Chemical Sensors Array from the Viewpoint of System

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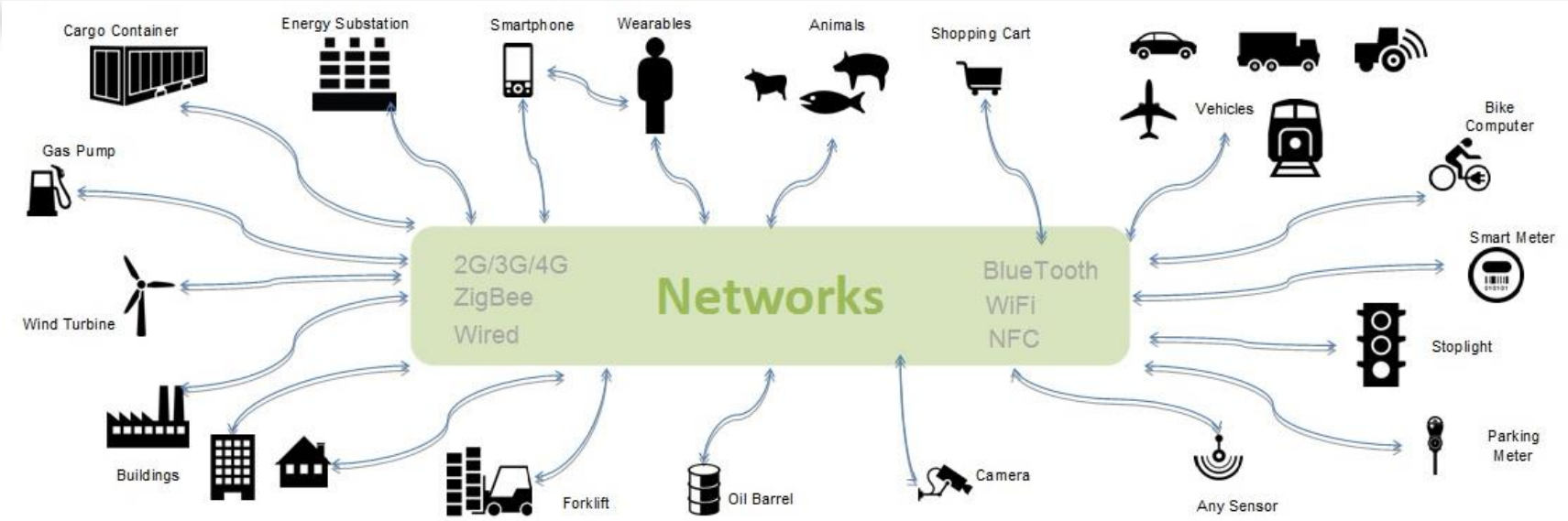
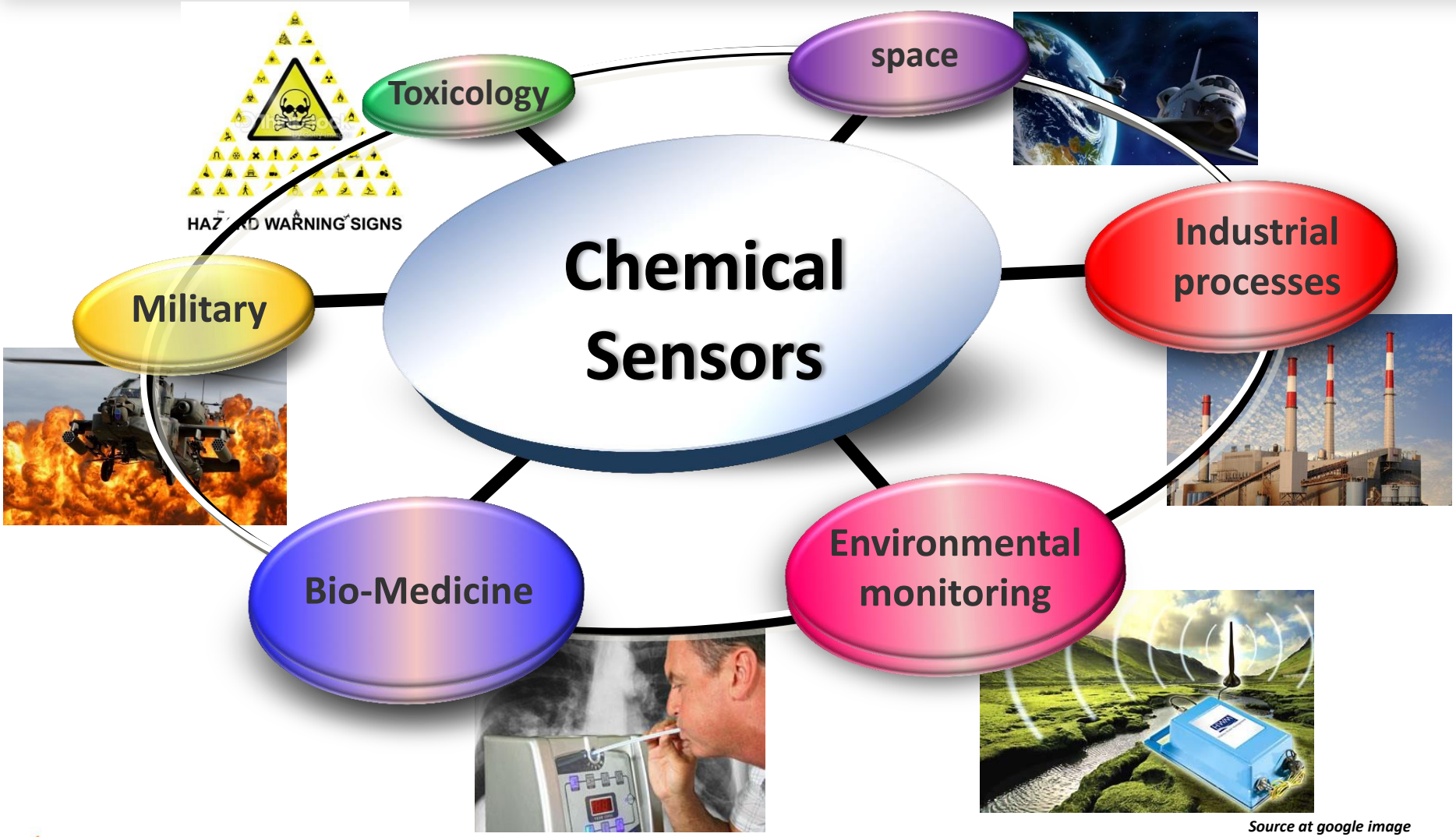
Introduction



- **IoT** - Connecting people to physical things and also among the physical things, all in real time.
- **IBM data source (IDC)** has estimated that by 2020 there will be 30 billion internet-connected and sensor-enabled objects.

Image from ibmcai.com, "The next phase of the Internet: The Internet of Things"

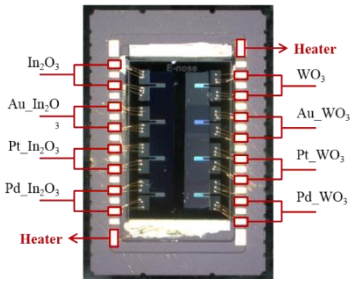
Introduction



Source at google image

Introduction – IoT with Chemical Sensors Array

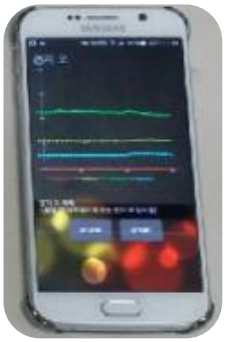
- **IoT(Internet of Things)**
  - **Multiple technologies including**



