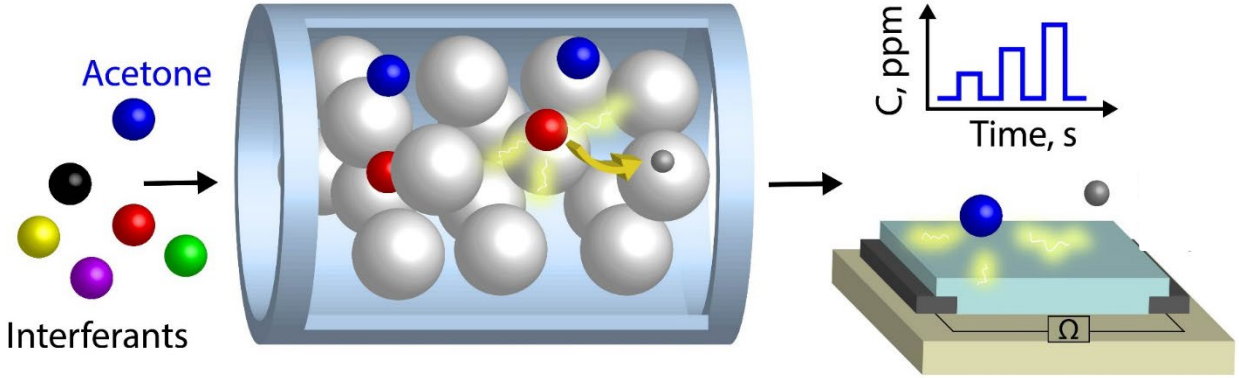
ETH zürich

Superior Selectivity of Acetone in Gas Mixtures By Pt/Al_2O_3 Catalyst-Filtered Si/WO_3 Sensors



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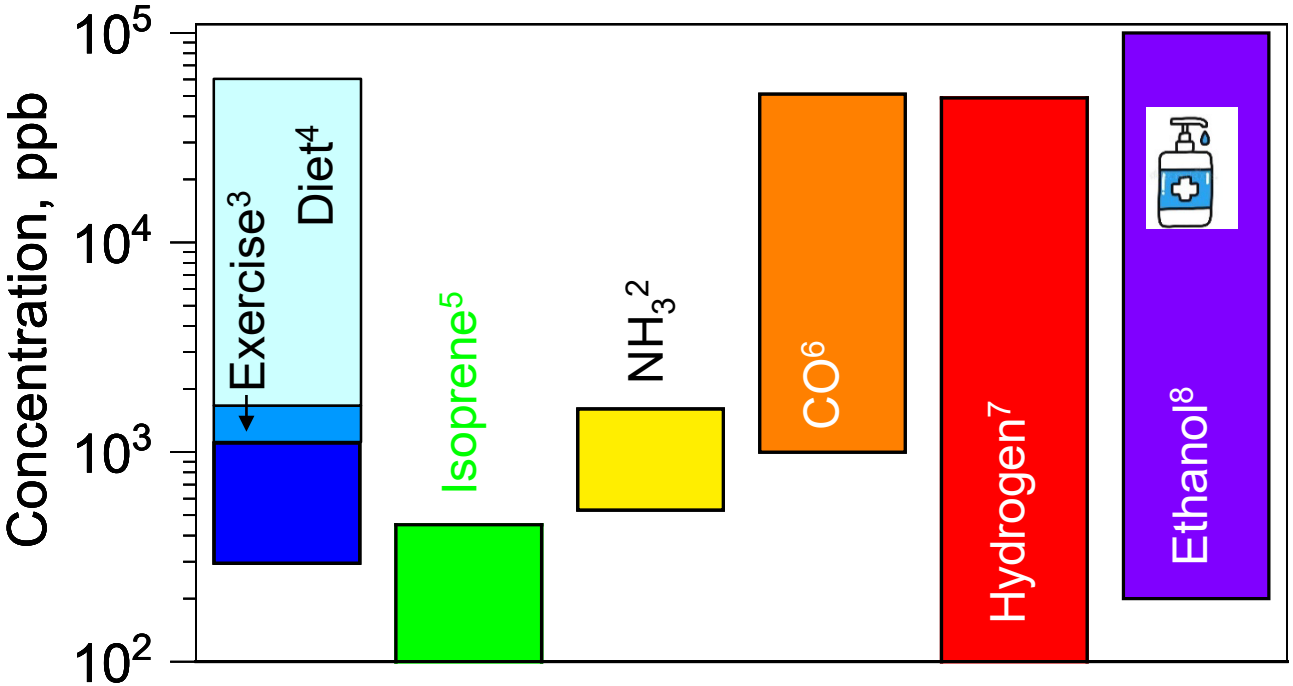
Breath acetone detection

