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THE HYSENS PROJECT

HYSENS is an acronym for:

"HYbrid molecule nanocrystal assemblies for photonic and electronic SENSing applications"

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 m3 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+, Ca2+, PO43-, F-) with ng/L detection limits. Industrial validation of 1D hybrid assembly into polymer microfluidic cells.

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Achievements to date:

- The synthesis of a library of metal and semiconductor nanocrystals is complete.
- The original list of seventeen selected hybrid (assembly) 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:
    1. Intelligent assembly 1
    2. PRET assembly 2
    3. 2D hybrid arrays 3
    4. 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.

Results & Expected Impact:

The HYSENS 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 detection offering:

- Higher performance detection,
- Low cost and
- Ease of use

The outputs of the HYSENS project are thus very attractive commercially for both the water and point-of-care markets.

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Project Co-ordinator:

Daniela Iacopino, Tyndall National Institute, University College Cork, Ireland.
Tel: +353-(0)21-490-4182
Email: daniela.iacopino@tyndall.ie

Project Website: www.hysens.eu

Project Team:

Tyndall National Institute, Ireland
University of Basel, Switzerland
University of Bologna, Italy
University of Birmingham, UK
University of Valencia, Spain
Technical University of Munich, Germany
Scriba Nanotecnologie s.r.l., Italy
Cellix Limited, Ireland
Mildendo GmbH, Germany

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