Chemical Sensors Array

Embedded System

Embedded SW



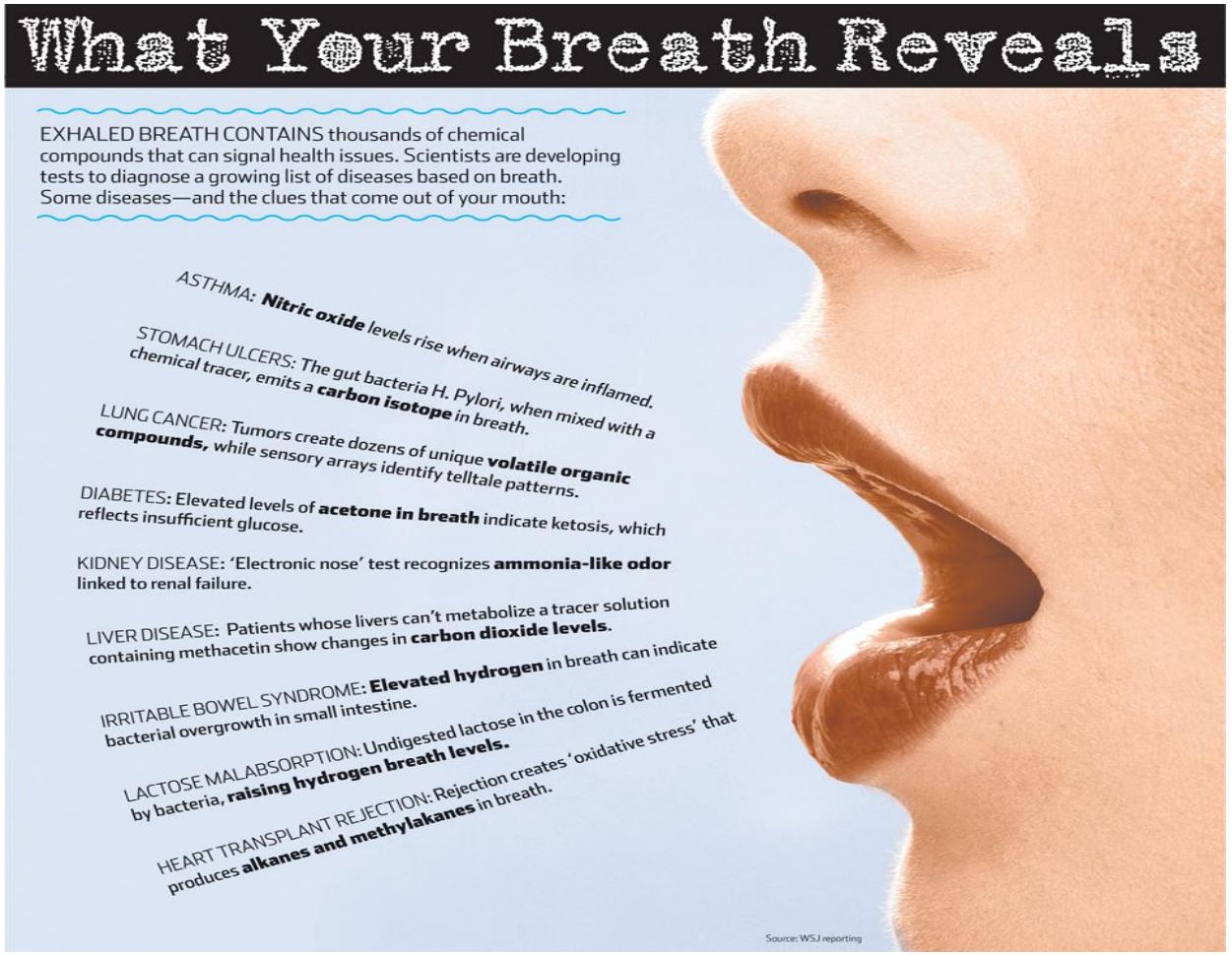
The Internet

Communication

Real-time analytics based on Machine Learning

Work we are doing (I)

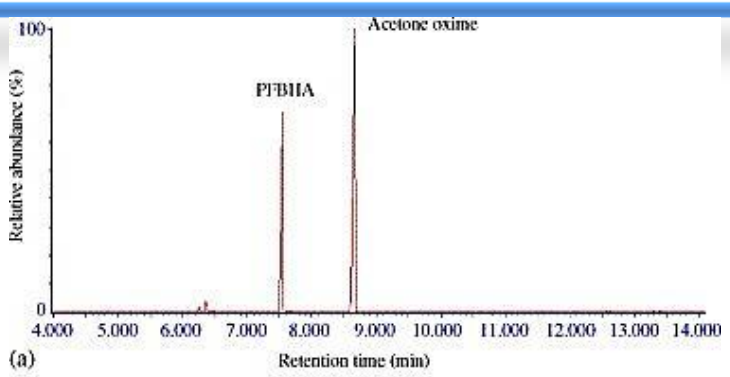
Exhale Breath Analysis based on Chemical Sensors Array



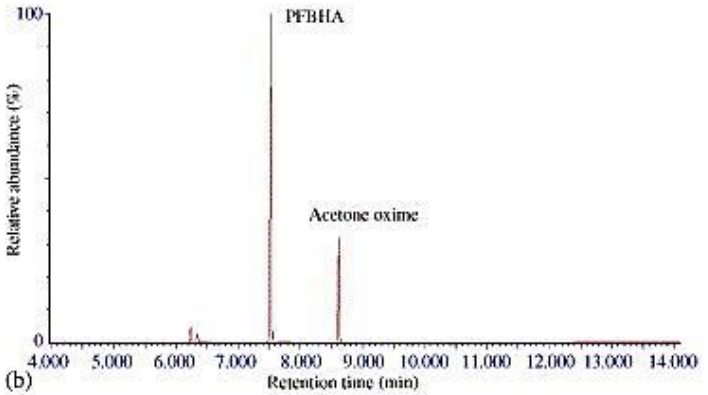
Exhale Breath Analysis (I)

- Control ：0.51 ±0.1 ppmv
- Patient：2.35±0.2 ppmv

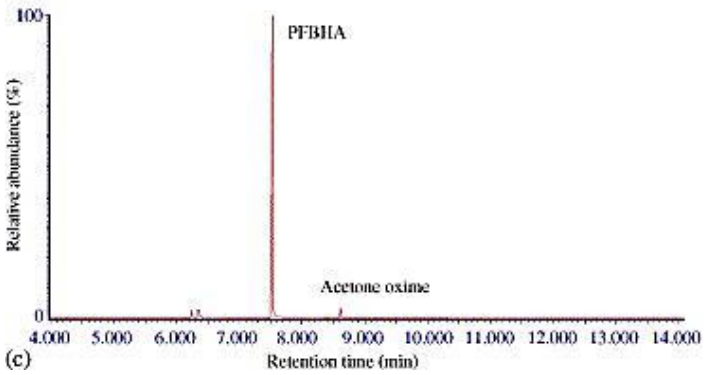
Diabetes patient



Control



Ambient air



- Reference
  - *C. Deng et al. / J. Chromatogr. B 810 (2004) 269–275*
  - *J. Breath Res. 7 (2013) 037109*

Exhale Breath Analysis (II)