Acetone: marker for fat-burn (among others)

- Metabolic health monitoring
- Non-invasive
- Personalized on-line monitoring

Detector requirements

- Sensitivity (down to ppb)
- Fast, compact & inexpensive
- Humidity Robustness
- Selectivity
- Complex gas mixtures (e.g, breath) > 1'000 interferants[1]



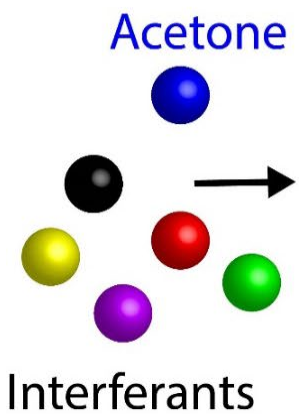
1. Drabinska N, Flynn C, Ratcliffe N, Belluomo I, Myridakis A, Gould O, Fois M, Smart A, Devine T, de Lacy Costello, P *J. Breath Res.* **2021,** 14, 034001.
2. Turner, C.; Španel, P.; Smith, *Physiol. Meas.* **2006,** 27, 321–337.
3. Güntner AT, Kompalla JF, Landis H, Theodore SJ, Geidl B, Sievi NA, Kohler M, Pratsinis SE, Gerber PA, *Sensors* **2018**, 18, 3655.
4. Königstein K, Abegg S, Schorn AN, Weber IC, Derron N, Krebs A, Gerber PA, Schmidt-Trucksäss A, Güntner AT, J. Breath Res. 2020, 15, 016006
5. King, J.; Kupferthaler, A.; Unterkofler, K.; Koc, H.; Teschl, S.; Teschl, G.; Miekisch, W.; Schubert, J.; Hinterhuber, H.; Amann, A. *J. Breath Res*. **2009**, 3, 027006.
6. Deveci, SE, Deveci, F, Acik, Y, Ozan AT, *Respiratory Medicine*, **2004**, 98, 551-556.
7. D. J. Calloway, E. L. Murphy, D. Bauer, *Am. J. Dig. Dis.* 1**969**, 14, 811. [24]
8. Bessonneau, V.; Thomas, O. *Int. J. Environ. Res. Public Health* **2012,** 9, 868–879.

