Metabolic Rate Monitoring Using Quartz Tuning Fork Based Sensors

Saurabh Parmar†, Bishakha Ray, and Suwarna Datar

†Department of Applied Physics, Defence Institute of Advanced Technology, Pune, MH, India
saby1611@gmail.com

Introduction

1. Detection of changes in level of acetone in breath can help in monitoring metabolism [1].
2. Liver breaks down fat from food and fat cells to produce ketone bodies.
3. Based on the metabolism and health state of an individual the amount of acetone varies in the exhaled breath.
4. Polymer Functionalized QTF sensor show change in resonant frequency depending on the level of acetone [2].
5. These sensors can be developed as a breathomic device which can be used as a dignostic and prognostic device.

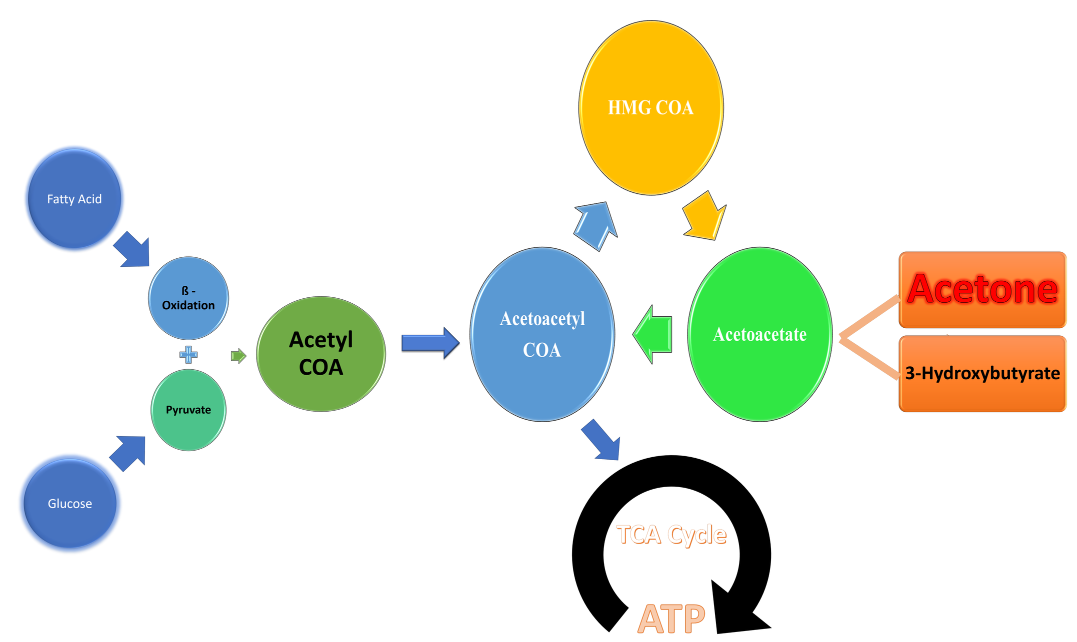

Fig. 1: Generation of ketone bodies by biological processes

Working

The resonant frequency of the QTF can be given by equation 1.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \qquad (1)$$

After interaction of the polymer film with the analyte the change in frequency can be quantified by equation 2.