ACS APPLIED MATERIALS & INTERFACES
Research Article
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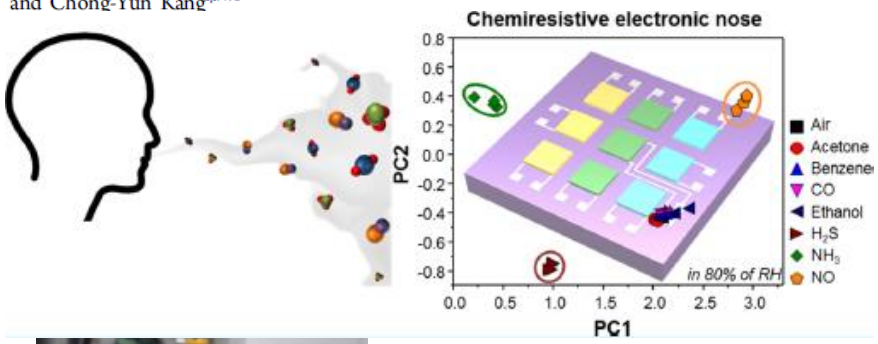
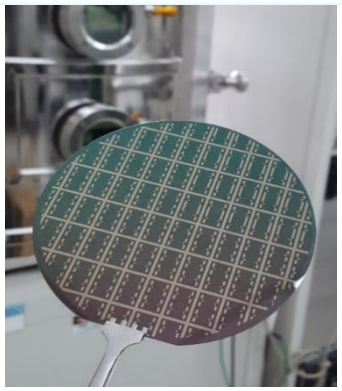
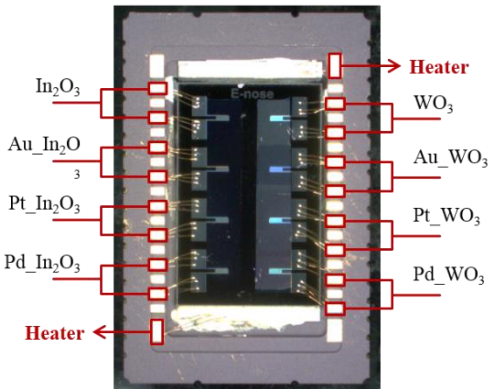
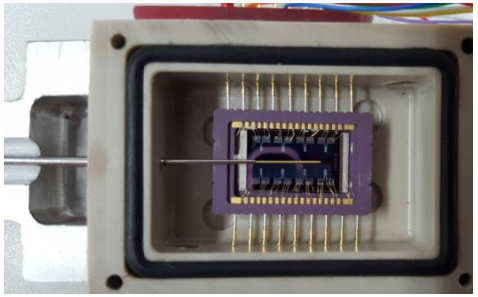
Chemiresistive Electronic Nose toward Detection of Biomarkers in Exhaled Breath

Hi Gyu Moon,[†,‡] Youngmo Jung,[‡,∥] Soo Deok Han,[†,§] Young-Seok Shim,[†] Beomju Shin,[⊥] Taikjin Lee,[⊥] Jin-Sang Kim,[†] Seok Lee,[⊥] Seong Chan Jun,[∥] Hyung-Ho Park,[*,‡] Chulki Kim,[*,⊥] and Chong-Yun Kang[*,†,§]

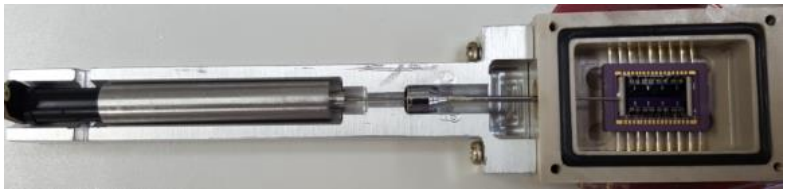




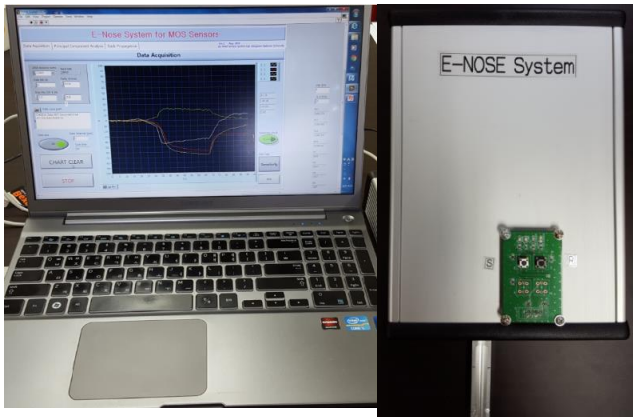




Sensor Array Chamber



Sample Delivery using SPME



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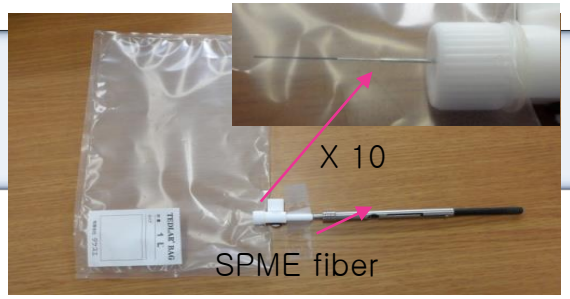
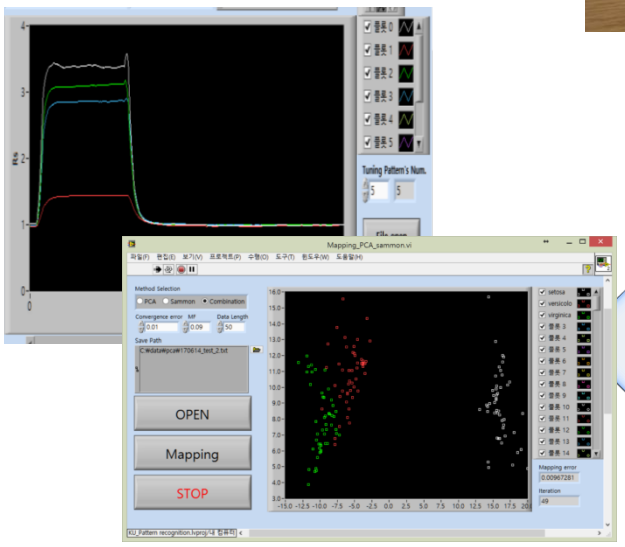
Exhale Breath Analysis (III)

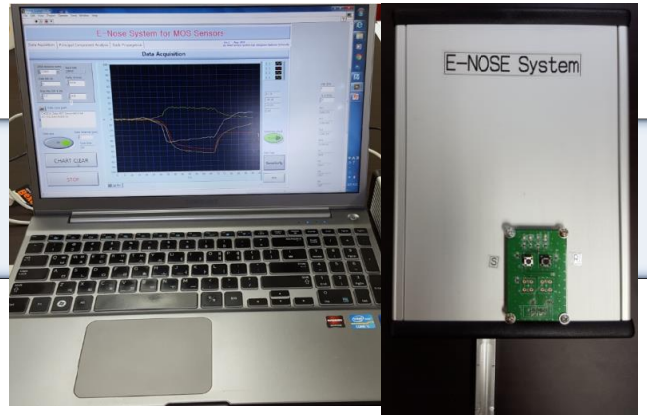
Breath Collection

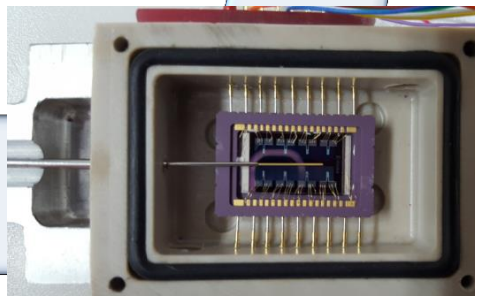
Breath Sampling

Breath Delivery









Identification

Breath test

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Blood Test (IRB: No. DSMC2016-11-021-001)