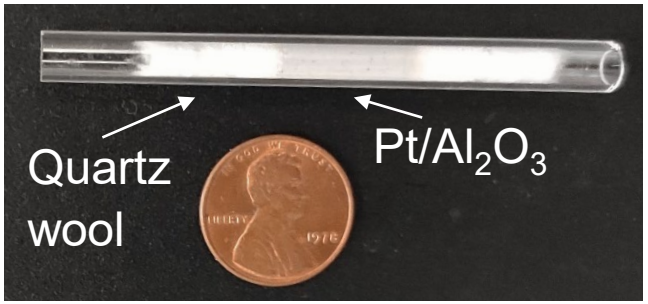
State-of-the-art

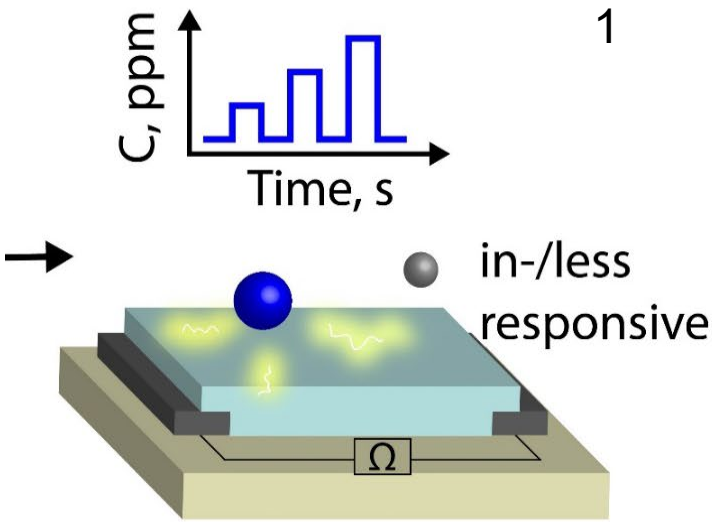
	Material	Selectivity ($S_{Acetone}/S_{Analyte}$), [-]				
		Ethanol	Isoprene	H_2	CO	NH_3
Composites	SnO_2 / reduced graphene oxide[1]	4.3	-	-	9.5	9.5
	SnO_2 / multi-walled carbon nanotubes[2]	1.8	-	-	2.9	-
	Ni-SnO_2 / graphene[3]	1.9	-	18	-	-
Metal Oxides	Al/ZnO[4]	-	3.6	-	7.4	6.9
	Au-vertical hematite nanotubes[5]	2.4	-	87	86	36
	Si/WO_3[6]	11.4	0.5	139	289	140
	Nb/WO_3[7]	23	-	120	>50	100
	Pt/Al_2O_3 + Si/WO_3[6]	>500	>1000	>250	>1000	>1000

1. Choi SJ, Jang BH, Lee SJ, Min BK, Rothschild A, Kim ID, *ACS Appl. Mater. Interfaces* **2014**, 6, 2588.
2. Narjinary M, Rana P, Sen A, Pal M, *Mater. Des.* **2017**, 115, 158
3. Singkammo S, Wisitsoraat A, Sriprachuabwong C, Tuantranont A, Phanichphant S, Liewhiran C, *ACS Appl. Mater. Interfaces* **2015**, 7, 3077.
4. Yoo R, Güntner AT, Park Y, Rim HJ, Lee HS, Lee W, *Sensors Actuators, B* **2019**, 283, 107.
5. Kim DH, Kim TH, Sohn W, Suh JM, Shim YS, Kwon KC, Hong K, Choi S, Byun HG, Lee JH, Jang HW, *Sensors Actuators, B Chem.* **2018**, *274*, 587.
6. Weber IC, Braun HP, Krumeich F, Güntner AT, Pratsinis SE, *Adv. Sci.* **2020**, 7, 2001503
7. Choi HJ, Chung JH, Yoon, JW, Lee JH, *Sensors Actuators, B* **2021**, 338, 129823.

