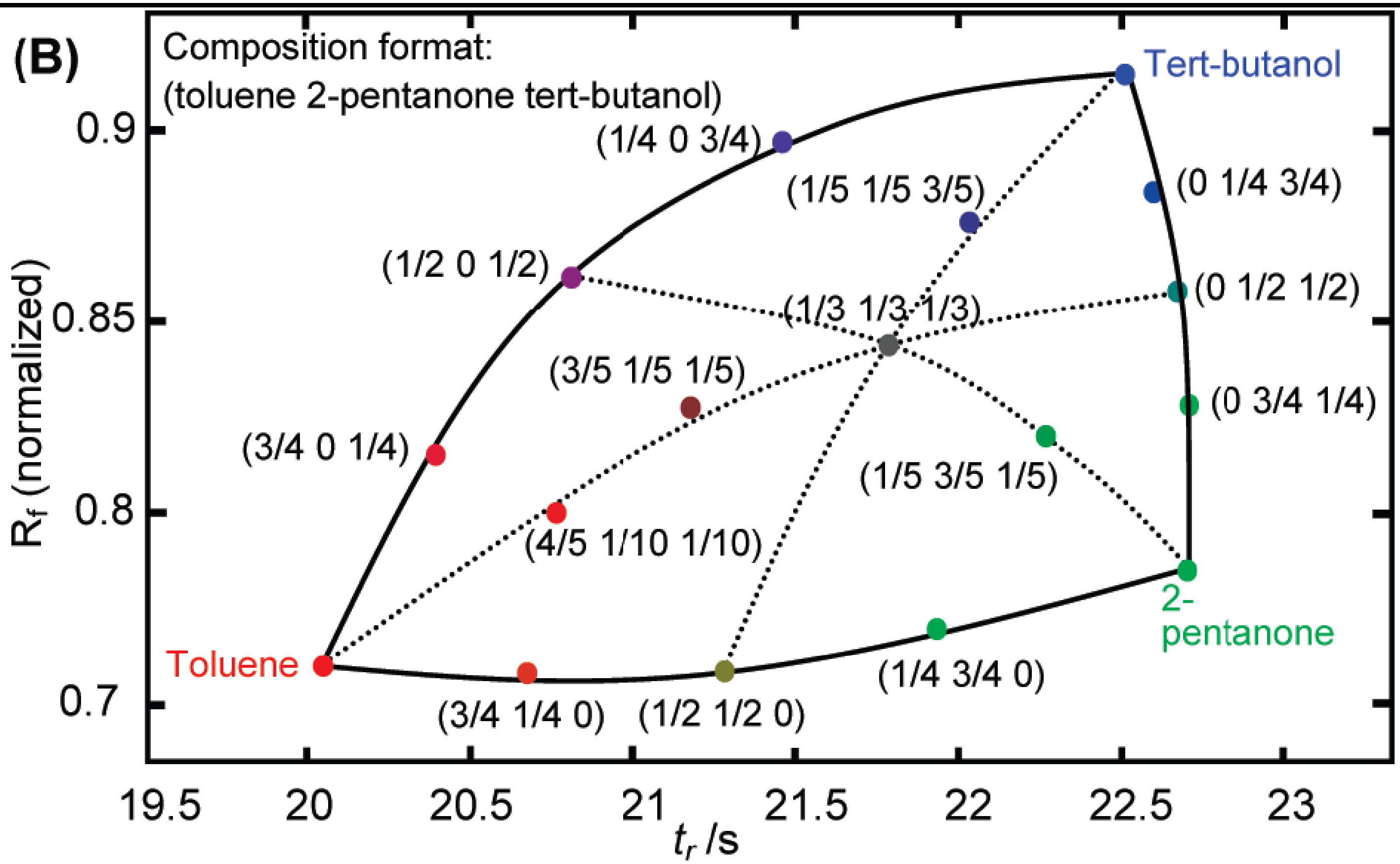
قابلیت جداسازی خانواده گازها



The sense of order in the locations of alcohols, ketones,and alkanes in the feature space.

