Industrial Case Studies I

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The Market of
Electronic Noses and Artificial Olfaction

Estimates of Enose Market

€ 5M	Nexus Report (in 2002)
€ 10-15M	Wall Street Journal (1998)
€ 10M	Greenberg (1998)
€ 12M	Attempto Service GmbH (in 2001)
€ 50 M	FutureTech Report
€ 145 M	Gardner / Bartlett (in 2000)
€ 1200 M	German Infotech (in 2004)
€ 4500 M	The Economist (1998)

» Source: Gardner 1st Workshop NOSE II

9 Commercial E-nose Companies in 1997

Product name	Supplier	Started	Sensor no./ type	Comments
Aromascanner	AromaScan Plc, UK	1994	32 CP resistors	Medium sized company. Market leader in 1997. Autosampler and air conditioning unit available
Bloodhound	University of Leeds Innovations Ltd	1995	32 CP resistors	Small company. Instrument based on research at Leeds University.
e-NOSE 4,000	Neotronics Scientific Ltd, UK	1995	12 CP resistors	Medium sized company. Available with autosampler and sister company to Neotronics Ltd (UK)
Fox 4,000	Alpha MOS, France	1993	18 MOS	Medium sized company. Autosampler and air conditioning unit available.
Moses II	Lennartz Electronics, Germany	1996	MOS/QCM	Modular system based on research at University of Tubingen, Germany.
Olfactometer	HKR Sensorsysteme GmBH, Germany	1994	6 QCM	Small company. Based on research at University of Munich, Germany.
Scentinel	Mastiff Electronic Systems Ltd	-	16 CP resistors	Small company. Instrument based on research at Leeds University aimed at sniffed palms for personal identification.
Rhino	USA	1994	4 MOS	Early instrument may no longer be available.
ScanMaster II	Array Tec	1996	8 QCM	Small company. Launch November 1996

Source: Gardner and Bartlett, Electronic Noses 1999, OUP

17 Commercial E-nose Companies in 2002

Company	Sensor Core	System
Agilent Technologies	MS	4440
Alpha M.O.S.	MOS, CP, SAW	Fox, Centauri
	MS and MS-EN	Kronos & Prometheus
	electronic tongue	Astree
Applied Sensor	MOSFET, MOS, OCM	3320, 3310
	4 x MOS, 8 xOCM	VOCseries ((ref 1))
	OCM	VOCcheck ((ref 1))
Bloodhound Sensors	CP	BH114
Cyrano Sciences Inc.	CP (composite)	Cyranose 320 ((ref 1))
Daimler Chrysler Aerospace	OCM, SAW, MOS	SAM system
Electronic Sensor Technology	SAW	zNose
Element	MOS	FreshSense
Environics Industry	IMCELL	MGD-1
Forschungszentrum Karlsruhe	MOS, SAW	Sagas
HKR Sensorsysteme	OCM, MS	OMB6
Lennartz Electronic	QCM, MOS, electrochemical	MosesII
Marconi Applied Technologies	CP, MOS, OCM	e-Nose 5000
Microsensor Systems	SAW	ProSat
Osmetech	CP	OMA and core sensor module
Quartz Technology	OCM	QTS-1
SMart Nose	MS	Smartnose-300
WMA Airsense Analysentechnik	MOS	PEN