Selective sensors enabled by catalytic filters





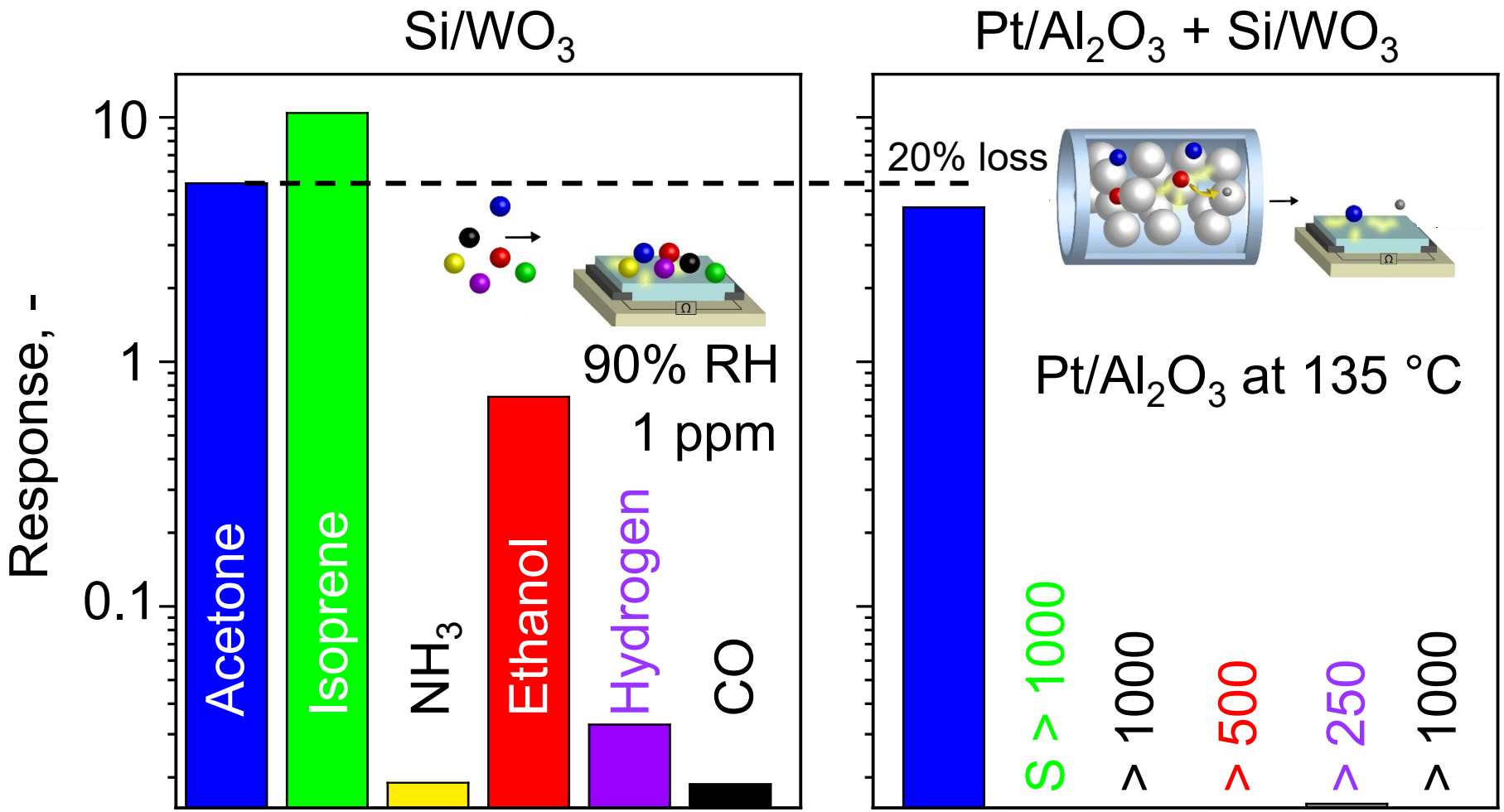


Pt/Al_2O_3 at 135 °C **Si/WO_3 at 400 °C**

- Continuous interferant removal by chemical reaction[2]
- Rapid measurements
- Differentiate between VOCs[3]
- Configuration: **packed bed** or overlayer[4]

1. Güntner AT, Weber IC, Pratsinis SE, *ACS Sensors*, **2020**, 5, 1058 – 1067.
2. Portnoff MA, Grace R, Guzman AM, Runco PD, Yannopoulos LN, *Sens. Actuators, B*, **1991**, 5, 231–235
3. Van den Broek J, Weber IC Güntner AT, Pratsinis SE, *Materials Horizons,* **2021**, 8, 661 - 684.
4. Moon, YK, Jeong SY, Jo YM, Jo YK, Kang YC, Lee JH, *Advanced Science*, **2021**, 8, 2004078

