PUBLISHABLE SUMMARY

Grant Agreement number:	**FP7 – 263091**
Project acronym:	**HYSENS**
Project title:	**Hybrid Molecule-Nanocrystal Assemblies for Photonic and Electronic Sensing Applications**
Funding Scheme:	**Small scale collaborative project**
Period covered:	**01 April 2011 (Month 1) to 30 September 2012 (Month 18)**
Project co-ordinator:	**Daniela Iacopino, Tyndall National Institute, University College Cork, Ireland**
Tel:	**+353-(0)21-490-4182**
E-mail:	**daniela.iacopino@tyndall.ie**
Project website address:	**http://www.hysens.eu**

Table of contents

1 Project Overview and Objectives

HYSENS Goal: Exploit organic functional molecules and inorganic nanocrystals as building blocks for the assembly of novel smart materials for detection of Group I, II, transition metal cations and anions in water and artificial serum matrices.

Why are we doing this? The increasing shortage of the water supply has led to the implementation of recycling plants for both potable water and technological applications, increasing the demand for low cost and rapid contaminant detection technologies. This presents a significant problem for existing and future industries, requiring the incorporation of both expensive ultrapure water and water analysis systems. For example, state-of-the-art wafer fabrication facilities consume 100-300 m^3 of ultrapure water per hour.

Industry Needs:

- Semiconductor Fabrication: In daily routine, inorganic cations on a silicon wafer surface and in ultrapure water are detected at concentrations down to (and below) the ng/L range using inductively coupled plasma mass spectrometry (ICP-MS). However this technique is at present prohibitively expensive to implement => **HYSENS solution is more cost-effective.**

- Healthcare: In clinical diagnostics, there is an increasing demand for the development of innovative low cost electrolyte analysis technologies that could be applied for example in emergency rooms to obtain a fast indication for the diagnosis of specific diseases. Existing techniques meet concentration specifications required. However, more accurate, selective and sensitive methods would revolutionise the field of diagnostics for early detection and management of renal, endocrine, acid-base, water balance disorders, and many other conditions => **HYSENS solution is more sensitive.**

HYSENS Objectives to achieve our Goal:

HYSENS relies on the use of hybrid inorganic-organic component materials leading to the development of sensors with enhanced selectivity and sensitivity. Inorganic nanocrystals and organic functional molecules will be used for the assembly of **four novel classes of hybrid nanostructures:**

1. **Intelligent assembly (1):** semiconductor nanocrystal - organic functional molecules for demonstration of optical "intelligent chemosensing" (**objective 1**) targeting ng/L concentration detection of Group 1 and II ions and anions (including Na^+, Ca^{2+}, PO_4^{3-}, F^-). Industrial validation of intelligent assembly 1 into polymer-patterned tag surfaces and microfluidic cells.
2. **PRET hybrid assembly (2):** metal nanocrystal - organic functional molecules for demonstration of optical sensing based on plasmon resonance energy transfer (PRET) mechanisms (**objective 2**) targeting ng/L concentration detection of transition metal including Hg^{2+} and Cu^{2+}. Industrial validation of PRET assembly 2 into polymer microfluidic cells.
3. **2D hybrid arrays (3):** metal nanocrystal - organic functional molecules for demonstration of large area sensing (**objective 3**) targeting electrical "intelligent chemosensing" of Group I and II cations and anions (including Na^+, Ca^{2+}, PO_4^{3-}, F^-) with ng/L detection limits.
4. **1D hybrid arrays (4):** metallic semiconductor nanocrystal - organic functional molecules interfaced on 1D Si FETs arrays for electrical readout based sensing (**objective 4**) targeting electrical "intelligent chemosensing" of Group I and II cations and anions (including Na^+, Ca^{2+}, PO_4^{3-}, F^-) with ng/L detection limits. Industrial validation of 1D hybrid assembly into polymer microfluidic cells.