Source: Vanneste, Handbook of Machine Olfaction (2002), Wiley-VCH

23 Commercial E-nose Companies in 2005*

Manufacturer	Products	Technologies
Airsense	GDA, PEN, i-PEN/MOD, KegControl, Proc.Ctrl Nose, EDU	MOS sensors, IMS, thermo desorption
Alpha M.O.S.	Fox, Prometheus, Gemini, Kronos, Astree	MOS, CP and QMB sensors, MS, GC, Electronic Tongue
AltraSens	OdourVector	QMB
AppliedSensor	Embedded modules	MOS, FE and QMB sensors
Dr. Födisch Umweltmesstechnik AG	OMD 1.10; OMD 98	MOS
Element	FreshSense	MOS
Environics Oy	Chempro 100, ...	IMS, sensor arrays
Electronic Sensor Technology	Znose	GC with SAW detector
Five Technologies GmbH	QMB 6, MS-Sensor, SensiTOF	QMB sensors, MS
GERSTEL GmbH & Co. KG	ChemSensor	MS, GC, MOS, TDS
Illumina Inc	BeadStation	Bead arrays
Lennartz electronic GmbH	MOSES II	MOS and QMB sensors
Meridiantek AG / Sensobi	DL 1000, DL 1000 IS, DL 1000 IS Smoke	SCP sensors
Microsensor Systems Inc	VaporLab, Hazmat, Eagle Monitor ...	SAW sensors, GC
Perkin Elmer	QMB6	QMB sensors
Quartz Technology Limited	QTS-1	QMB sensors
RST Rostock System-Technik GmbH	SAM detect, ...	MOS sensors
SACMI	EOS 835	MOS sensors
Scensive Technologies Ltd	Bloodhound, ST214	CP and DLC sensors
SMart Nose Ltd	SMart Nose	MS
Smith Detection /Cyrano Sciences	Cyranose 320	Carbon black polymer sensors
Sysca AG	Kamina	MOS
Technobiochip	Libra Nose	QMB sensors

Source: JLM Innovation / NOSE II, Market Survey Electronic Nose 2005

Application Areas and Potential Markets

Quality assessment of food and beverages

- very fragmented, low volume, various deployments

Pharmaceutical and chemistry applications

- very fragmented, low volume, various deployments

Medical applications

- Highly regulated, mid to high volumes, no deployments yet

Safety and military applications

- Mid volumes, various deployments

Environmental and agricultural applications

- Fragmented, low to mid volumes, few deployments

Embedded Applications

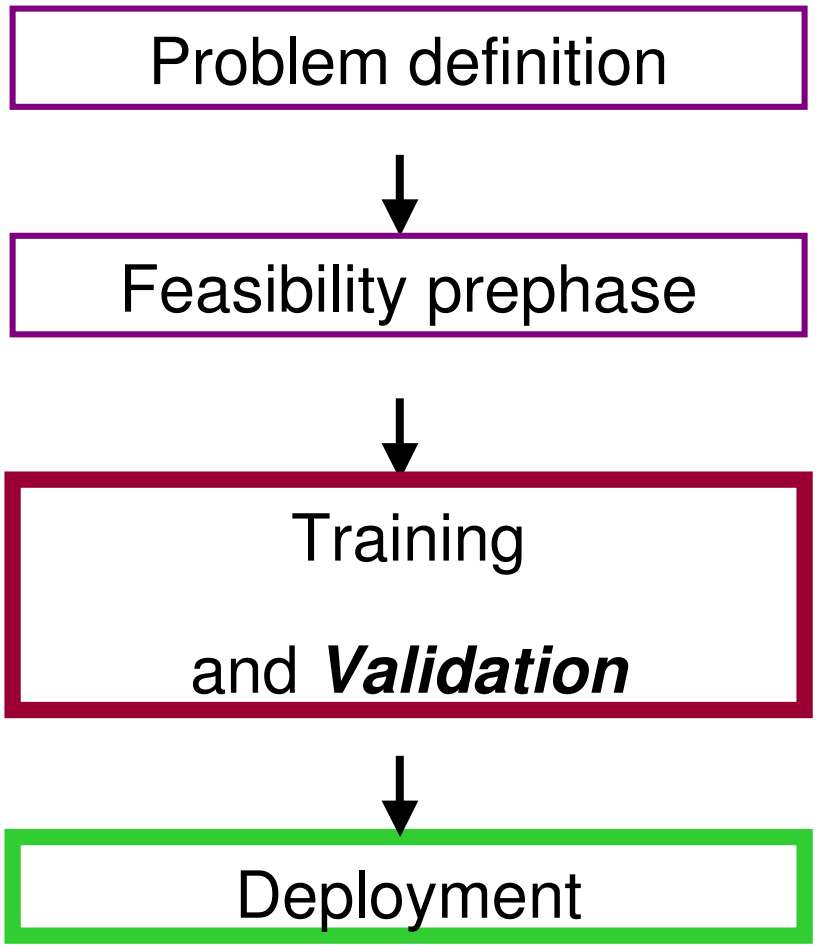
- Mid to high volumes, very cost sensitive, few deployments