Hossein-Babaei, Faramarz, and Vahid Ghafarinia. "Gas analysis by monitoring molecular diffusion in a microfluidic channel." *Analytical chemistry* (2010).

قابلیت تشخیص مخلوط گازی



The sense of order in the locations of alcohols, ketones,and alkanes in the feature space.

Hossein-Babaei, Faramarz, and Vahid Ghafarinia. "Gas analysis by monitoring molecular diffusion in a microfluidic channel." *Analytical chemistry* (2010).

بینی الکترونیکی – نوع ۳ (استفاده از مدولاسیون دمایی)

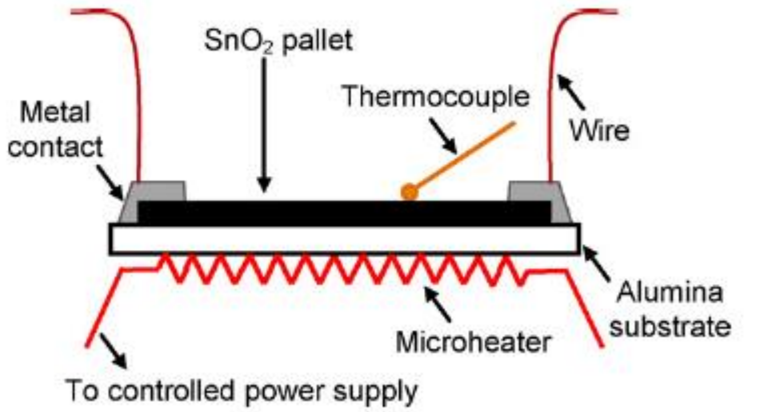
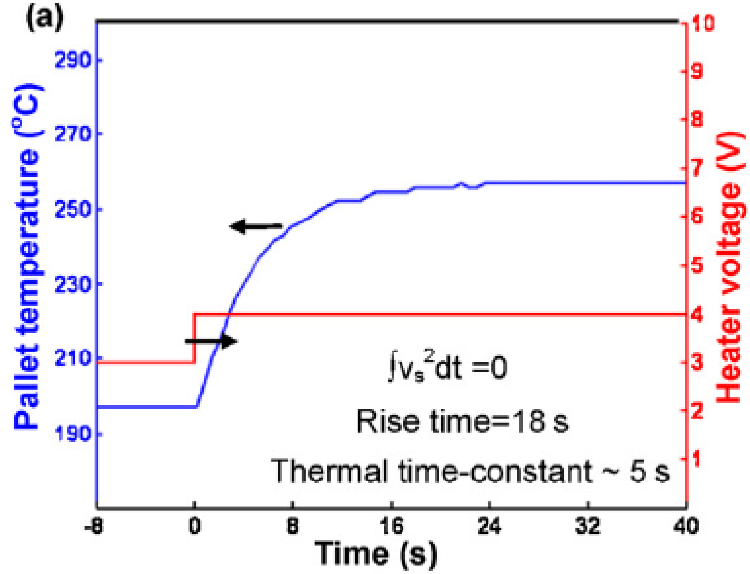
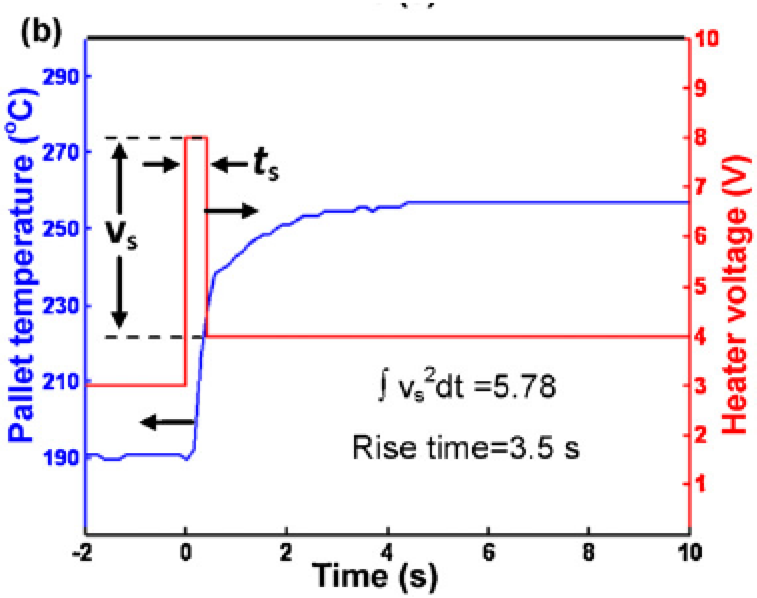
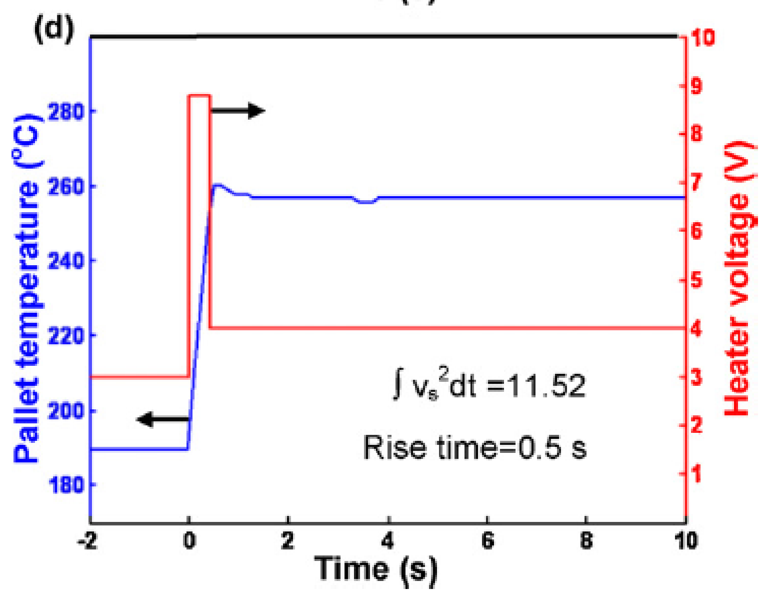