2 Work Performed in the First Period

2.1 Project Objectives for Period 1: April 2011 – Sept 2012

The key objectives for the first 18 months of the project were:

i) the screening of inorganic/organic components towards synthesis of a selected number of hybrid structures
ii) individuation of a selected number of hybrid structures and their initial opto-electronic characterisation
iii) fabrication of electrochemical cells, microfluidic cells and Si FET nanowires as substrates for industrial validation of hybrid structures.

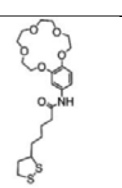
In particular, tasks to be achieved included:

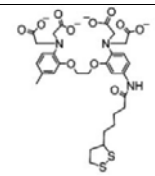
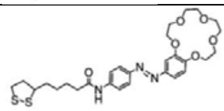
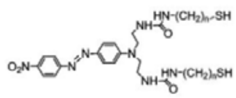
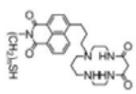
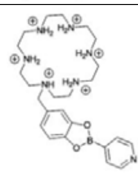
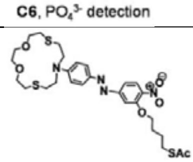
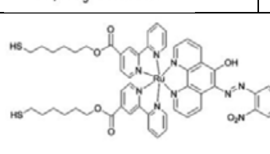
- Development of efficient methodologies for inorganic nanocrystal synthesis
- Synthesis of organic functional molecules targeting Group I, II, transition metal cations and anions.
- Assembly and characterisation of prototypes of:
    - Intelligent hybrids **1**
    - PRET hybrids **2**
    - 2D hybrid arrays **3**
    - Hybrid arrays **4**
- Opto-electronic sensing validation of 2D hybrid array **3**
- Photoconductance characterisation of PRET assembly **2**
- Optical sensing of intelligent assemblies **1** with electroluminescent detection.
- Fabrication of:
    - Si nanowire test structures
    - electrochemical cells
    - microfluidic cells
- Development of working-document mini-business plan.
- Dissemination and exploitation of results.
- Project management.

2.2 Work performed under WP1: Synthesis and characterisation of building blocks

A range of ionic analytes were selected as targets for detection in aqueous, point-of-care, environments including sodium, potassium, calcium, phosphate, nitrate and (possibly) fluoride ions. **Five organic ligands were selected for further studies** during the second part of the project: **C1, C2, C4, C5 and C8:**

2.2.1 Organic functional molecule synthesis (Task 1.2)

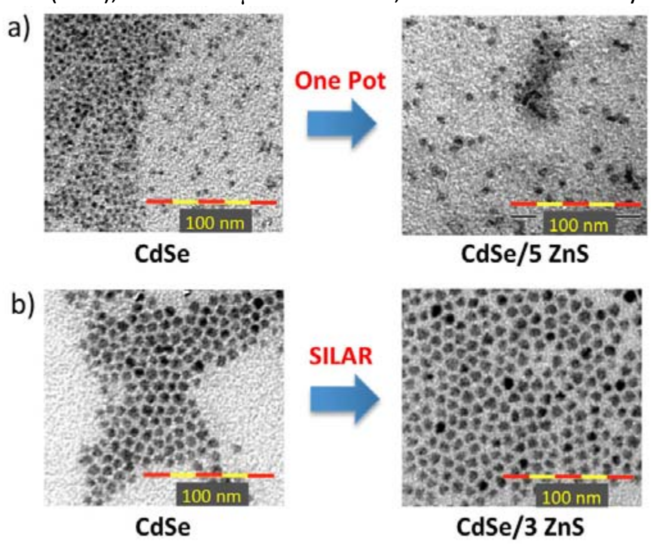
Analyte Detected			**Partner Responsible for synthesis**	**Characterisation**
Na^+	**C1**	 **C1**, Na^+ detection	**<u>UNIBAS-CHEM:</u>** • Synthesized in gram & multigram quantities. • Upscaling possible • Delivered to UNIBAS-Phy & UNIBO.	NMR => acceptable selectivity of Na^+ over K^+.