Electronic NOSE survey 2005

- Generic instruments, handheld instruments, dedicated systems and embedded devices were covered
- More than 30 companies involved in electronic nose instrumentation and technology
- Applications in food industry, chemistry and pharmaceutics, medicine, safety and military, environmental and agricultural, and automotive
- Market for generic instruments is very fragmented with low growth.
- Dedicated systems for medical and safety applications have a lot of potential. Several companies are focused on these markets.
- Simple embedded devices are being introduces to automotive and consumer markets with strong growth.
- For many application further improvement of the technology is necessary.

Limitations of the classical Electronic Nose

Application Steps



Specifications / Requirements

Expert analysis

Tests with limited sample set

Extensive sample set (all classes, good bad, cross sensitivities)

Reference methods

Expert know-how

Installation at (multiple) sites

Feasibility vs. Application dev.

Feasibility Study

-> Check for discrimination (e.g. PCA-Plot)

-> Assess main components / cross interference

=> No final answer for success!

Application Development

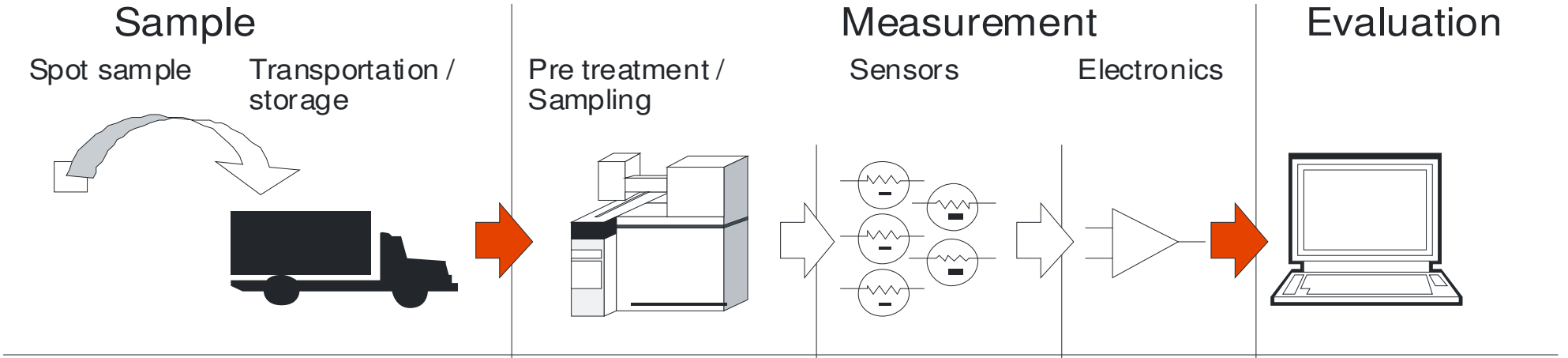
-> Optimization of method (technology, ...)

-> Validation

-> Reproducibility, Reliability, ...

=> Ready for implementation (or not...)

Typical error sources



Non represantative spot sample, changing matrix, Influence of temperature, pressure, humiditz, contaminations during sampling, transport and storage.	Contamination, Influence of temperature, pressure, carrier gas, amount and volume on headspace	Drift, poisoning, temperature, pressure, carrier gas, reference gas, gas flow.	Component drift, temperature, noise. Resolution or measurement range too small	Error in reference data or recalibration data. Numerical effects. Inadequate algorithms.