Fig. 1. Schematics of a generic metal oxide gas sensor (colored online).







Hossein-Babaei, Faramarz, and Amir Amini. "A breakthrough in gas diagnosis with a temperature-modulated generic metal oxide gas sensor." *Sensors and Actuators B: Chemical* (2012).

بینی الکترونیکی – نوع ۳ (استفاده از مدولاسیون دمایی)

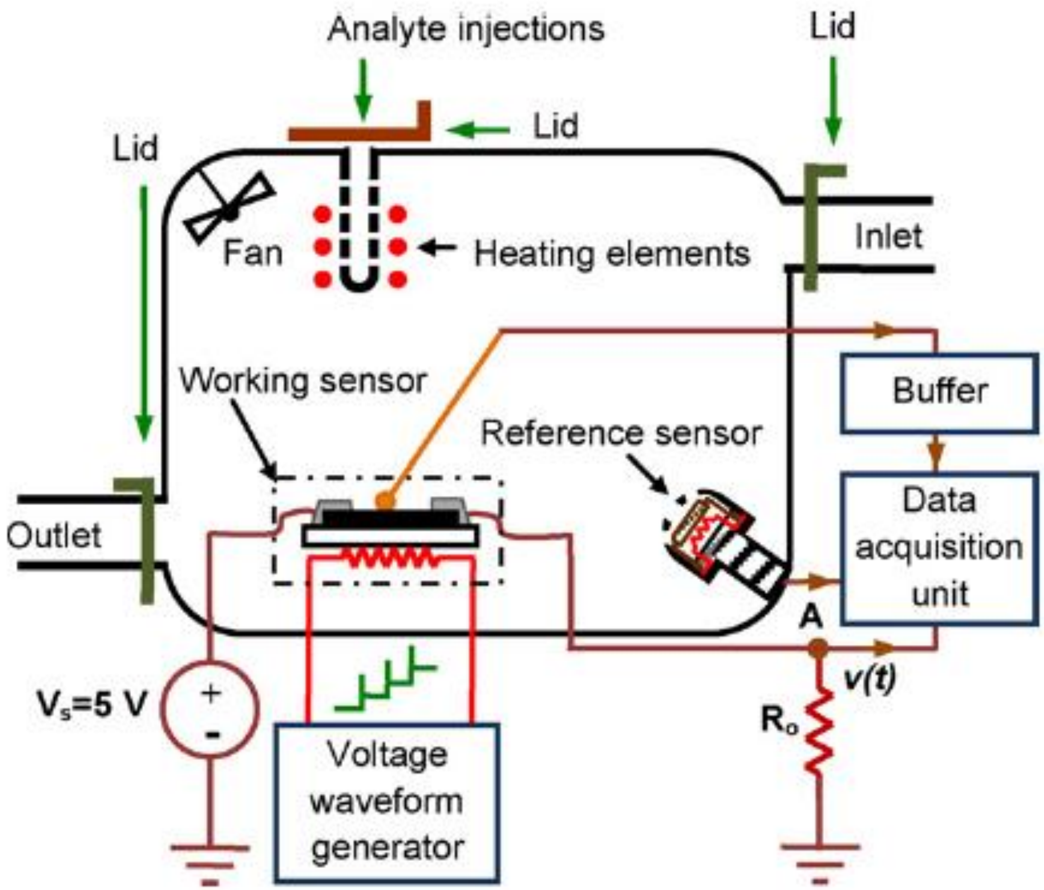
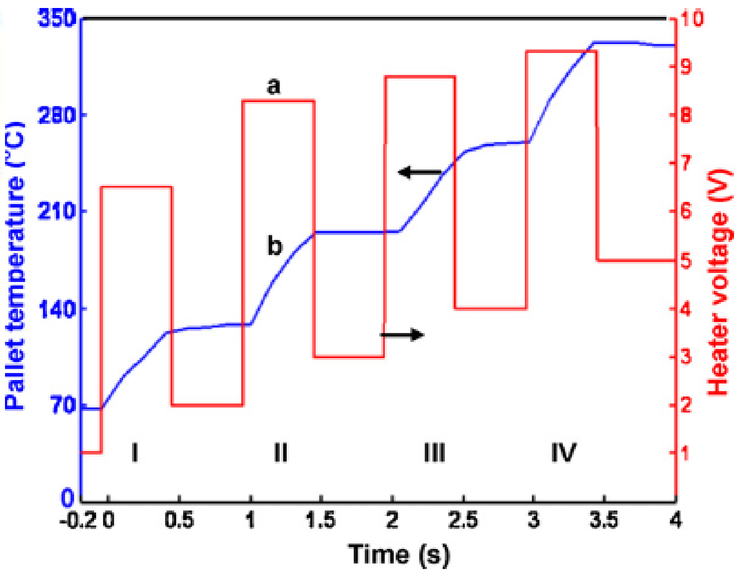


Fig. 5. The schematics of the experimental setup (colored online).