Selective acetone detector

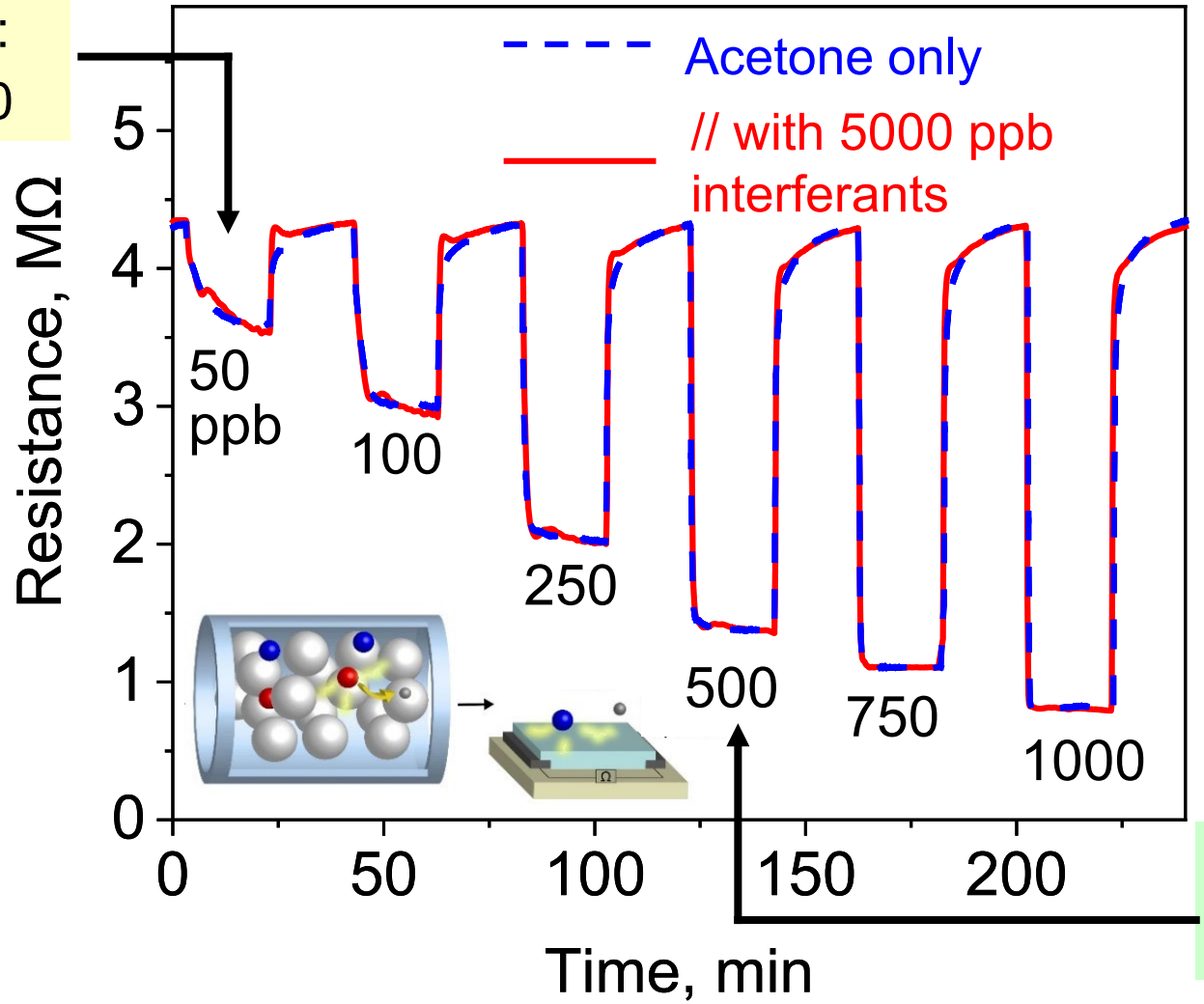


Catalytic filter enables superior acetone selectivity!