Time to successful application

	Months
First contact	0
Second contact: Initiation of collaboration Feasibility study	2-3
Discussion + budget allocation	6 – 12
Application development	> 6
Acceptance + budget allocation	6 – 12
=> Repeat sales	======
	Min 2 years

Classical Enose: Cost per sale

Instrument development	x M€ / sold instruments
Instrument manufacturing	x k€
Marketing	Marketing cost / sold instr.
Feasibility	0.x k€
Application development	0.x M€ / (sold instr./ appl.)
Customer support	x k€

Optimum: Few applications with high numbers

Real world: Average sale per customer: 1.x

Success strategies ?

Price ≠ Cost ≠ Manufacturing cost

-> Price = Customer Value

Be efficient

-> Don‘t waste your money on

-> impossible applications (technology fit)

-> non profit applications (nice to have)

Adopt your business modell

-> Concentrate on your strength

-> We need more specialization and open exchange

From research to real life

From research to real life

Example 1:

Quality control of packaging material

Examples: PARFUM / ESCAPE

Philips-DAP, Netherlands
Philips-LEP, France
CSEM, Switzerland
Microsens, Switzerland
MOTECH, Germany
Neotronic Scientific, UK
Nestlé, Switzerland
AppliedSensor, Sweden
Gerstel, Germany
INRA, Dijon, France
Wall, Austria
Univ. Tübingen, Germany

Quality control of packaging material

State of the Art:

Human Odour Panel

Development

Automated investigation

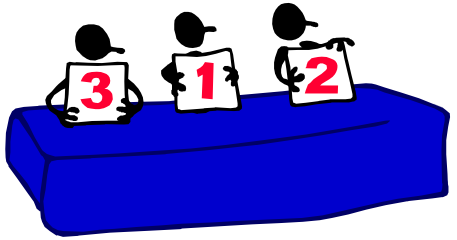
with “Electronic Nose”

Better called application specific sensor system (a triple s)

Scoring

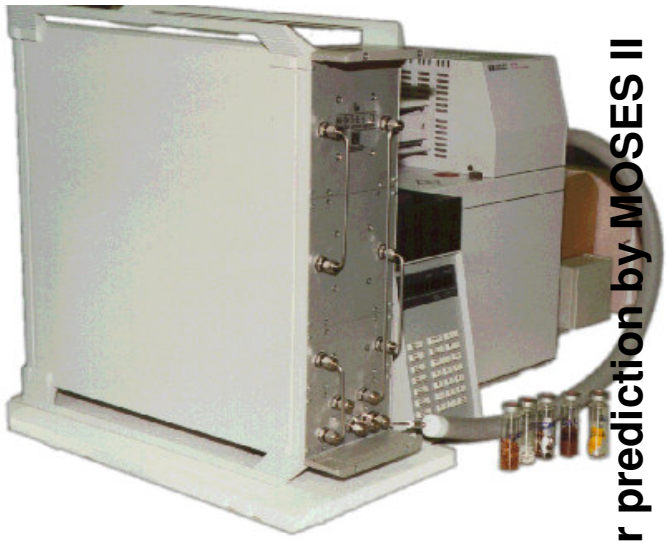
Evaluation of odor and taste in comparison with a reference material. The difference is estimated according to the following category scale:

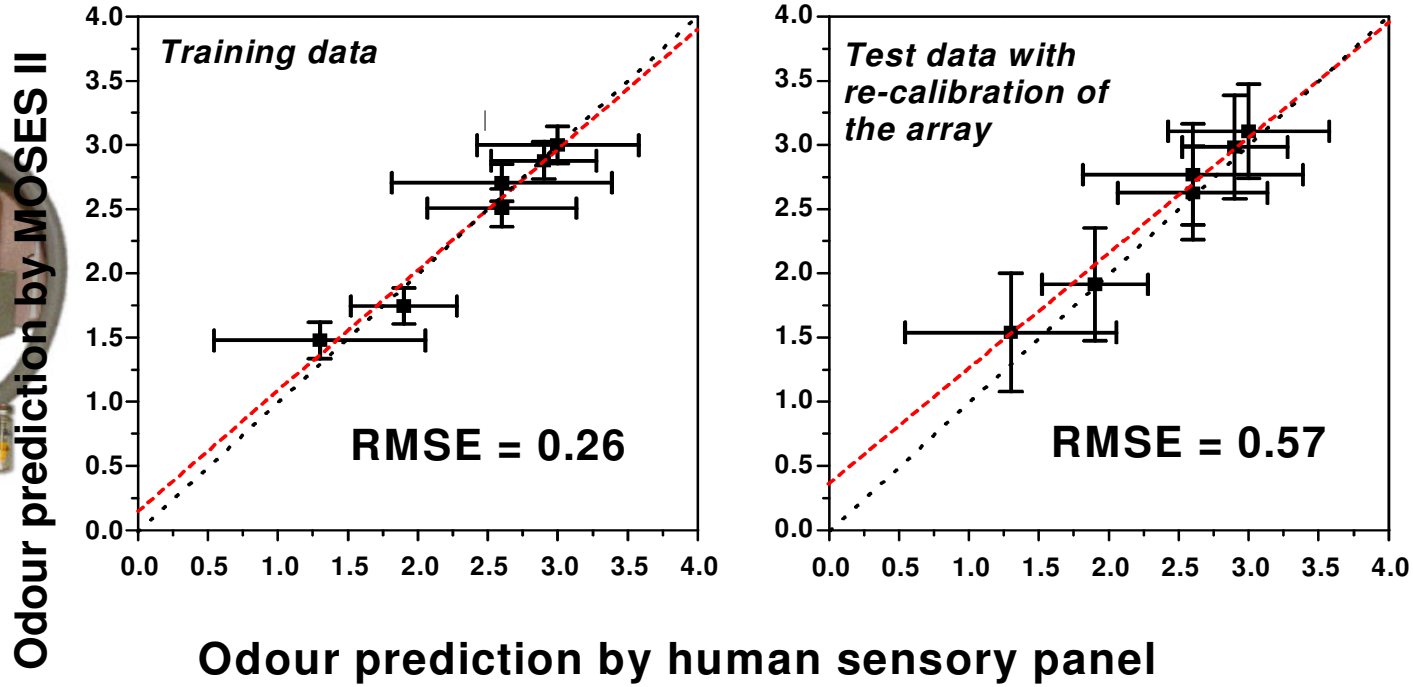
- 0: no difference with the reference
- 1: hardly perceptible difference (not definable)
- 2: slight difference (just definable)
- 3: strong difference (clearly definable)
- 4: very strong difference



