



# The Future for Gas Sensors?

## MNT Gas Sensor Forum: progress to date

### GAS DETECTION

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#### Introduction

Gas sensor technology has been slow to evolve, with electrochemical cells dominating the industrial safety market and metal oxides used where cost must be at a minimum. But all this could be set to change. The gas sensor industry is not as large as telecommunications, portable computers, mobile phones or the consumer entertainment markets, but can benefit from the advances in the core technologies these markets fuel and can use the new components designed for these larger markets. However, the gas detection market is fragmented and the new technological opportunities are diverse. Wanting to better understand the next step in gas sensing, the DTI commissioned two workshops, through the MNT (Micro and Nano Technology) Initiative. Although their report was adequate, many of the expert participants felt that a deeper understanding was needed for this difficult industry, so a grassroots group was formed, the MNT Gas Sensor Forum. In September 2005 volunteers formed a Steering Committee (members are listed at the end of this article). The result is a roadmap that brings together user needs with technical advances in micro and nano technology.

#### Scope of the roadmap

The **purposes** of this roadmap are:

1. To introduce emerging MNT and optical technologies to the gas detection community.
2. To help ensure the UK gas sensor community does not miss out on recent technological opportunities.
3. To inform providers of generic MNT and optics technology and components about exploitation opportunities in the field of gas sensors.

The **three target audiences** for this roadmap are:

1. UK Department of Trade and Industry and Research Councils, to help them prioritise core technologies and markets.
2. MNT and optical technology providers, to offer direction and opportunities for their technologies and components.
3. The gas detection community, to show where companies and academia can cooperate.

#### Our approach

As we approached this daunting task, we laid down some general **principles**:

1. Include as many experts from the gas detection community as possible, using UK networks such as the Gas Analysis and Sensing Group (GASG), the Council for Gas Detection and Environmental Monitoring (CoGDEM) and both the Sensors and Optocem KTNs. The Steering Group has members from all of these groups.
2. Take an application-led approach, with individual roadmaps that focus on specific markets.
3. Accept that we do not have all the answers, and engage with communities with the aim of reaching a consensus. We recognise that roadmaps may be contentious or be proven in time to be wrong.

The gas detection market is diverse and fragmented, so we agreed to **structure** the roadmap in three stages:

1. Generate a matrix of markets versus applicable technologies. This matrix is finished – see table 1.
2. Create roadmaps for each market, showing how the market drivers and enablers push the available technologies and components to be included into new products, meeting the market needs. Draft roadmaps for each market are available on our website.
3. Unify the matrix and roadmaps into a report, with explanations of each technology, component and market, as well as proposing market required new products. Underway.

#### Progress to date

##### Matrix

The technology-push, market-pull matrix was our first step. Trying to define the relevant markets and components/ technologies required many iterations, and our full matrix can be found at:

[www.gas-sensor-roadmap.com](http://www.gas-sensor-roadmap.com)

We present here a simplified matrix, table 1. The industry is rife with acronyms and abbreviations, so table 2 spells out these abbreviations but a full explanation of each acronym is beyond this summary article.

ASIC	Application Specific Integrated Circuit
BAW	Bulk Acoustic Wave
BTEX	Benzene, Toluene, Ethyl Benzene, Xylene
CNT	Carbon Nanotube
FPGA	Field Programmable Gate Array
GC	Gas Chromatography
IMS	Ion Mobility Spectroscopy
LEL	Lower Explosive Limit
MEMS	Micro Electro Mechanical System
MO	Metal Oxide
MS	Mass Spectrometry
NIR	Near Infrared
PIC	Programmable integrated Circuit
PM10, PM 2.5	Particulate Matter 10 (um), 2.5 (um)
QD	Quantum Dot
QMB	Quartz Microbalance
SAW	Surface Acoustic Wave
THz	TeraHertz
WWT	Wastewater Treatment

Table 2. Abbreviations for Gas sensor road mapping.

Studying the matrix reveals that certain markets need new optical devices, while other markets appear to be awaiting MEMs or new sensing materials. Even the arguably entrenched technologies of electrochemistry and physical chemistry are gaining new opportunities, with advances in catalysts and electrolytes for electrochemical cells, or MEMS devices for calorimetry and determining bulk gas characteristics.