$$E = \frac{2Lk_{fork}}{A} \triangle f_0 \qquad (2)$$

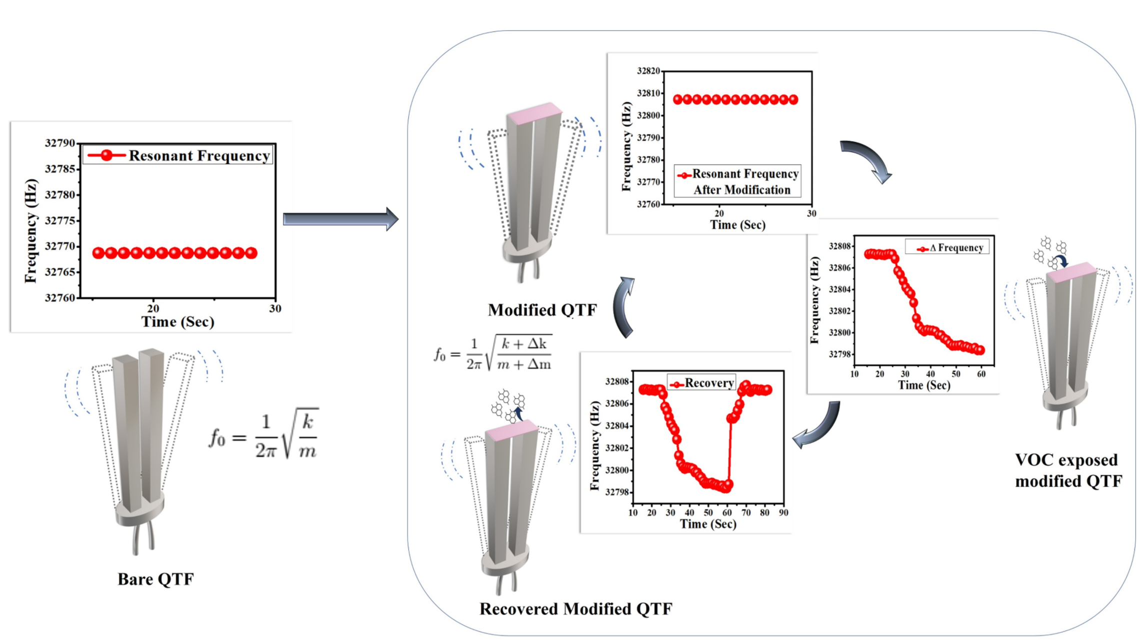

Fig. 2: Working of a QTF sensor

Modification of QTFs

For this work, a 5 percent polystyrene (PS) blend in aniline and a 1 percent blend of Polystyrene- Cellulose Acetate (PS+CA) in aniline were prepared. Using these polymers, QTFs were modified. The following figure demonstrates the modification process.