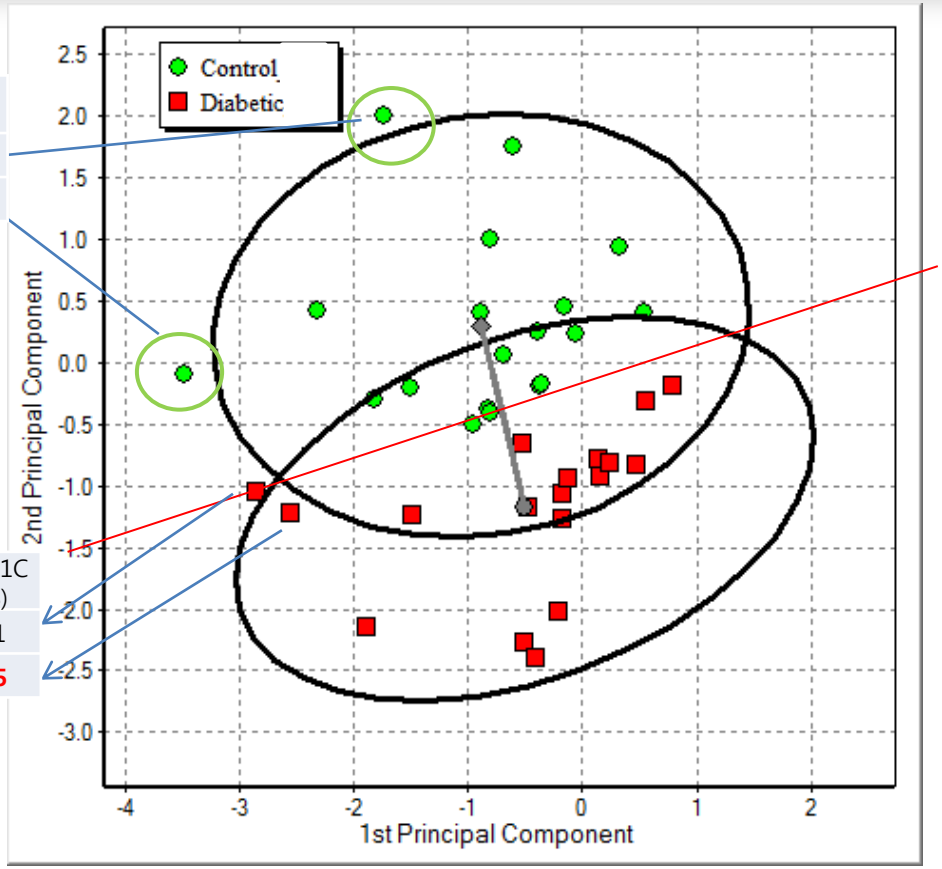
	PLT (x10^3/uL)	Glucose (mg/dl)	BUN (md/dl)	T.Bilirubin (mg/dl)	ALP (U/L)	AST (U/L)	ALT (U/L)	HbA1C (%)
Standard for Diagnosis	130~400	<100	5~23	0.3~1.0	66~220	0~35	0~35	<6
Average of Control	261	94	12.96	0.8264	61.7	22.44	**20.84**	**5.232**
Average of Diabetes	273	145	17.24	0.6984	76.8	23.44	**21.28**	**6.452**

- BST(blood sugar test)
- PLT(platelet)
- **Glucose**
- BUN(blood urine nitrogen)
- T.Bilirubin
- ALP(alkaline Phosphatase)
- AST(Alanine aminotransferase)
- ALT(Aspartate aminotransferase)
- **HbA1C: glycated haemoglobin glicose**

Exhale Breath Analysis (IV)

	PLT (x10^3/uL	Glucose (mg/dl)	BUN (md/dl)	T.Bilirubin (mg/dl)	ALP (U/L)	AST (U/L)	ALT (U/L)	HbA1C (%)
Healthy_ No.2	247	97	14	0.5	45	13	5	5.3
Healthy_ No.3	247	87	8	0.95	70	30	56	4.9

	PLT (x10^3/uL	Glucose (mg/dl)	BUN (md/dl)	T.Bilirubin (mg/dl)	ALP (U/L)	AST (U/L)	ALT (U/L)	HbA1C (%)
DiabetesNo.23	**194**	108	**9**	1.92	68	20	21	6.1
DiabetesNo.1	**727**	125	**7**	0.28	**101**	34	**52**	**7.5**



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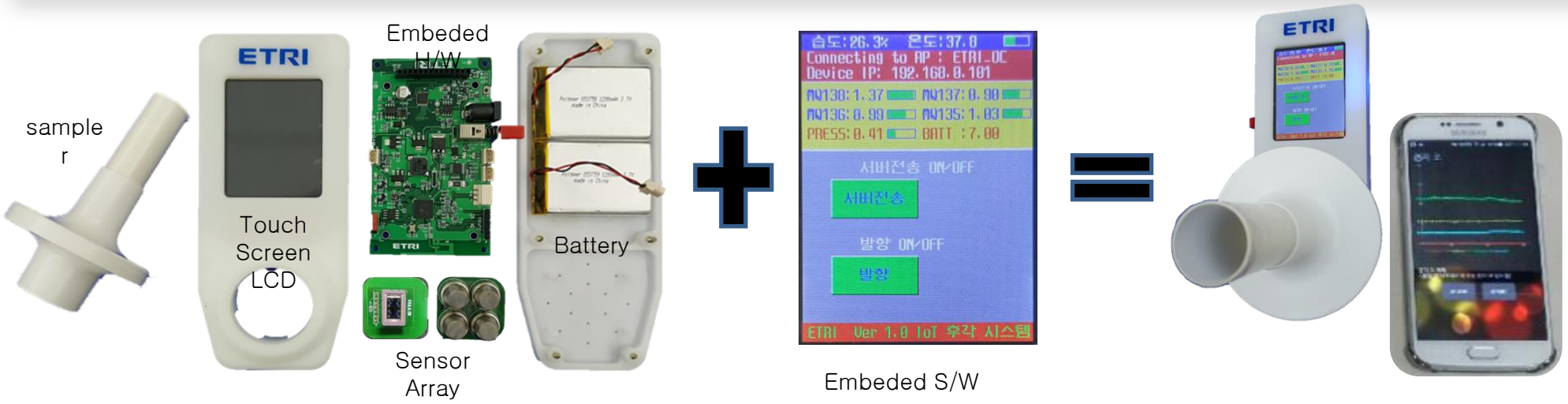
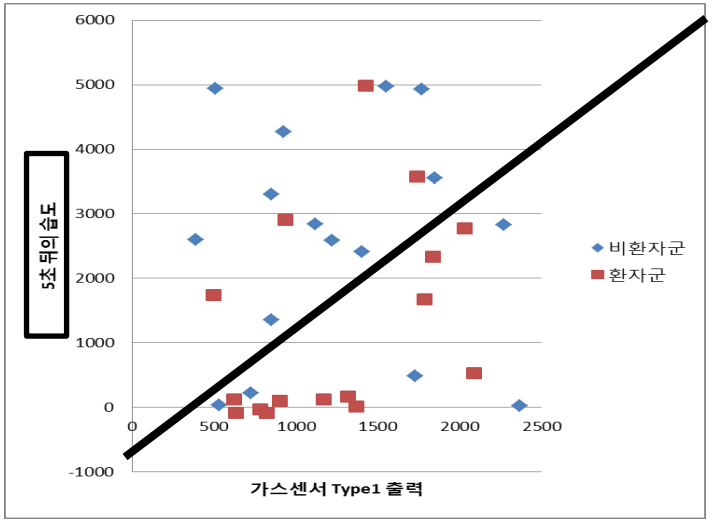
Exhale Breath Analysis (V)





Work we are doing (II)