Weber IC, Braun HP, Krumeich F, Güntner AT, Pratsinis SE, *Advanced Science*, **2020**, 7, 2001503.

Selective acetone sensing in gas mixtures

SNR:
> 100

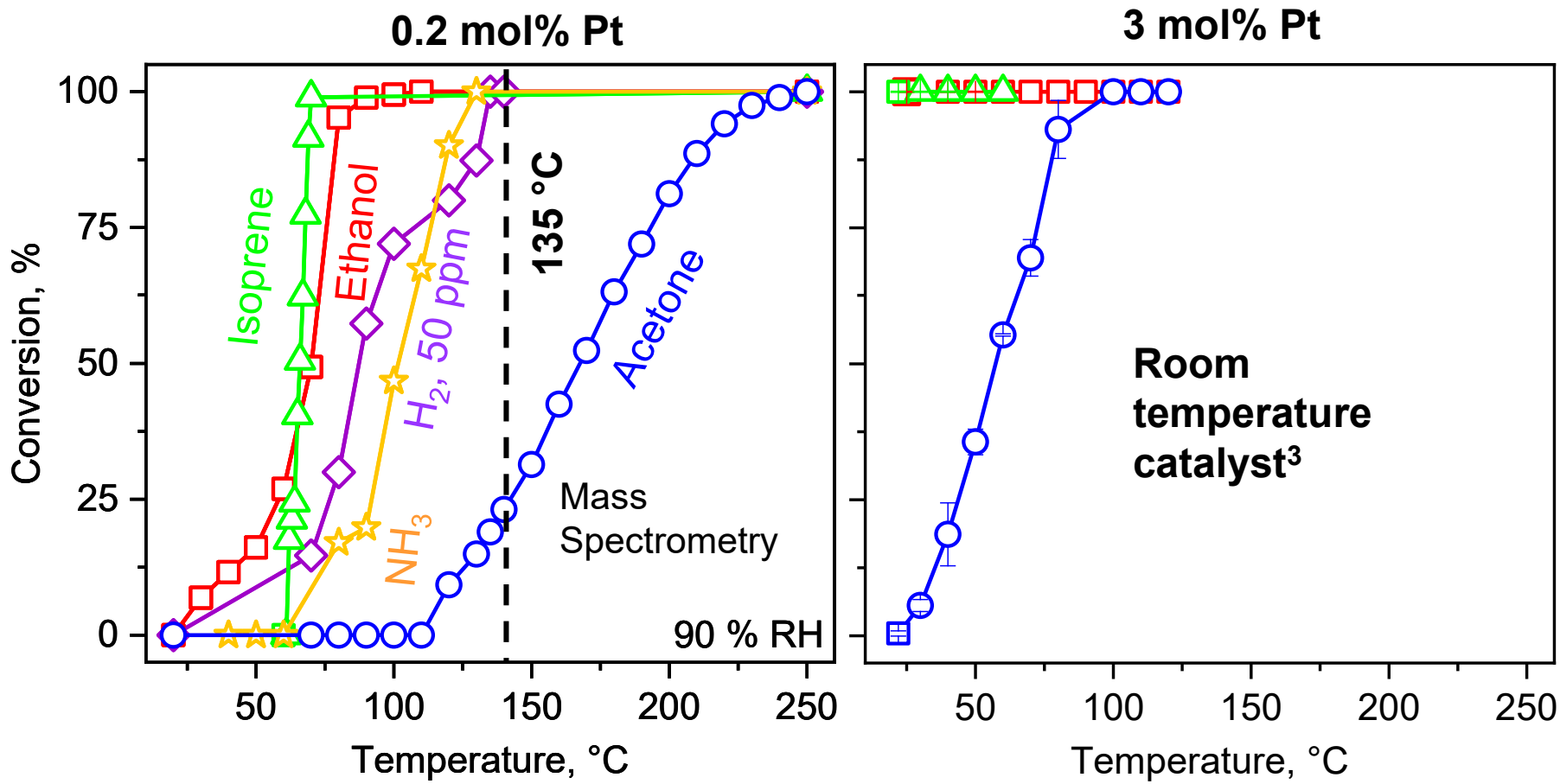


Interferants:
Each 1000 ppb
- Ethanol
- Isoprene
- H_2
- CO
- NH_3

Response time:
55 s