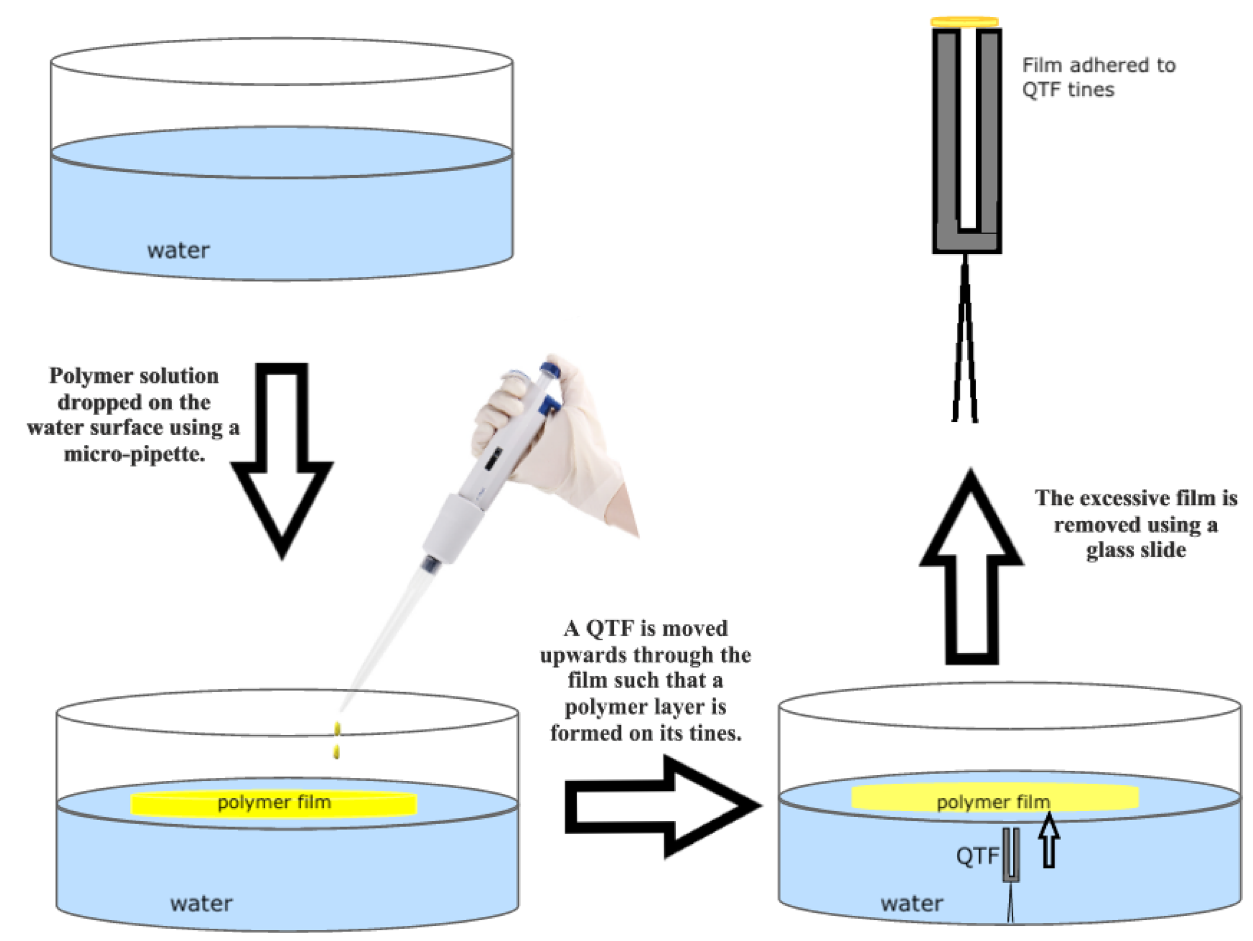

Fig. 3: Modification of a QTF with polymer film

Results

The sensor response indicates that PS+CA is selective towards acetone. PS+CA gave a 4 Hz drop as compared to 1.5 Hz for PS. PS+CA gave a staggering 38 Hz response for 400 ppm as compared to 14 Hz for PS.