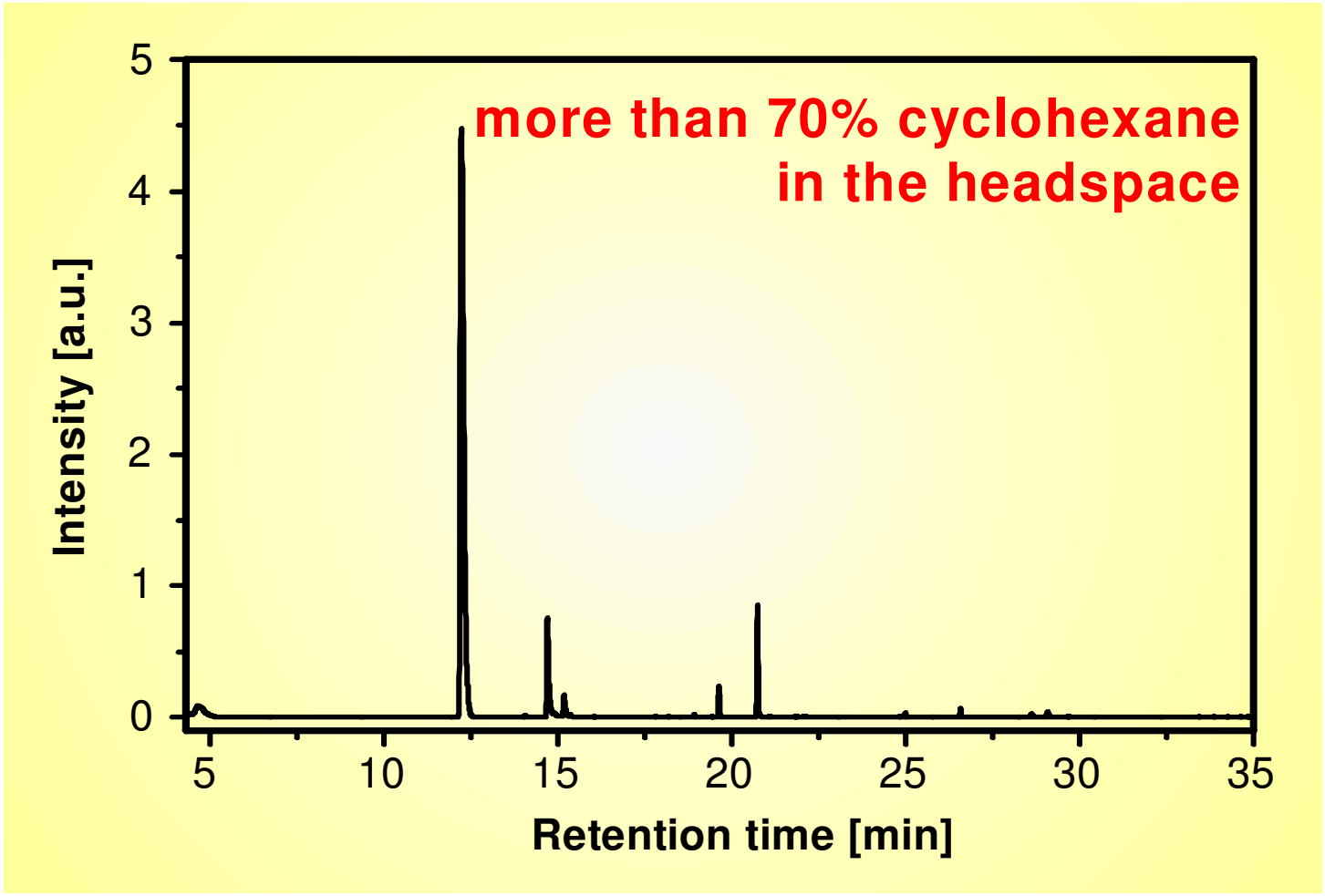
Any packaging materials with a median score equal or greater than 2.5 is considered to be of doubtful quality and should be submitted to further analyses.