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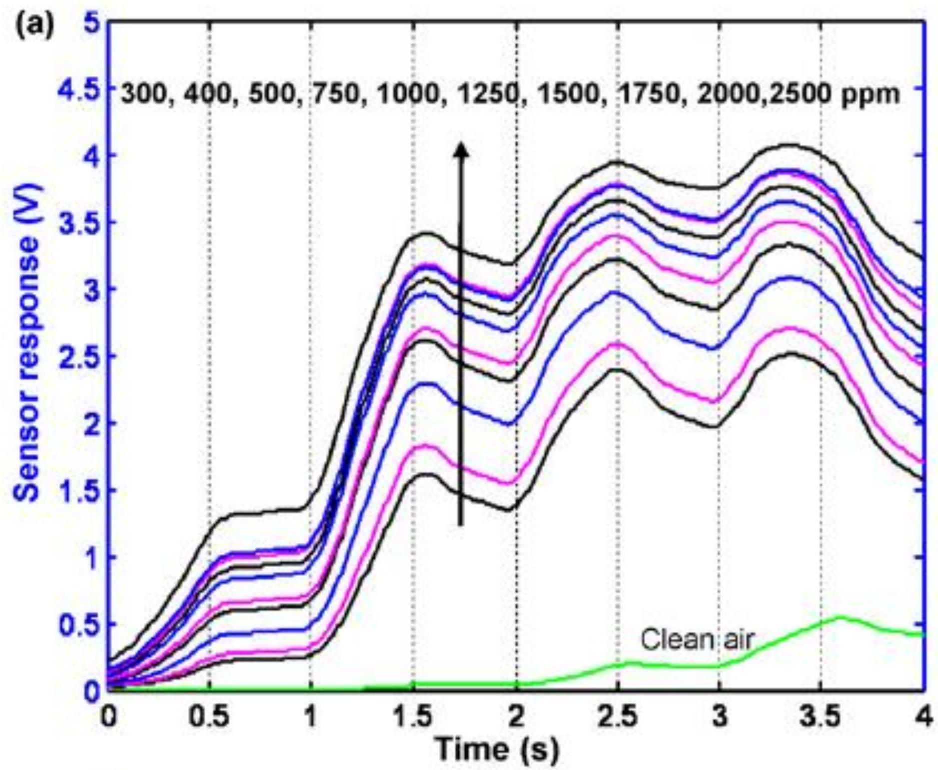
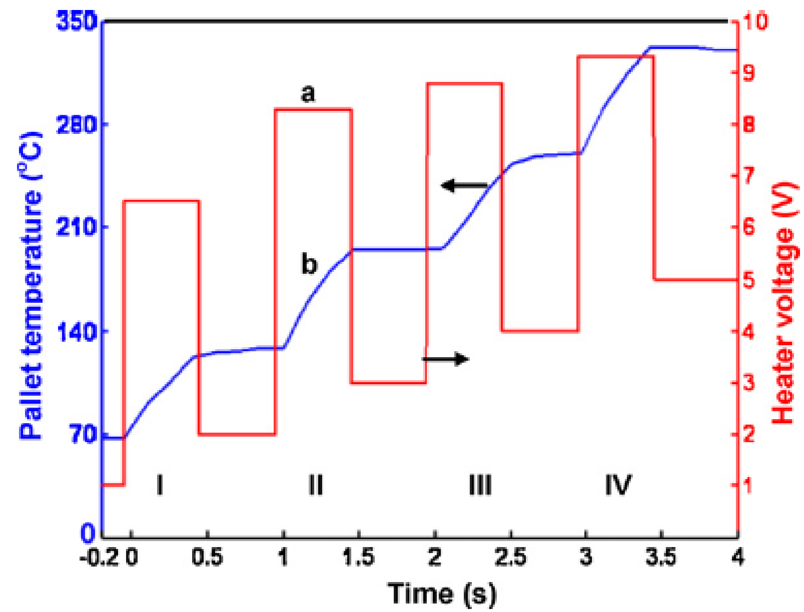
بینی الکترونیکی – نوع ۳ (استفاده از مدولاسیون دمایی)