#### Roadmaps

Over a dozen roadmaps have been created, one for each market, in the form of a timeline. Figure 1 (Overleaf) shows the roadmap for fire detection. Each roadmap is divided into 5 categories:

Market Drivers	Market demands, legal and regulatory requirements
Products	Market specific instrumentation/ detection systems, requiring new technologies and new components to achieve market requirements. A product is defined as something that an end user might buy.
Components	New optical, electronic or MEMS components, mostly coming from technology advances and components developed for larger markets.
Technologies	Background materials and technological advances which either directly drive product development or push new component development.
Enablers	Fundamental scientific knowledge, or removal of market constraints, needed to either make the products reliable or to drive the technology and component developments.

	Existing markets		Domestic safety		Automotive		Industrial safety		Process control			The Law	Emerging markets		Niche			Air quality			Homeland security	Medical	
	Fire and home safety	Leak detection	Car emissions	PM10, PM2.5	Industrial safety & LEL	Confined space entry	Stack emissions	Process control and analysis	Food processing, transport and storage	Breathalyzer / alcohol & drugs	Hydrogen: fuel cells	Extreme environments (planetary, oil)	Ammonia	Benzene, BTEX	Outdoor air	Indoor air	Asthma, allergies	Odours (WWT, landfill)	Explosives/ terrorism	Breath analysis & capnography			
<b>Components</b>																							
Lasers and optics	2	5	4	4	4	3	5	5	3	3	2	4	4	1	5	5	1	4	5	5	5	5	
UV, IR, microplasma sources	4	3	4	4	5	4	5	5	3	5	1	3	4	4	4	5	1	4	4	4	5	5	
Wavelength separation MEMS	3	2	4	1	2	2	3	5	4	3	1	3	4	4	2	4	2	4	2	4	4	4	
Low cost optics, detector arrays	4	3	3	4	4	3	3	3	4	4	1	1	3	4	2	5	1	2	1	4	4	4	
Fibre optics	2	3	2	4	4	3	4	4	4	1	3	5	2	1	2	2	2	2	3	3	4	4	
Micro GC	1	2	1	4	1	1	2	4	3	3	1	1	1	5	3	4	1	3	5	3	3	3	
Micro MS	1	2	1	1	1	1	4	4	4	3	5	5	1	3	1	2	1	1	4	2	3	2	
PID, IMS	1	4	2	1	4	4	2	4	4	3	2	1	3	5	2	5	2	4	5	3	3	3	
QMB, SAW, BAW	1	2	1	1	1	1	1	4	3	2	1	2	3	3	1	1	1	3	4	3	4	3	
Sensor arrays	4	4	2	1	3	4	4	4	4	3	3	3	4	4	3	4	4	5	3	4	4	4	
Microprocessors/ FPGAs/ PICs/ ASICs	3	1	5	5	5	5	3	5	5	3	3	4	3	5	4	5	5	4	5	5	5	5	
Wireless	3	3	2	3	4	4	3	3	3	1	3	1	2	3	5	5	2	5	4	4	4	4	
<b>Technologies</b>																							
MEMS	3	2	2	3	2	2	2	4	4	3	4	2	4	5	5	3	4	4	4	4	4	4	
Nanomaterials (QDs, CNT, nano MO)	2	2	2	1	2	2	2	3	3	2	4	4	4	5	3	4	4	3	3	3	3	3	
Polymers, liquid crystals	2	1	2	1	2	1	2	2	4	3	1	2	3	3	2	4	1	3	2	3	3	3	
Electrochemistry	4	2	4	1	5	4	4	4	2	4	4	4	4	2	4	5	4	4	2	3	3	3	
Separation science	3	5	5	3	5	5	1	3	5	4	4	5	5	5	2	3	5	4	3	4	4	4	
Physical chemistry (enthalpy, speed of sound)	2	4	3	1	4	4	2	2	1	1	4	4	1	2	1	3	1	1	1	1	2	2	

Table 1. Market-Technology Matrix. Each cell has been graded by importance: 1 is considered not viable, irrelevant or occupying a very small niche, while 5 has the highest relevance or opportunity of that technology or component for each market column.