Data Analysis for Chemical Sensors Array

Gases (Odors) Sampling System

$Sensor_0$

$Sensor_1$

$Sensor_N$

Signal Processing Electronics

Array processor

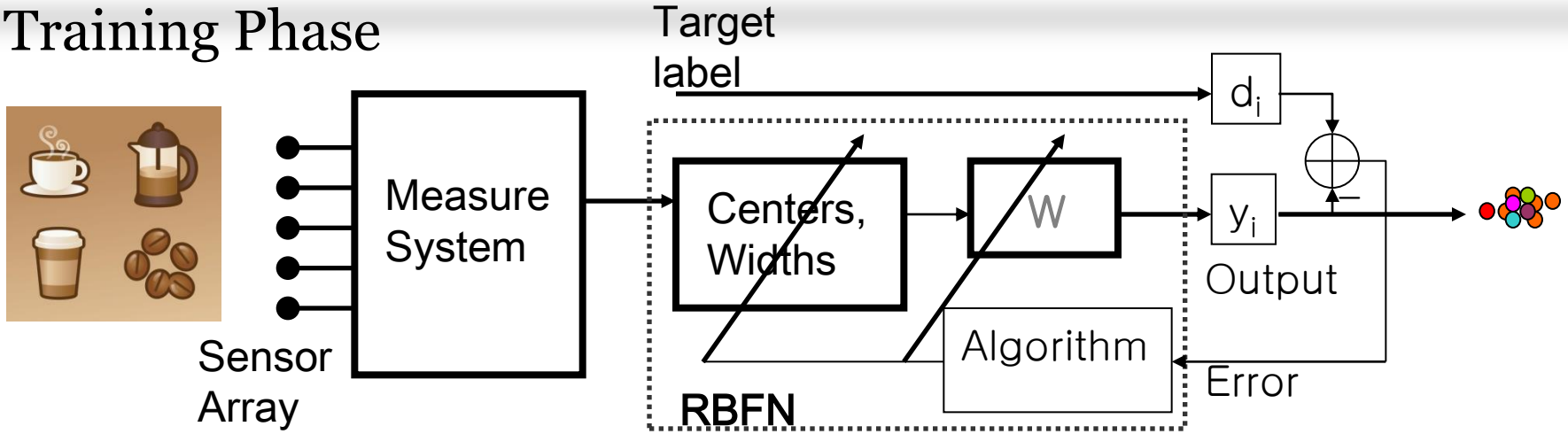
Knowledge Base

PARC Engine

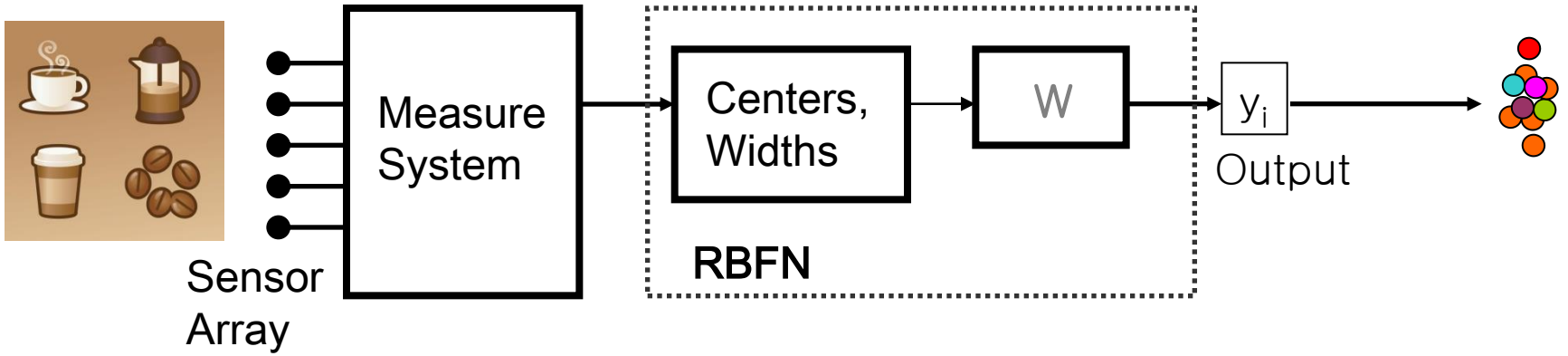
Classifier Outputs

Radial Basis Function Network Classifier (I)

Training Phase



Test Phase



Radial Basis Function Network Classifier (II)

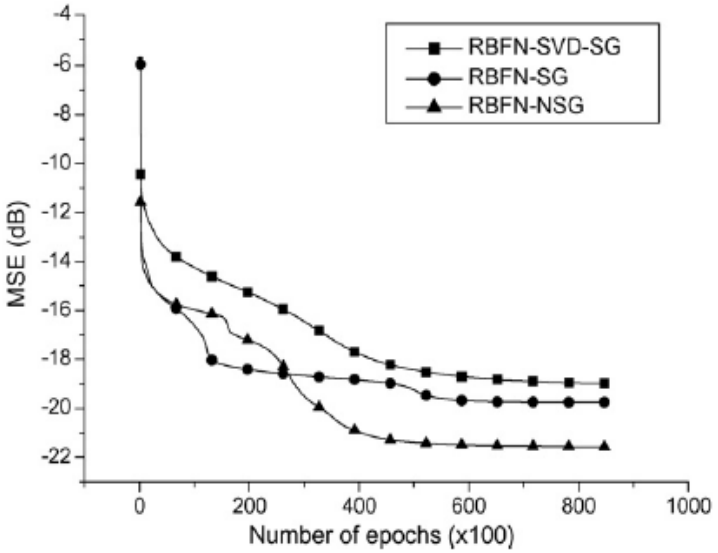


Fig. 4. The learning performance for training algorithms of RBFN-SVD-SG, RBFN-SG and RBFN-NSG. Convergence coefficients for RBFN-SVD-SG and RBFN-SG are 0.00005 and 0.001, respectively. The constant a for ${}^{*}\mu_c^{(n)}$ is 1400. ${}^{*}\mu_w^{(n)}$ in RBFN-NSG and μ_s in RBFN-NSG are 400 and 0.001, respectively.