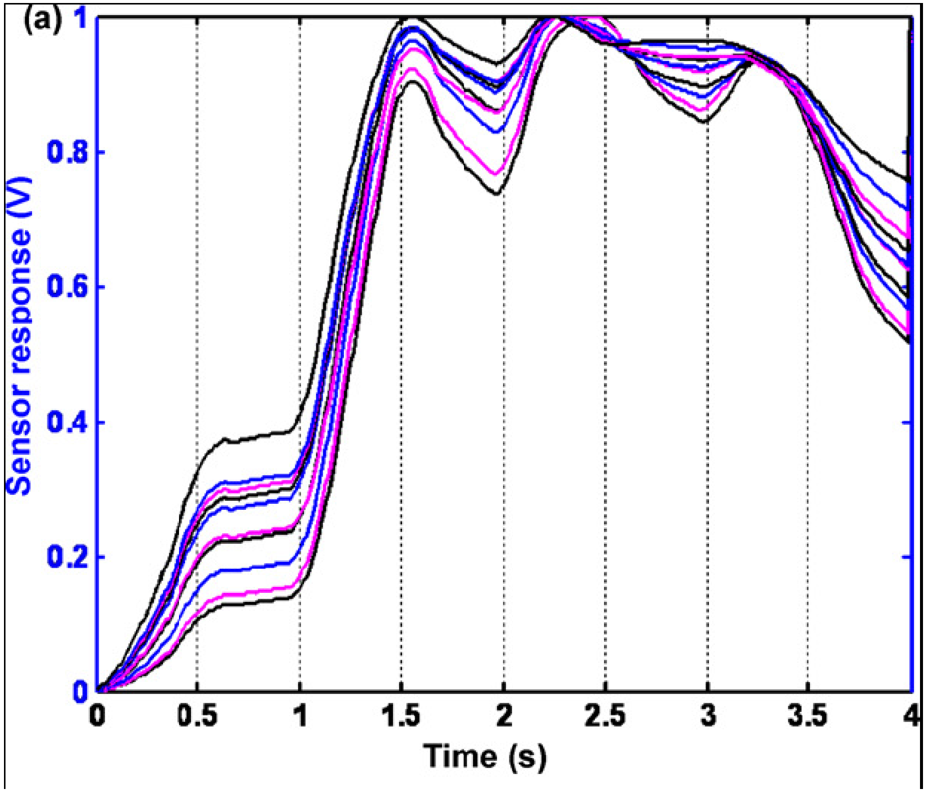
Raw response patterns recorded for 2-propanol