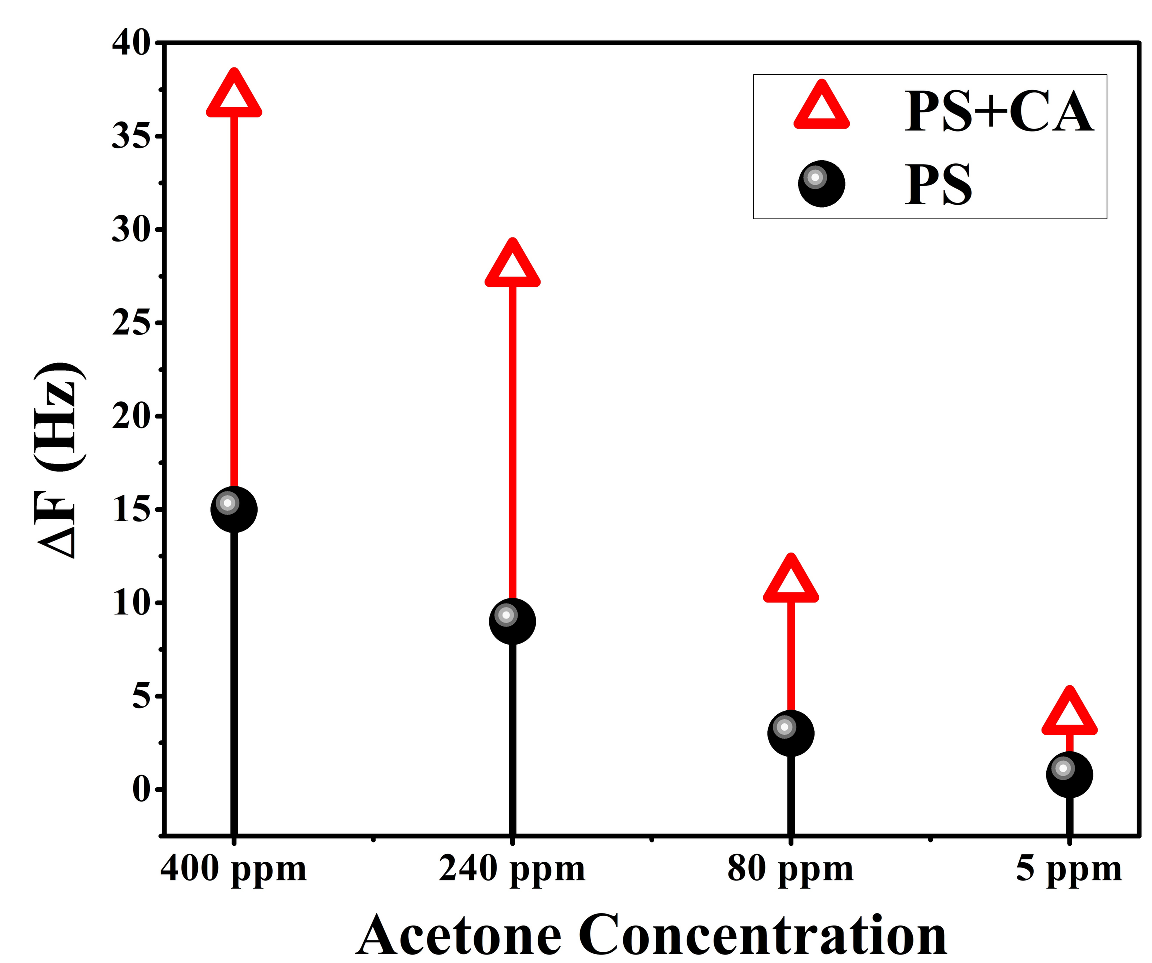

Fig. 4: Sensor Response for varying concentration of Acetone for polystyrene and polystyrene + cellulose acetate

Classification

Moderate and low levels of acetone were detected with 100 percent accuracy. Whereas, a few points of high levels of acetone were incorrectly classified leading to a 95.2 percent accuracy.

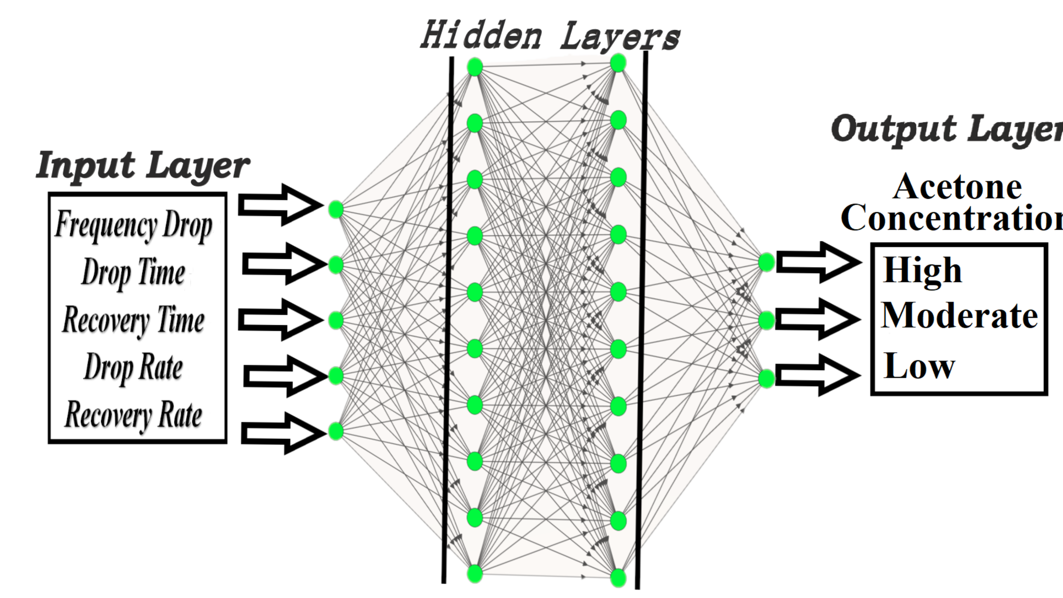

Fig. 5: Neural network for classification

	Low	Moderate	High	Accuracy
Low	28	0	0	100%
Moderate	0	16	0	100%
High	0	2	44	95.60%

Fig. 6: Confusion matrix for neural network

Conclusion

1. The sensor modified with polystyrene and cellulose acetate showed a better response for the varying levels of acetone.
2. The sensor data collected was utilized to train and test a multilayer neural network.
3. The neural network was able to predict the level of acetone with an overall accuracy of $\sim$97%.

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References

[1] Michael D Davis, Stephen J Fowler, and Alison J Montpetit. "Exhaled breath testing–A tool for the clinician and researcher". In: *Paediatric respiratory reviews* 29 (2019), pp. 37–41.

[2] Abraham Sampson et al. "Quartz tuning fork based sensor for detection of volatile organic compounds: towards breath analysis". In: *Materials Research Express* 5.4 (2018), p. 045407.