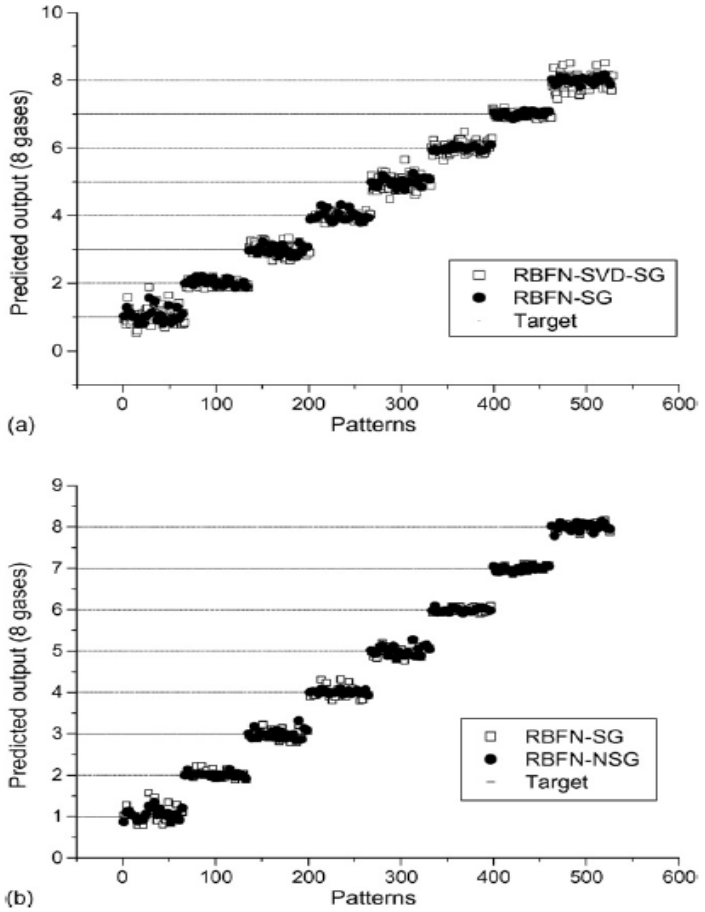
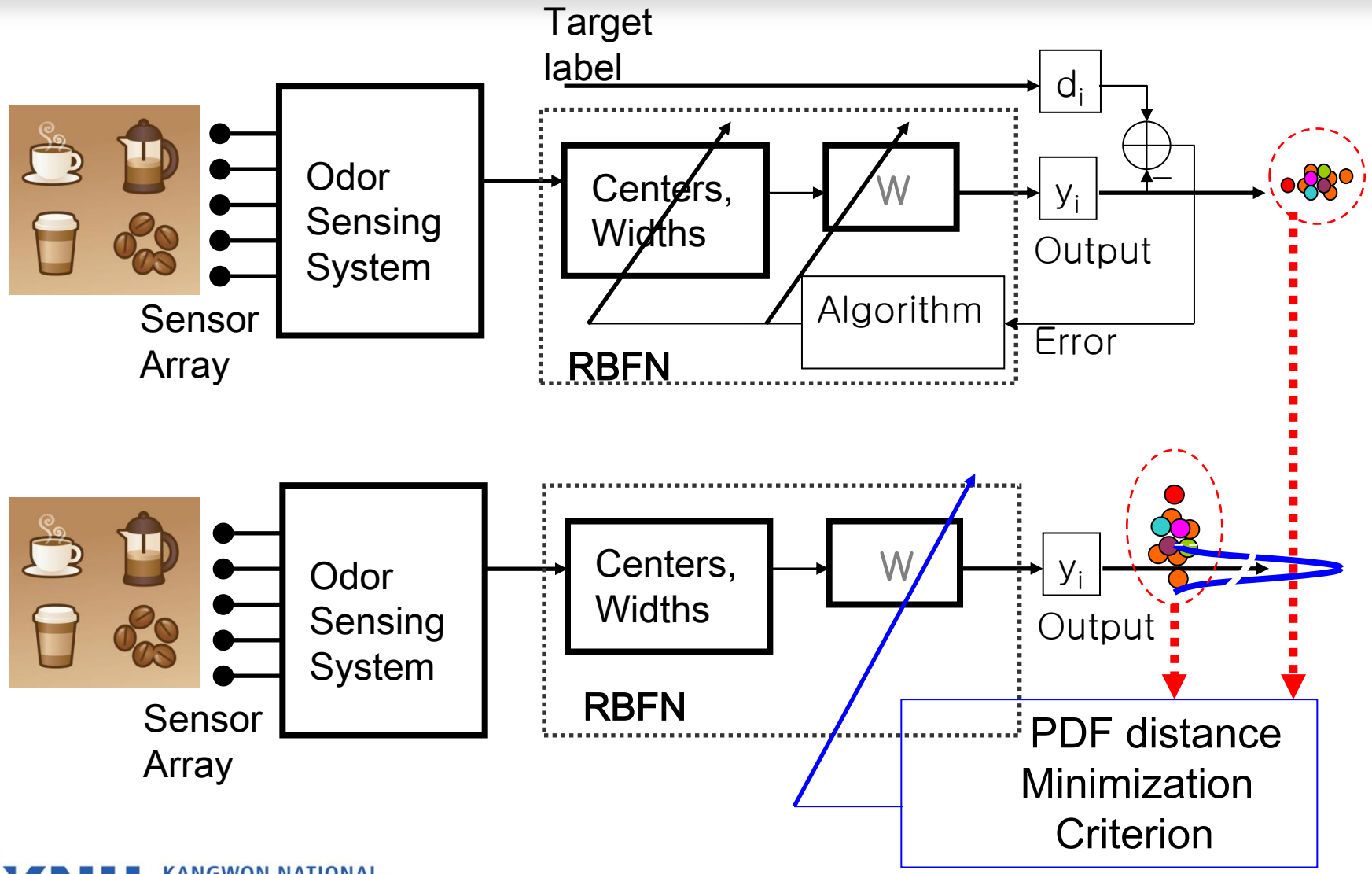
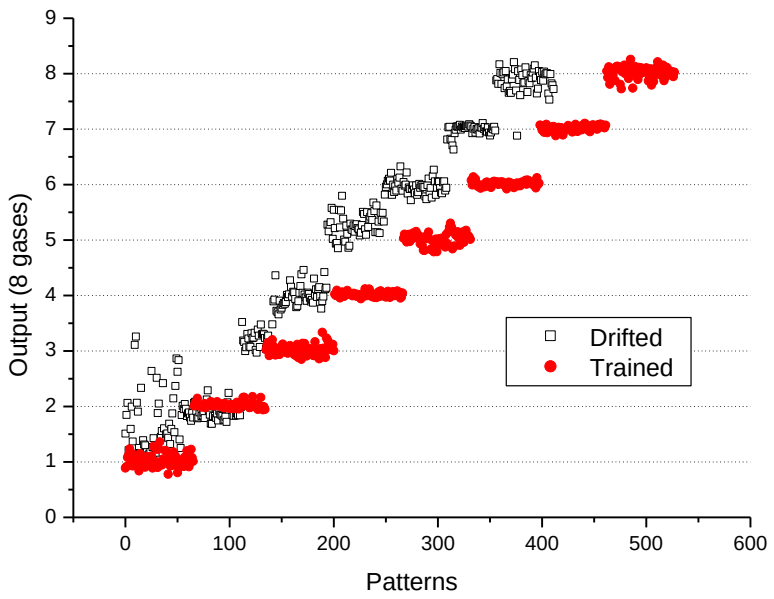


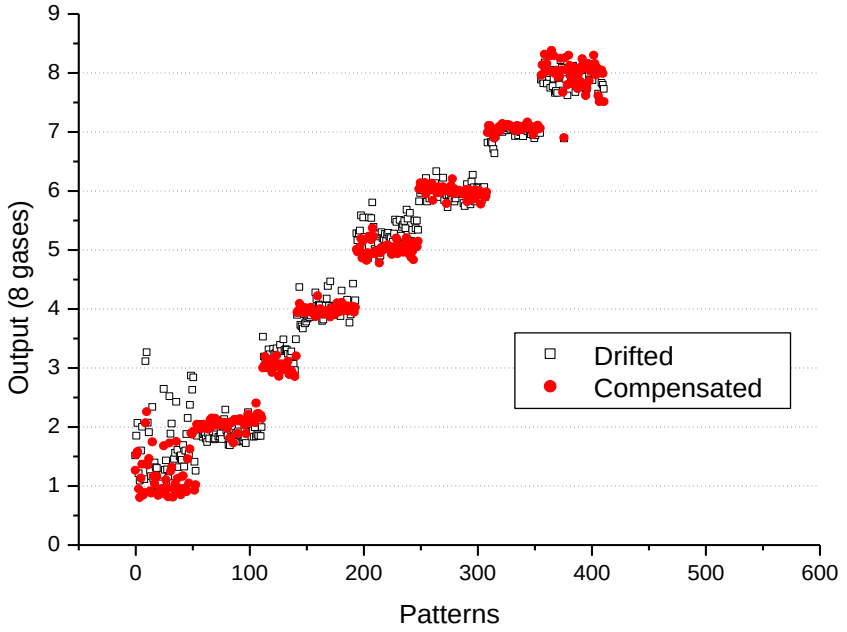
Fig. 5. Classification results for 8 solvent vapors with associated concentrations (1: ac1, 2: ac10, 3: ae, 4: bu, 5: me, 6: pr1, 7: pr10, 8: wa). X-Axis is the number of input patterns. For clearer performance comparison, two algorithms are compared: (a) for conventional RBFN-SVD-SG and RBFN-SG, and (b) for the same RBFN-SG and the proposed RBFN-NSG.

Drift Compensation based on RRFN (I)