Acetone sensing despite *orders of magnitude* higher interferants

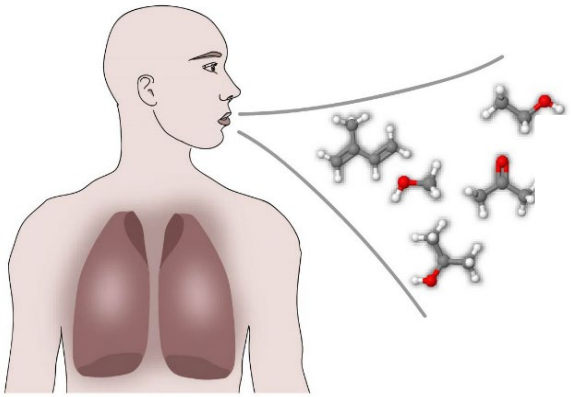
Catalyst conversion mechanism

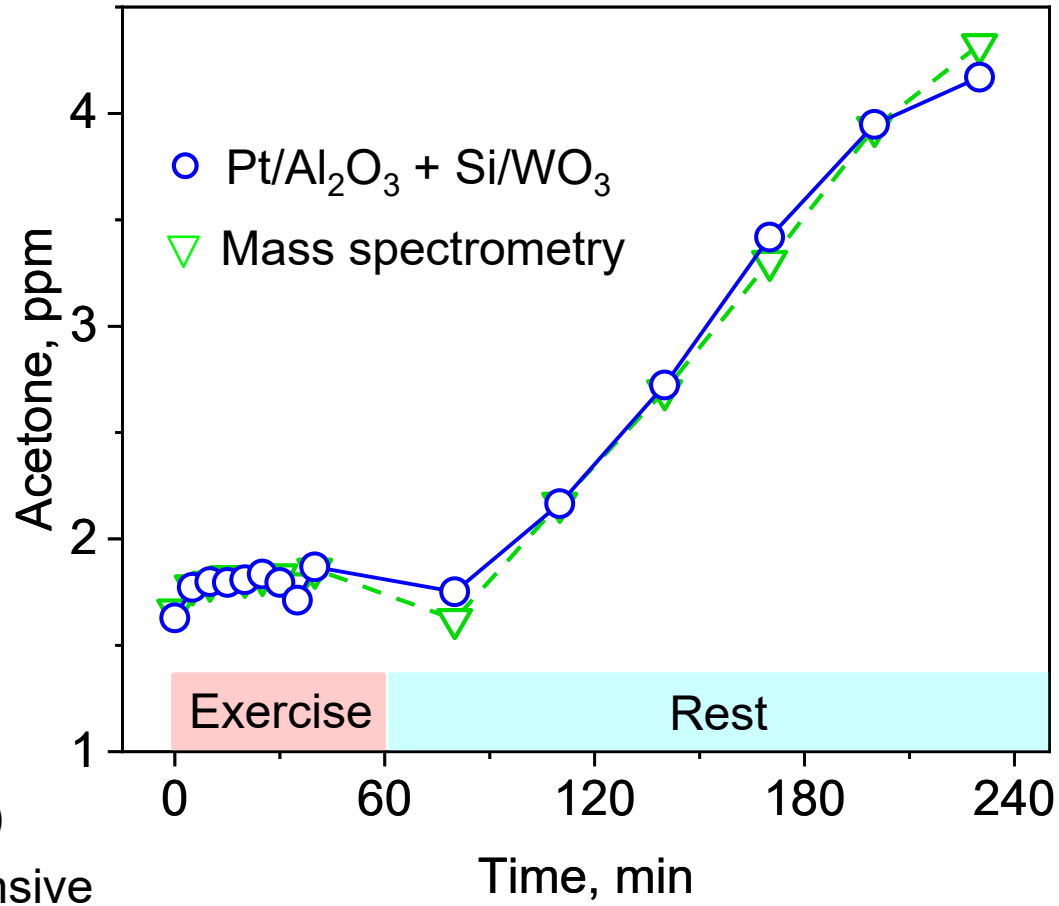


- Interferant conversion on surface-adsorbed hydroxyl species[1]
- Acetone conversion is blocked by water that dissociates on Lewis acid sites[2]