Ca^{2+}	**C2**	 **C2**, Ca^{2+} detection	**UNIBAS-CHEM:** • Synthesized in gram & multigram quantities. • Upscaling underway. • Delivered to UNIBO.	UV/vis titration against MCl_2 => Zn^{2+} ions interfere but Mg^{2+} does not.
Na^{+}	**C3**	 **C3**, Na^{+} detection		
Cu^{2+}	**C4**	 **C4**, Cu^{2+} detection	**UNIBHAM:** • Not Synthesized as removal of Ac groups has not proved possible. • Synthesized as thioacetate-protected form; preliminary binding studies to gold nanoparticles complete.	
Cu^{2+} / Hg^{+}	**C5**	 **C5**, Cu^{2+}/Hg^{2+} detection	**UNIBHAM:** • Synthesized in 100mg quantities. • Delivered 50mg to Tyndall-UCC.	**UNIBHAM:** Shown that C5 selectively binds to Cu and Hg through UV/Vis studies. These studies being repeated with C4-Ac.
PO_4^{3-}	**C6**	 **C6**, PO_4^{3-} detection		
NO_3^{-}	**C7**	 **C7**, NO_3^{-} detection		
F^{-}	**C8**	 **C8**, F^{-} detection	**UNIBAS-CHEM:** • Structurally modified and synthesized in 100 mg quantities. • Delivered to UNIBO.	

2.2.2 Nanocrystal synthesis (Task 1.1)

Objective: Synthesize stable, luminescent **ZnSe and ZnTe nanocrystals**.

- UNIBO successfully synthesized ZnTe Quantum Dots (QDs) with good size control but they exhibited poor stability and no luminescence.
- Several methodologies for the synthesis of ZnSe nanocrystals were tested at UNIBO. In most cases nanocrystals were obtained but with poor size control and no luminescence.
- As a result, UNIBO concentrated its efforts on the **production of CdSe-ZnS type I core-shell nanocrystals** of high quality and purity. The procedures for both core synthesis and shell growth were further optimised during the first period of the project and UNIBO can now produce ca. 20mL of 5μM solution of hydrophobic QDs per batch. Delivery of samples to other partners in the first period:
    - CdSe-ZnS (5 sh), 7 mL 3μM in CHCl3, sent to Tyndall-UCC on September 2011.
    - CdSe-ZnS (5 sh), 7 mL 3μM in CHCl3, sent to UVEG on September 2011.
    - CdSe-ZnS (5 sh), 5 mL 3.3 μM in CHCl3 and 5 mL 1.5 μM in hexane, sent to UVEG on December 2011.
    - CdSe-ZnS (3 sh), 15 mL 4.4 μM in hexane, sent to UVEG on July 2012.



Gold nanoparticles (**Au NPs**)are also used in the HYSENS project (sizes 10 – 60 nm) as carriers for the molecular recognition functionalities. Au NPs have been micro-contact printed and these structures are currently being evaluated.

2.3 Work performed under WP2: Assembly and characterisation of hybrid structures

	Assembly	Characterisation	Notes
Intelligent assembly 1	**UNIBO:** Various **C1**/PEG ratios were tested yielding intelligent assemblies 1 with good solubility in water.	Absorption and luminescence spectroscopy confirmed the functional ligands are attached to the QDs.	Attempts to functionalize QDs with **C2** but small amount available for this liand did not allow any optimisation in this case.
PRET assembly 1	**Tyndall-UCC:** Attached Au NPs (60nm) on transparent substrates	Dark-field scattering analysis: immersion in C5:EtOH leads to a peak shift	Further investigation to confirm that C5 is attached to NPs via thiol