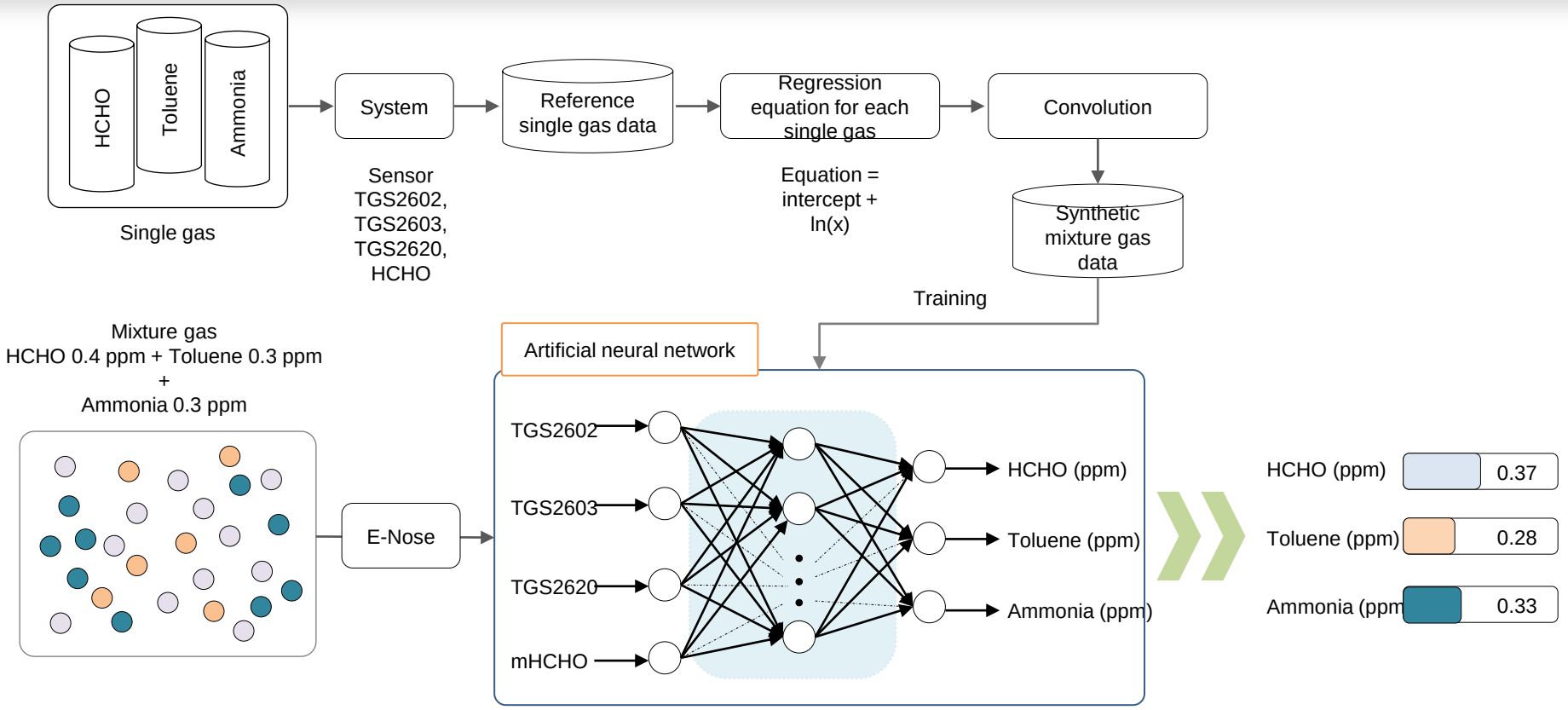


Drift Compensation based on RRFN (II)

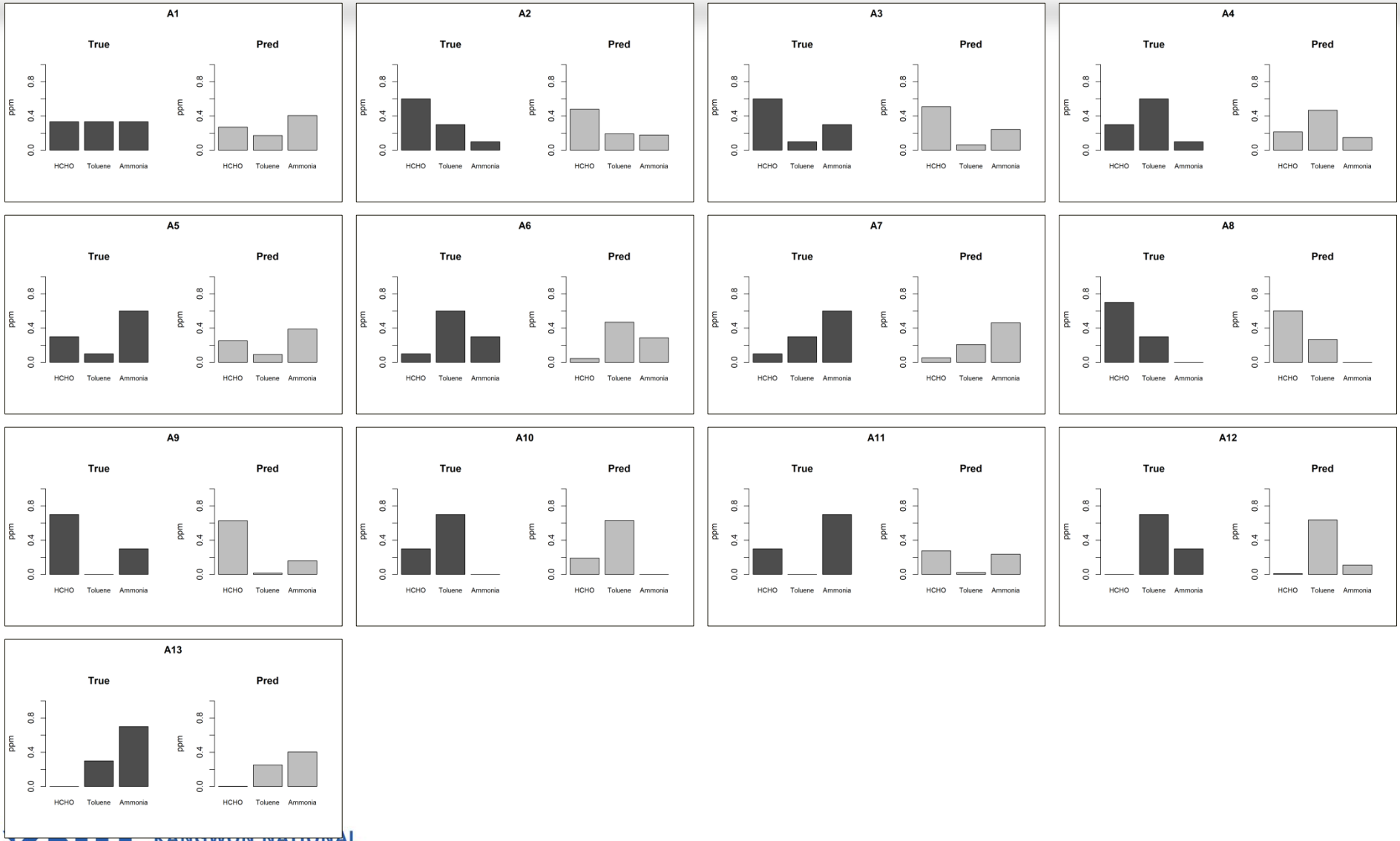




Identification & Concentration Estimation Using AI(I)



Identification & Concentration Estimation Using AI(II)



Work we want collaborating (I)