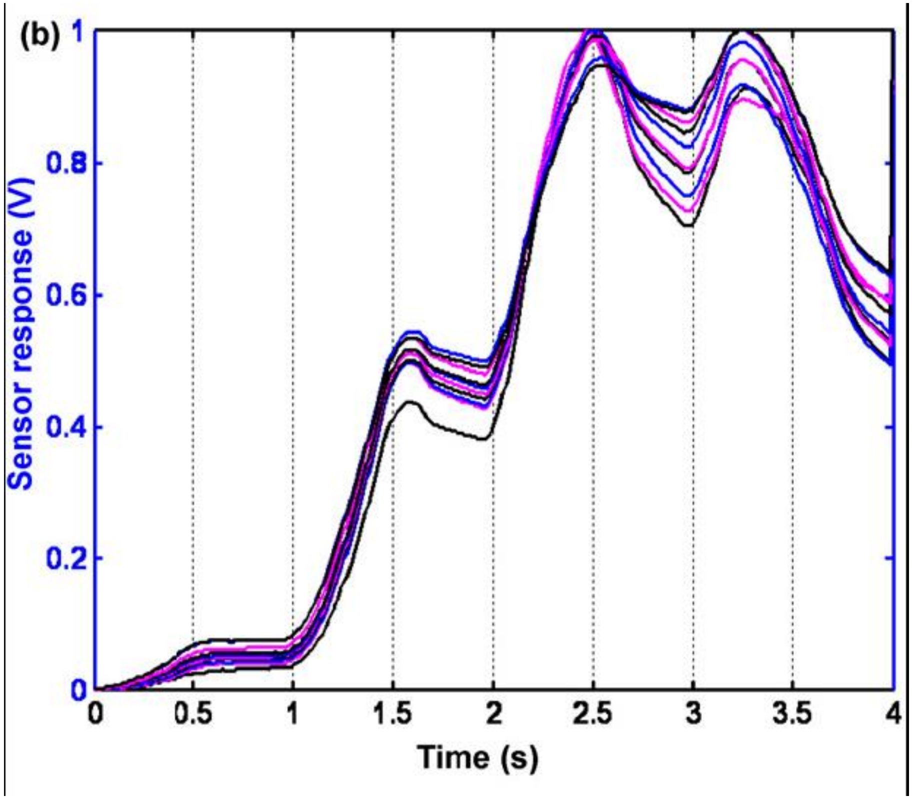


Heater pulses and recorded temperature

Hossein-Babaei, Faramarz, and Amir Amini. "A breakthrough in gas diagnosis with a temperature-modulated generic metal oxide gas sensor." *Sensors and Actuators B: Chemical* (2012).

بینی الکترونیکی – نوع ۳ (استفاده از مدولاسیون دمایی)