	and functionalised with C5.	of the plasmon peak due to refractive index of NPs' environment induced by C5 molecule. SERS & Raman spectra: support C5 deposition on Ag substrate and on Ag NPs.	group leaving reception unit accessible for target analyte.
2D hybrid arrays 3	**UNIBAS-Phys:** Successfully prepared: • Self-assembly of Au NPs and transfer of NP array using microcontact printing. • C1 Molecular species inserted into array by immersion of device in solution.	Electrical Conductance: • Presence of C1 in the Au NP array increased conductance by one order of magnitude. • Subsequent exposure to Na^+ ions resulted in slight increase of conductance -> indication of efficient trapping of the Na^+ ions by the C1 molecule.	Further investigation to clarify if C1 compound promotes efficient trapping in the array or not. Raman spectroscopy to be used.
1D hybrid array 4	**UNIBAS-Phys:** Successfully fabricated silicon nanowire (Si NW) field effect transistors (FETs) and SI NW FETs covered by different metal surfaces.	Electrical: Response to pH changes and different salt concentrations investigated.	Modifying surface using functional organic molecules proposed to obtain selective detection of ions by electrical response.

2.4 Work performed under WP3: Optical sensing functionality in hybrid structures

	Optical sensing functionality	Notes
Intelligent assembly 1	Fluorescence quenching upon analyte binding as a result of interactions between the nanocrystals unit and the organic multi-component unit regulated by analyte (Na^+) binding. **Luminescence titration curve** (λ_{exc} = 400 nm, λ_{em} = 566 nm) obtained by adding $NaNo_3$ to a 5.5×10^{-8} M solution of intelligent assembly 1 (CdSe-ZnS QDs functionalized with **C1**/PEG) in distilled water at room temperature. Values determined for the Na^+ concentration in these samples are comparable with those declared on the label (for bottled water) or by the utility provider (for tap water). **Electroluminescence readout:** Significant difficulties have been encountered with the preparation of LECs incorporating nanoparticles (NPs) as intelligent assemblies.	**UVEG:** Parallel study incorporating intelligent assemblies 1 into light emitting electrochemical cells (LECs) that change their electroluminescence properties (intensity and/or colour) upon analyte detection. **Scriba:** Fabricated patterns containing optical tags to assess fluorescence imaging as read-out method.
PRET assembly 2	Rayleigh scattering light emission regulated by analyte (Hg^{2+}) binding.	

2.5 Work performed under WP4: Electrical Sensing Functionality in hybrid structures

	Opto-electrical and Electrical sensing functionality	Notes
PRET assembly 2	**Photoconductance measurements by TUM:** Au nanorods assembled into ordered 1-3 dimensional arrays on fused silica substrates and embedded into test-structures. TUM verified the longitudinal Plasmon resonance peak and in combination with a linear laser power dependence, the plasmonic sensing principle was proved.	**Tyndall-UCC:** Corresponding influence of target analytes on the optoelectronic properties of the PRET-assemblies will be explored.
2D hybrid arrays 3	**Photoconductance measurements by TUM:** sub-linear dependence on the laser intensity. Photoconductance could be shown to be caused by the resonant excitation of the molecular transition. Such arrays are very sensitive to a local life of the Coulomb blockade by optical means.	**UNIBAS-Phys:** Continued investigation to determine initial sensitivity and selectivity curves in water solutions of known analyte composition.
1D hybrid array 4	**Conductance, transconductance and charge carrier mobility of Si NW FETs:** Al_2O_3 or HfO_2 gate oxide in liquids to show the electrical sensing functionality for pH sensing. Verified maximum response of 60mV/pH corresponding to ideal Nernstian response predicted by theory. No influence has been found relating to background electrolyte concentration from 0.1µM to 1mM underlying the high selectivity of the pH sensor for protons and demonstrating they behave as idea pH sensors.	**UNIBAS-Phys:** Continued investigations with particular emphasis on interband excitations in semiconductor nanoparticle arrays and surface plasmons in metal nanocrystals arrays. Förster energy transfer processes between the stamped arrays and Si NW FET conductors will be explored.