Quality control of packaging material

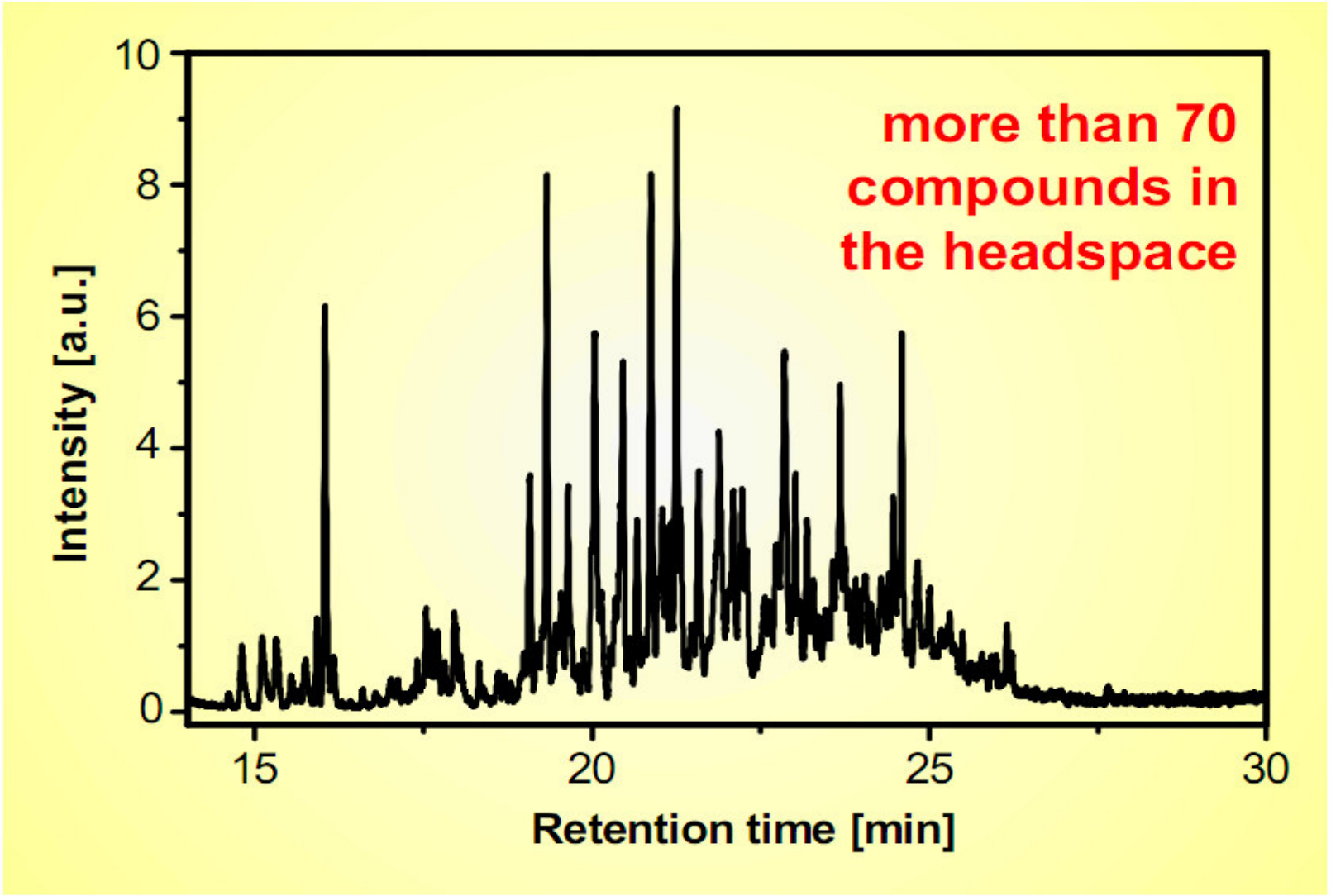




GC/MS of Nestlé Packaging Material



GC/MS of Packaging Material, Bad Case



Quality control: Final Product

Application specific sensor system (a triple s)

Quality Control: Lessons learned

Odor quality assessment by panels delivers imprecise data

Solutions are possible in simple cases (few components)

Reference analysis is critical

Methods cannot easily be transferred to new sample types

Reference sample sets are expensive and hard to get

Successful, validated method does not guaranty commercial success

Project characteristics

2 consecutive projects, total duration more than 6 years

Commercialization after the second project

Effort for commercialization low in comparison to research projects

- Prototypes during project based on commercial products
- Low volume
- Small certification requirements
- No challenging production cost constraints

From research to real life

Example 2:

Control of air intake in automobiles

Examples: CIA

VDO Germany

FIAT, Torino, Italy

Telecom Italia

Univ. Warwick, UK

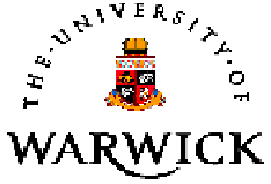
Univ. Southampton, UK

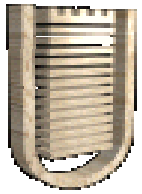
Univ. Rome, Italy

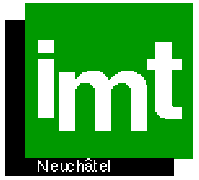
Univ. Linköping, Sweden

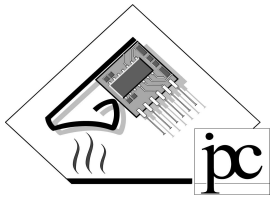
Univ. Neuchâtel, Switzerl.