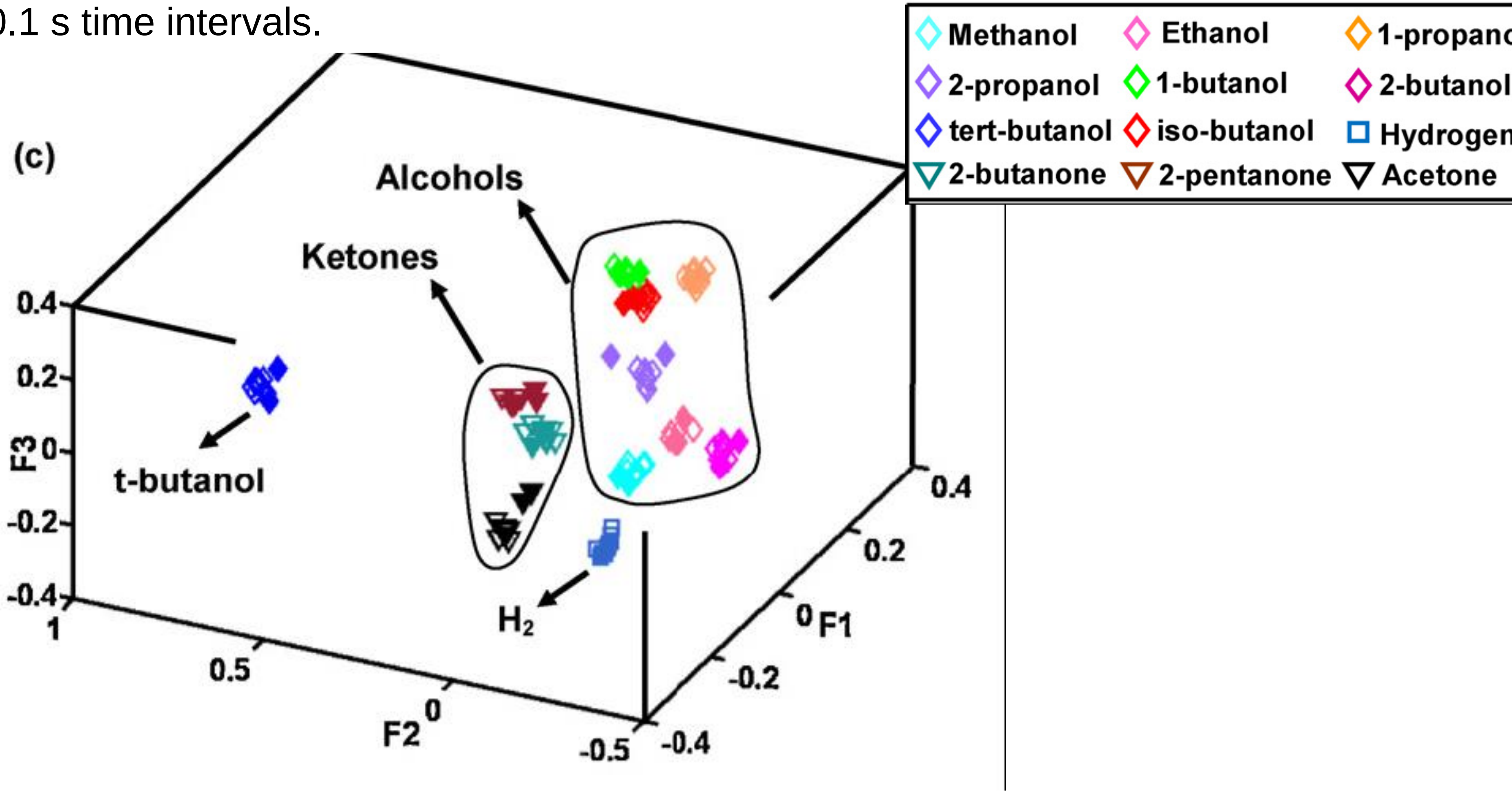


Baseline-corrected and normalized response patterns related to 2-propanol (a), acetone (b)

Hossein-Babaei, Faramarz, and Amir Amini. "A breakthrough in gas diagnosis with a temperature-modulated generic metal oxide gas sensor." *Sensors and Actuators B: Chemical* (2012).

بینی الکترونیکی – نوع ۳ (استفاده از مدولاسیون دمایی)

Each normalized temporal response pattern is defined with 40 samples each taken at 0.1 s time intervals.

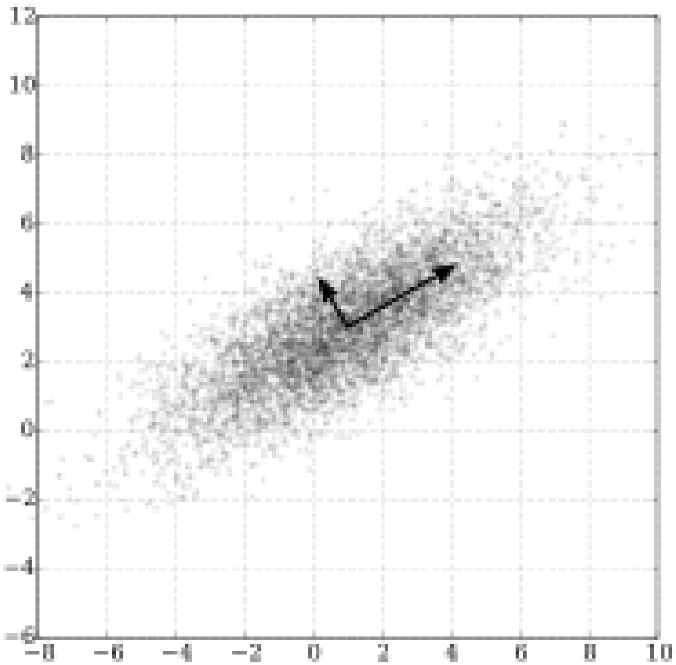


Feature space presentation resulted from PCA mapping of the feature vectors related to all recorded response patterns demonstrating the segregation of the different classes;

Hossein-Babaei, Faramarz, and Amir Amini. "A breakthrough in gas diagnosis with a temperature-modulated generic metal oxide gas sensor." *Sensors and Actuators B: Chemical* (2012).

Principal component analysis (PCA) is probably the most popular multivariate statistical technique.

PCA analyzes a data table representing observations described by several dependent variables, which are, in general, inter-correlated. Its goal is to extract the important information from the data table and to express this information as a set of new orthogonal variables called *principal components*.



PCA of a multivariate Gaussian distribution centered at (1,3) with a standard deviation of 3 in roughly the (0.866, 0.5) direction and of 1 in the orthogonal direction. The vectors shown are the eigenvectors of the covariance matrix scaled by the square root of the corresponding eigenvalue, and shifted so their tails are at the mean.