1. Mallat T, Baiker A, *Chem. Rev*. **2004**, 104, 3037
2. Panov AG, Fripiat JJ, *J. Catal.* **1998**, *178*, 188
3. Weber IC, Wang, CT, Güntner AT, *Materials*, **2021**, 14, 1839

Reality check: Breath





Requirements

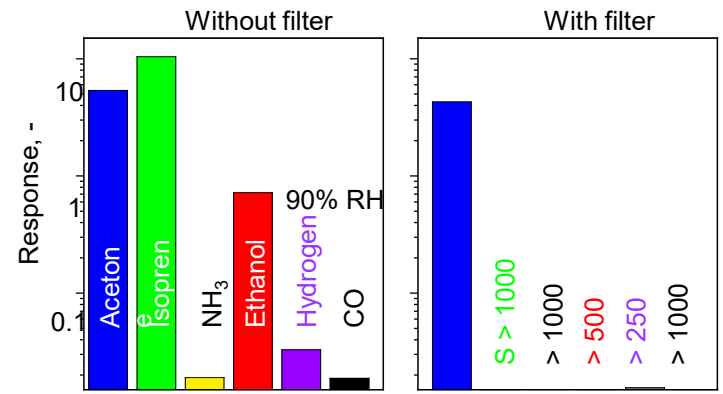
- ✓ Sensitivity (down to ppb)
- ✓ Fast, compact & inexpensive
- ✓ Humidity robustness
- ✓ Selectivity
- ✓ Complex gas mixtures (e.g, breath)

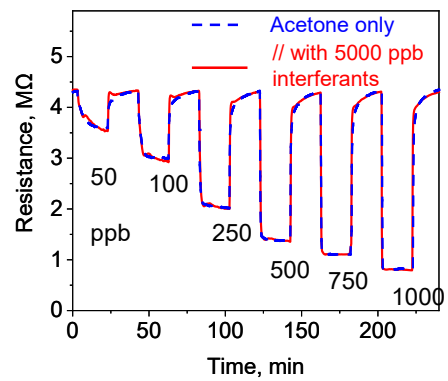
IMCS 02-1342:
Multiple volunteers,
146 samples

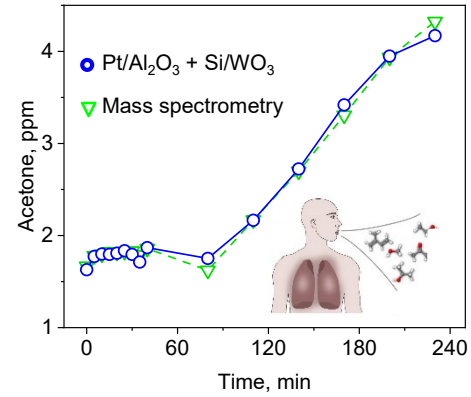
Weber IC, Derron N, Königstein K, Gerber PA, Güntner AT, Pratsinis SE. *Small Science*, **2021**, 2100004

Conclusions

- Unprecedented **acetone selectivity** by catalytic Pt/Al_2O_3 filter
- Acetone detection in **gas mixtures** with orders of magnitude higher interferants
- Miniaturization potential: catalyst at **room temperature**
- Accurate acetone quantification in **breath**







Ongoing: Randomized Clinical trial
72 volunteers

Weber IC, Braun HP, Krumeich F, Güntner AT, Pratsinis SE, *Advanced Science*, **2020**, 7, 2001503.