Univ. Tübingen, Germany





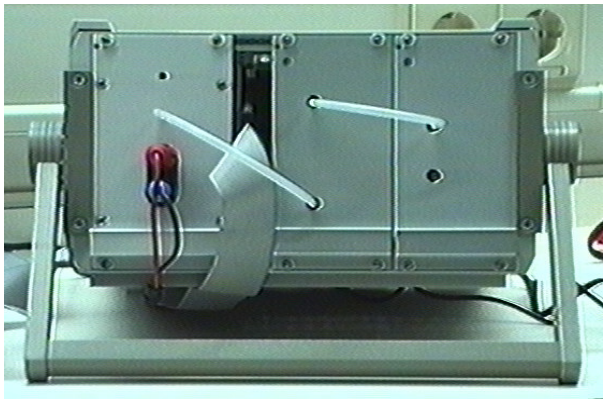


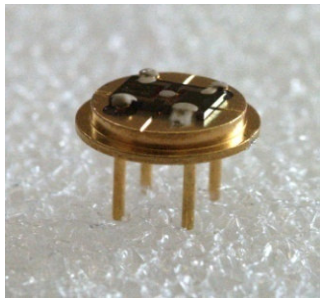


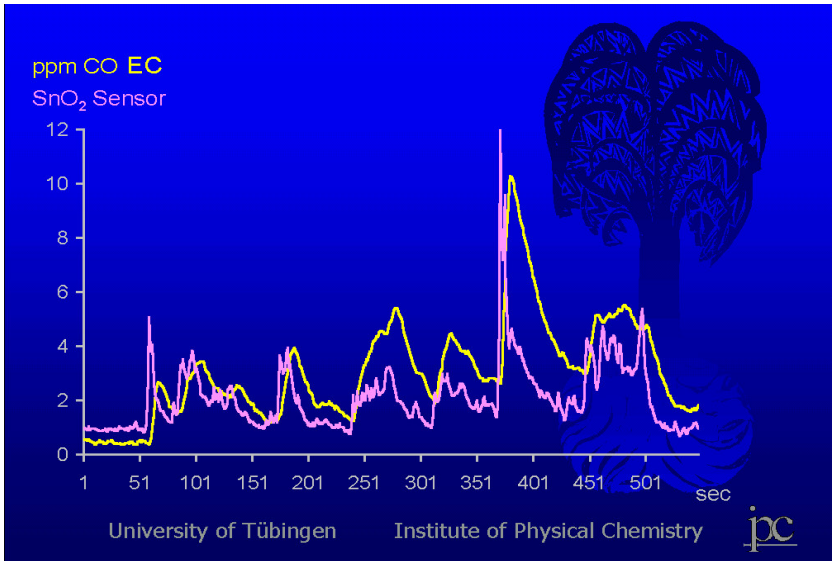
Automotive application

Automatic switching of the re-circulation flap

- Increase of cabin air quality
- Safety issue
- Comfort aspect







Methodology during project

Development of prototype instruments containing different sensor technologies

Real life tests with the prototypes (test drives)

Optimization of the sensor technologies for the application

Development of pattern recognition techniques

Automotive Product

IAQ module from AppliedSensor

Project characteristics

Duration 3 Years

Outcome of the project

- Optimized prototype gas sensors
- Selected sensor technology
- Development methodology

Effort for commercialization very high!

- Prototypes used in project not suitable for commercialization (complete redevelopment)
- High certification requirements
- High volume, very cost sensitive
- New partners required

General remarks / discussion

Criteria for application difficulty

Odor (human perception) > generic

Complex mixture > simple mixture

Variable samples > stable samples

Varable matrix > stable matrix

Minor compound > major compound

Trace detection > high concentration

Unknown analytes > known composition

Reference samples hard to get > easily available

High thru put / short measurement time > no time constraint

Traceability required > not required

No false predictions > indication

Certifications > unregulated

Application economics

Economical potential

- Volume (number of deployments)
- Cost sensitivity / gross margin
- After sales

Development effort

Development risk

Initial costs for production

Sales cycle

Spin off opportunities

Thanks for listening!