2.6 Work performed under WP5: Industrial validation

This workpackage comprises the fabrication and customisation of the following test structures: i) polymer optical tags, ii) plastic microfluidic cells. Although no deliverables within WP5 fall in the M1-M18 period, industrial partners have already fabricated the first generation of test structures. Preliminary work is being carried out on the incorporation of hybrid materials or hybrid components into these structures with the aim of having optimised test structures ready for incorporation of optimised hybrid materials in the second part of the project. Key achievements in the first period of the project include:

		Notes
Intelligent assembly 1	• **Fabrication and validation on polymer optical tag surfaces:** **Scriba** has developed the fabrication process of optical tags, which have a multilayer architecture. • **Fluorescence detection in microfluidics cells:** **Mildendo** has designed a first generation of microfludic cells. **Cellix** and **UNIBO** are developing protocols for the fluorescence detection of assembly 1 in microfluidic cells. • **Fluorescence detection in serum matrix in**	Cellix also focused on the identification of a reliable, precise cutting technique for microscope glass coverslips, integration and imaging inside the flow cell of HYSENS biochips. Mildendo and Cellix also performed fluidic tests to evaluate the sealing conditions with flow

	microfluidics cells: Using dark field microscopy, **Cellix** tested immobilization of 60 nm Au nanoparticles on pre-cut 5mm x 5mm glass slides of thickness 0.17mm.	rates 1.3µL/s, 2.6µL/s dispensed at each of the 3 inlet ports using Cellix Mirus Evo Nanopump. The test showed positive outcomes with no fluid leakage even when using these quite significant flow rates.
PRET assembly 2	• **Optical sensing validation on polymer optical tag surfaces:** **Scriba** has tested different processes to achieve homogeneous and low-density patterning of gold nanoparticles. • **Validation of optical sensing in microfluidic cells:** **Cellix** has defined a standard pattern for preliminary validation of optical sensing using PRET assembly 2. Darkfield microscopy images after integration of the samples into the flow cell show promising results for the optical detection of assembly 1 and PRET assembly 2.	

2.7 Work performed under WP6: Innovation Management & Dissemination

Publications or proceedings:

- UNIBO

1) M. Amelia, T. Avellini, M. Semeraro, S. Silvi, A. Credi. Quantum Dots Functionalized with Photo- or Redox-Active Species for Luminescence Sensing and Switching. *Curr. Phys. Chem.* **2011**, *1*, 181-194.
2) M. Amelia, A. Credi. Photosensitization of the luminescence of CdTe nanocrystals by noncovalently bound Zn tetraphenylporphyrin. *Inorg. Chim. Acta* **2012**, *381*, 247-250.
3) M. Amelia, C. Lincheneau, S. Silvi, A. Credi. Electrochemical properties of CdSe and CdTe quantum dots. *Chem. Soc. Rev.*, in press.

- Tyndall-UCC: Martin, C. Schopf, A. Pescaglini, A. O'Riordan, D. Iacopino. Synthesis, Optical Properties and Self-Assembly of Gold Nanrods, JEN, 7, 2012, 688–702
- TUM:

1) M. Mangold, M. Calame; M. Mayor, and A.W. Holleitner Negative Differential Photoconductance in Gold Nanoparticle Arrays in the Coulomb Blockade Regime, ACS Nano DOI: 10.1021/nn300673t (2012).
2) M. Mangold, M. Calame; M. Mayor, and A.W. Holleitner, Resonant Photoconductance of Molecular Junctions Formed in Gold Nanoparticle Arrays, *J. Amer. Chem. Soc.* **133**, 12185 (2011)

- SCRIBA: M.Cavallini, D.Gentili, P. Greco, F.Valle, F. Biscarini, Micro- and nanopatterning by lithographically controlled wetting, *Nature Protocols*, submitted

Oral or poster presentations:

- UNIBO

1) A. Credi. Photoinduced functions in multicomponent nanosystems. *1st Scientific Meeting, COST action CM1005 "Supramolecular chemistry in water"*, Frascati, Italy, November 19–21, 2011; Plenary lecture.