### MNT Gas Sensors Roadmap - fire detection

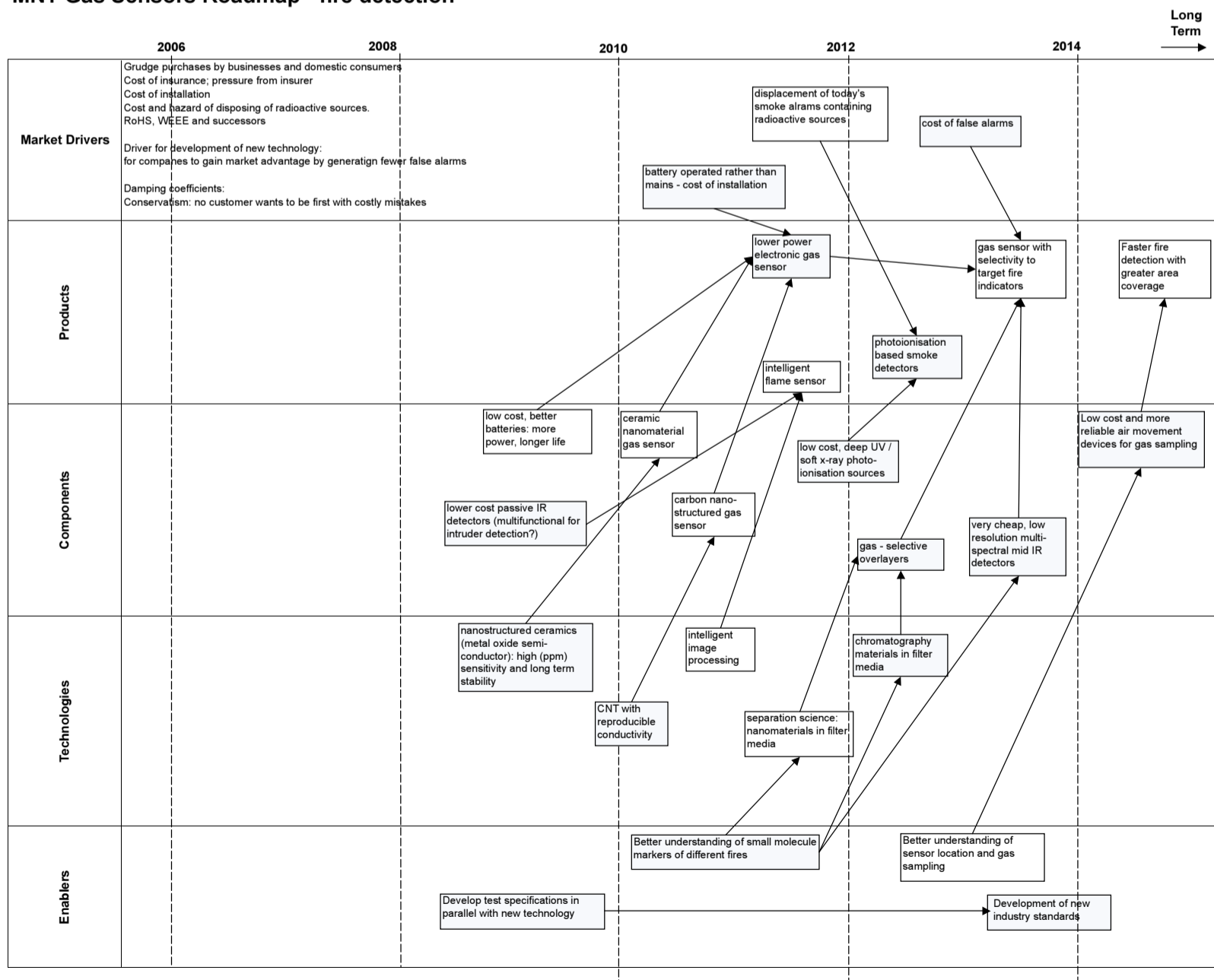


Figure 1. Typical gas sensor roadmap, depicting here expected developments in fire detection.



## Full Report

This last step is underway. We aim to produce a draft for comment, to promote dialogue between the gas sensing and technology provider communities. The roadmap will be updated but needs your feedback!

## Conclusions to date

- In the short term, optical advances will stem from single line IR lasers or NIR spectrometers.
- Electronic support will be especially necessary for NIR spectroscopy and sensor arrays.
- Wireless-enabled sensors will become ubiquitous.
- Separation science (IMS, GC, MS) holds great opportunities, but with greatest commercial risk.
- Advanced nanomaterials for gas separation may deserve greater attention.
- Where analytical science advances, gas detection can follow.

### MNT Gas Sensor Forum Steering Committee

Jane Hodgkinson (Co-Chair)	Cranfield University	GASG
John Saffell (Co-Chair)	Alphasense	CoGDEM
Jonathan Luff	SIRA	Sensors KTN
John Shaw	Tyco Safety Products	
Jeremy Ramsden	Cranfield University	
Carlos Huggins	e2v	
Robert Bogue	Robert Bogue and Partners	Optocem KTN
Roger Carline	MNT Network	