Exhale Breath Analysis based on Chemical Sensors Array

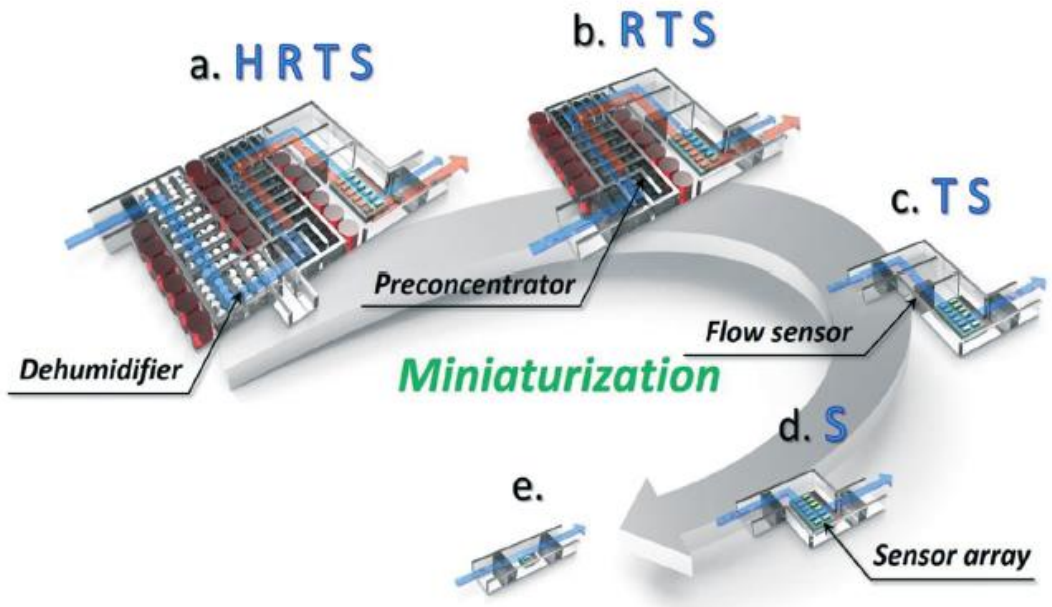
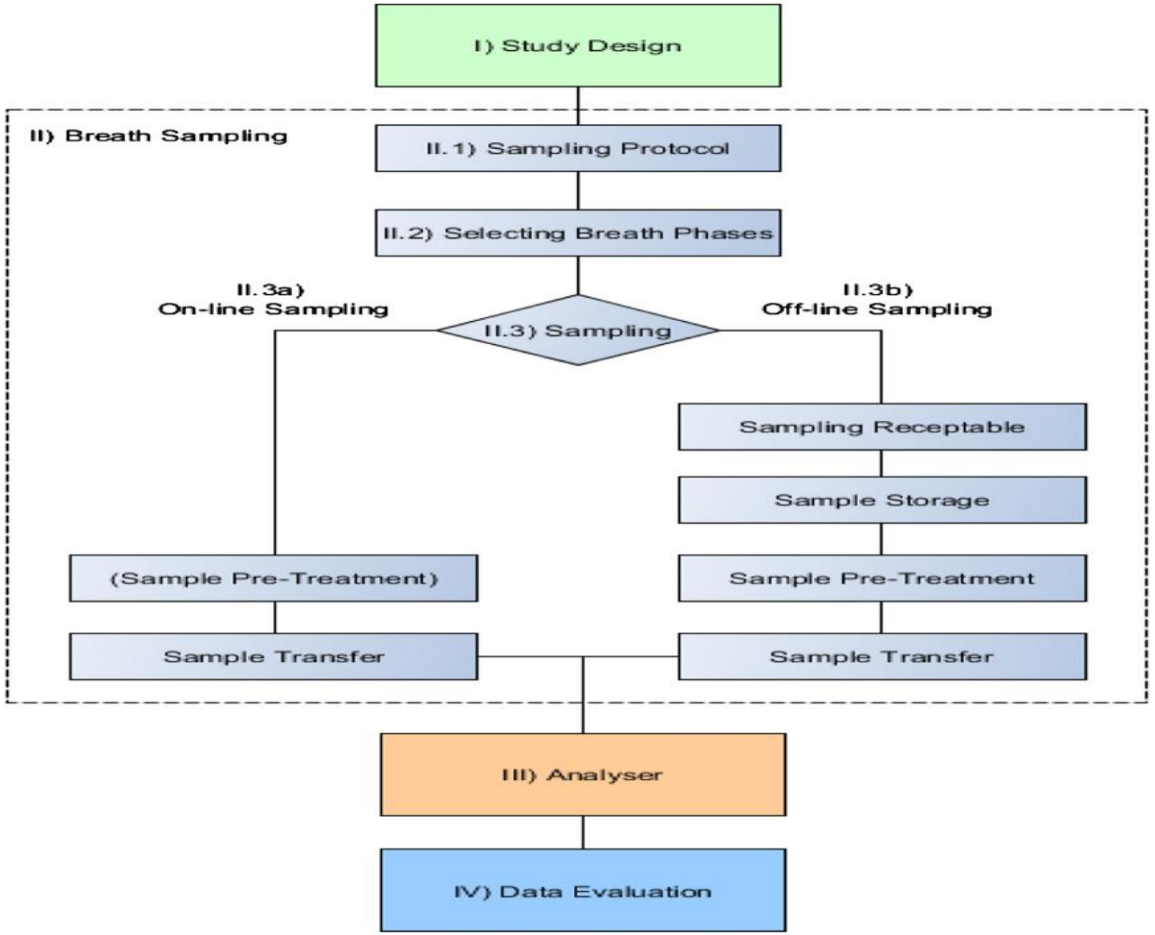


Fig. 8 Integrating microsystems for disease diagnosis into a chip-scale device through improvements in gas sensing characteristics of the sensing materials. Microsystems consisting of: (a) a dehumidifier, preconcentrator, flow sensor, and sensor array; (b) a preconcentrator, flow sensor, and an array of sensors with negligible humidity interference; (c) a flow sensor and an array of sensors with high response and negligible humidity interference. (d) An array of sensors with high response and negligible interference from humidity and sensor temperature. (e) A gas sensor with high response, excellent selectivity toward a specific biomarker gas, and negligible interference from humidity and sensor temperature (H: Humidity-dependent sensor; R: low Response sensor; T: Temperature-dependent sensor; S: low Selectivity sensor).

J. Lee et al Ref. Lab on a Chip 2017, 17, 3537-3557

Work we want collaborating (II)

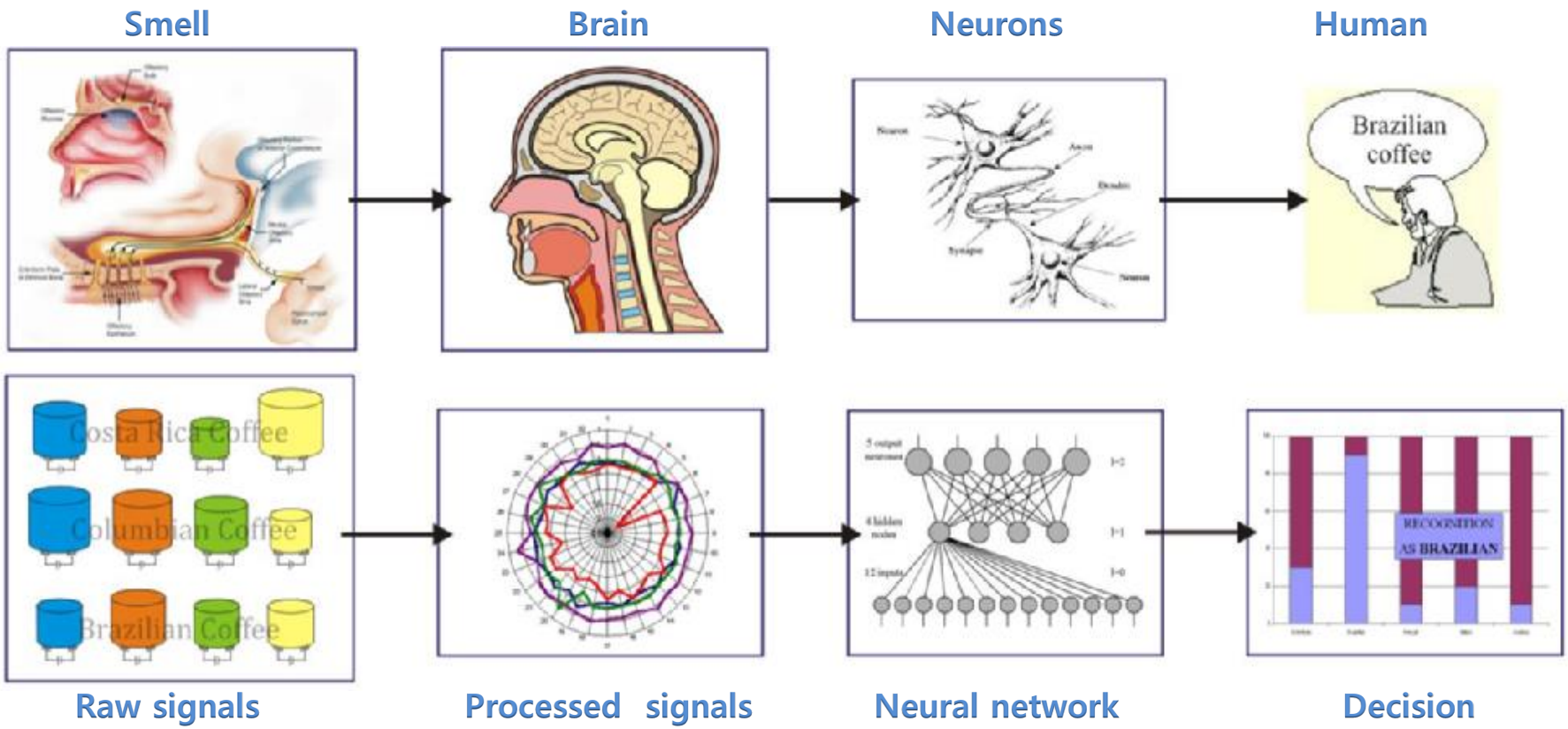
Standard Operation Protocol for Exhale Breath Analysis based on Chemical Sensors Array



Jens Herbig & Jonathan Beauchamp " Toward standardization in the analysis of breath gas volatiles" J. Breath Res. 8 (2014)

Work we want collaborating (III)

Real-time Data Analysis based on Chemical Sensors Array



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& Dr. Joon Bu Yu (Kangwon National University)