2) T. Avellini, M. Amelia, S. Silvi, A. Credi. Self-assembled complexes of quantum dots and anthracene derivatives. *Central European Conference on Photochemistry 2012*, Bad Hofgastein, Austria, February 5–9, 2012; P44. Poster presentation by T. A.
3) C. Lincheneau, M. Amelia, S. Silvi, A. Credi. Synthesis and study of Cd-free quantum dots. *Central European Conference on Photochemistry 2012*, Bad Hofgastein, Austria, February 5–9, 2012; P51. Poster presentation by C. L.

- UNIBAS Chem: A. Wright, E. C. Constable, C. E. Housecroft, C. J. Martin, S. Müller. Hybrid Assemblies for Detection Applications. *MRS Spring Meeting, San Francisco April, 2012.*
- UNIBAS Phys:

1) R. L. Stoop, M. Wipf, A. Tarasov, K. Bedner, W. Fu, M. Calame, C. Schönenberger. Chemical sensing with silicon nanowire field-effect transistors. *Annual meeting of the Swiss physical society, Zurich, June 21-22, 2012*.
2) M. Calame. Insights into the electronic and mechanical structure of molecular junctions. *Joint International Conference of the Israel Institute for Advanced Studies and the Israel Science Foundation on Molecular Electronics – Hebrew University, Jerusalem, Israel, July 16-20, 2012.*
3) R. L. Stoop, M. Wipf, A. Tarasov, K. Bedner, W. Fu, M. Calame, C. Schönenberger. Silicon nanowire field-effect transistors for sensing applications. *Complex Systems 2012 conference, Lavin (Switzerland), August 24-29, 2012*.
4) R. L. Stoop, M. Wipf, A. Tarasov, K. Bedner, J. Kurz, W. Fu, M. Calame, C. Schönenberger, Sensing with Silicon Nanowire Field-Effect Transistors. *Eurosensors 2012 conference, Krakow, September 9-12, 2012*.

- Tyndall-UCC

1) C. Schopf, A. Pescaglini, A. O'Riordan, D. Iacopino. Dark field optical microscopy of single nanoparticles and ordered nanoparticle arrays, *Sensors & their Application XVI*, Cork, September 2011 (best poster prize)
2) C. Schopf, E. Noonan, G. Lévêque, A. J. Quinn, D. Iacopino. Correlated Optical/Electron Microscopy Imaging and Spectroscopy of Metal Nanostructures**.** *RSC Postgraduate Symposium on Nanotechnology*, Birmingham, December 2011 (best poster prize)

- TUM:

1) J. Schopka, March *meeting of the "Deutsche Physikalische Gesellschaft (DPG)*", Berlin, 25th-30th of March, 2012
2) A. Holleitner (invited), "Workshop on transport through molecules", *FU Berlin*, 21st October, 2011
3) A. Holleitner (invited), "Workshop on frontiers on functional interfaces" *Institute for Advanced Studies, Technical University Munich*, 13th September, 2011
4) Ms. Nadine Erhard "*17th International conference on electron dynamics in semiconductors, optoelectronics, and nanostructures (Edison 17)*", August 8-12, 2011, Santa Barbara, USA

Education and training:

1) Several concepts related to HYSENS are inserted in the program of the course "Molecular Nanotechnology", held by Prof. A, Credi in the master in Photochemistry and Molecular Materials, Faculty of Sciences, University of Bologna
2) Experimental internship of undergraduate students of the above master
3) Training of PhD (Tommaso Avellini) and post-doctoral researchers (Matteo Amelia, Christophe Lincheneau)

Outreach to the general public:

- HYSENS activities were mentioned in the invited presentation of Prof. A. Credi at "Festival della Scienza" (Genova, Oct.-Nov. 2011), the most important initiative for public dissemination of science in Italy.
- Cellix and Tyndall-UCC had a press release on the HYSENS project not long after the start date. We also put details of the HYSENS project on our website and emailed our database of contacts to inform them of the grant.

2.8 Overview of achievements for Period 1: April 2011 – Sept 2012

- The synthesis of a library of metal and semiconductor nanocrystals is complete.
- The original list of **seventeen** selected hybrid structures has been **reduced to eleven** (kick off meeting) in order to focus the energies and resources of the consortium into the assembly and testing of hybrid structures.
- At the first annual scientific meeting, a funnelling phase was implemented, whereby **five organic ligands were selected for further studies** during the second part of the project. Therefore, synthesis of organic ligands is completed, molecules have been distributed to partners and routes for scaling up synthesis at gram scale are being developed by partner UNIBAS Chem.
- Assembly of the following prototypes are complete and opto-electrical characterisation of the assemblies are underway:
    - Intelligent hybrids **1**
    - PRET hybrids **2**
    - 2D hybrid arrays **3**
    - Hybrid arrays **4**
- In particular, intelligent assembly **1** composed of C1 and CdSe quantum dots (QDs) has been synthesised and its luminescent and electrical behaviour response to Na ions is currently under investigation.
- The fabrication of electrochemical cells is complete. These cells are now being tested for use with quantum dot (DDs) materials.
- Si nanowire FETs have been fabricated and will be tested with the Hysens hybrid structures.
- Preliminary investigation of the deposition of metal nanoparticles and QDs on patterned tags has been achieved with fluorescent tags fabricated by partner SCRIBA.
- A first generation of microfluidic cells has been fabricated by Mildendo and distributed to partners. Methodologies for the incorporation of metal nanoparticles in microfluidic cells have been developed by Tyndall-UCC in collaboration with Cellix.
- A mini-business plan has been written identifying potential partners for commercialization of the technology.
- Dissemination and exploitation of results.

2.9 Expected final results and their potential impact and use

The HYSENS proposal is focused on generation of new knowledge, processes and materials, which will improve the competitiveness of European industry in the key emerging area of nano-sensing leading to (i) improved monitoring of water quality for health and technological/manufacturing applications and (ii) higher quality of diagnostics for health care applications. This will be achieved through the development of new high knowledge-content nano-hybrid structures, together with scalable processes for assembly and incorporation into low-cost test structures. The hybrid material detection capabilities (detection sensitivity and sample volume requirements), and analysis format (electrical and optical) will lead to technology development in a wide range of applications. In the medium term, applications ranging from home water testing to water control for emerging and rapidly growing technological areas such the microelectronics industry, as well as serum electrolyte analysis for diagnostic and point-of-care applications can be expected. In the medium to long term, further development of devices that could be implemented for on-line water quality monitoring in refinement plants or accurate and fast point of care diagnosis of relevant pathologies can be foreseen.

The competitiveness of European industry depends largely on gaining new knowledge and new ways of integrating and exploiting existing knowledge. Europe will benefit from bringing specialist disciplines together to create recognised leadership in specific application areas. Research on organic-inorganic hybrid nanosystems is mostly concentrated in the USA where extensive funding programmes support the development of sensing technologies for environmental, medical and security applications, thus HYSENS would form the basis for the EU to become competitive with the USA in hybrid nanomaterial science and technology. Regarding test structures, the European industry is strong in the field of non-silicon microsystems, especially in polymer-based microfluidics. The expected results will lead to a further strengthening of this market position, especially in the light of the growing competition coming from Asian countries like South Korea or Japan, where this area has been identified as one key technology field for future products. The hybrid material detection capabilities (detection sensitivity and sample volume requirements), and analysis format (electrical and optical) will lead to technology development in a wide range of applications with medium to long-term exciting possibilities. The HYSENS project will develop a key enabling technology sensing platform that will sustain and enhance Europe's competitiveness by enabling substantial technological innovation, specifically focused on the development of novel nano-sensing solutions with a wide variety of integration possibilities.

The project is on track to achieve all of its ambitious objectives and deliver four optimised hybrid structures displaying enhanced selectivity and sensitivity of detection towards selected metal anions and cations, in water and serum matrices. A successful Hysens project will provide a number of clear benefits over the current method of detections offering: higher performance detection, low cost and ease of use and make the outputs of the Hysens project very attractive commercially in the water and point of care markets.