# Fluorescent and Magnetic Quantum Nanostructures for Biosensing

**Regina Maria Chiechio[1], Antonino Scandurra[1,2,3], Stefano Boscarino [1], Cristiano Lo Pò [1], Riccardo Reitano[1], Paolo Musumeci[1], Maria Grazia Grimaldi[1,2], Maria Chiara Spadaro [1,2,4], Francesco Salutari [4], Jordi Arbiol [4,5], Claudia Ferro [6], Salvatore Baglio [6], Salvatore Graziani [6], Annalinda Contino [7], Giuseppe Maccarrone[7], Thierry Guizouarn[8], Valerie Marchi[8], Ludovica Maugeri[9], Salvatore Petralia[9,10], Francesco Ruffino[1,2]**

*1. Dipartimento di Fisica e Astronomia "Ettore Majorana" Università di Catania, Via S. Sofia 64, 95123, Catania, Italy.*

*2. CNR-IMM, Via S. Sofia 64, 95123, Catania, Italy.*

*3. Research Unit of the University of Catania, National Inter University Consortium of Materials Science and Technology (INSTM-UdR of Catania), Via Santa Sofia 64, 95125 Catania, Italy.*

*4. ICN2, CSIC and BIST, Campus UAB, Bellaterra, 08193 Barcelona, Catalonia, Spain.*

*5. ICREA, Pg. Lluís Companys 23, Barcelona, Catalonia, 08010, Spain.*

*6. Department of Electrical Electronic and Computer Engineering —DIEEI, University of Catania, 95125 Catania, Italy.*

*7. Dipartimento di Scienze Chimiche, Università degli Studi di Catania, Catania 95125, Italy.*

*8. Institut des Sciences Chimiques de Rennes ISCR, UMR CNRS 6226, University Rennes, 35042 Rennes, France.*

*9. Department of Drug and Health Sciences, University of Catania, 95125 Catania, Italy.*

*10. CNR-Institute of Biomolecular Chemistry, Via Paolo Gaifami 18, 95126 Catania, Italy.*

**Abstract**: Nanomaterials leveraging quantum confinement effects, including gold nanoclusters for ultrasensitive fluorescence-based biomolecular detection and iron oxide nanoparticles for advanced magnetic sensing, demonstrate sustainable and adaptable solutions for diagnostics, environmental monitoring, and integrated quantum sensing systems.

This study, developed under the framework of the National Quantum Science and Technology Institute (NQSTI), aims to present all the UNICT Spoke 7 activities: Complete Quantum Systems focuses on leveraging nanotechnology to address challenges in sensing and diagnostics. Gold nanoclusters (AuNCs) and iron oxide nanoparticles (IONPs) are explored for their unique quantum properties, which enable the development of highly sensitive and sustainable platforms.

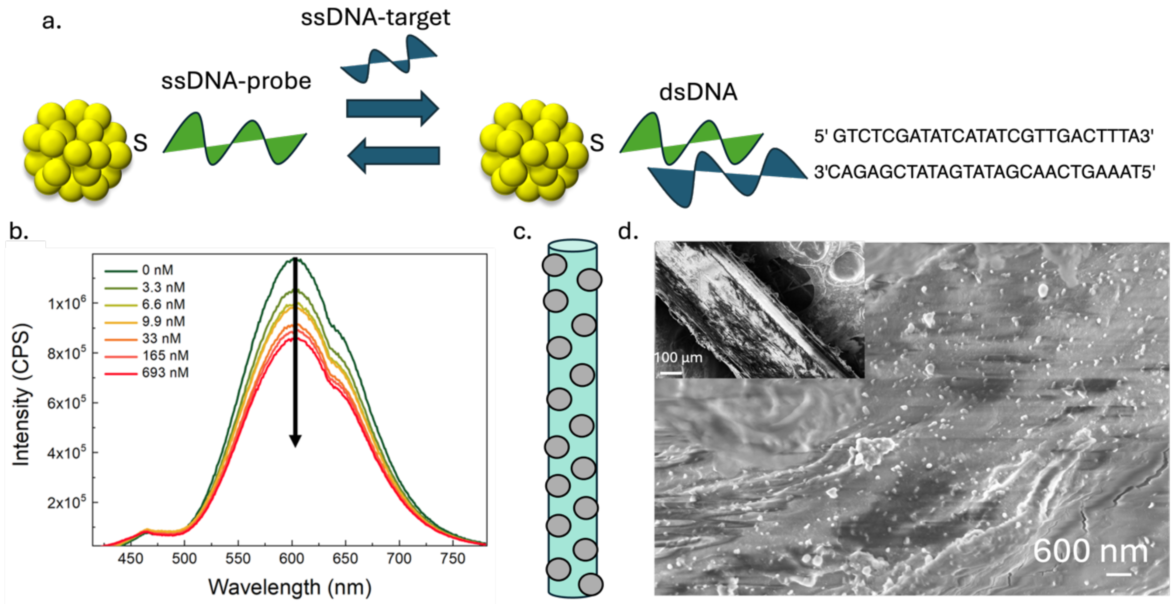


**Fig. 1** *a) Schematic representation of the interaction equilibrium between the two DNA strands of the AuNCs sensor in the presence of complementary DNA. b) Fluorescence spectrum of the AuNCs sensor incubated with different concentrations of ssDNA target. c) Schematic representation of* Iron oxide nanoparticles based magnetic sensor. d) SEM micrograph of Iron oxide NPs on nylon thread-based sensor.

AuNCs, synthesized via an eco-friendly green chemistry process [1,2], exhibit photoluminescence due to quantum confinement effects, which give rise to their molecule-like electronic structures. This makes them highly suitable for applications requiring precision at the nanoscale [3]. Functionalized with thiolated single-stranded DNA (ssDNA), the AuNCs serve as label-free sensors capable of detecting specific DNA sequences through fluorescence quenching. These sensors achieved an attomolar detection limit and demonstrated high specificity, even in complex biological matrices such as blood. The ability to detect low-abundance analytes, including cancer biomarkers and pathogenic DNA, highlights the potential of AuNCs in early diagnostics. Furthermore, their modular functionalization enables adaptation for a wide range of targets, such as peptides and other biomolecules, broadening their applicability in both medical and environmental fields (Fig.1a and b).

IONPs, on the other hand, exhibit superparamagnetic behavior due to quantum confinement effects within their magnetic domains. Synthesized via laser ablation in water or in solutions containing citrate, or glutathione, these nanoparticles were tailored for use in advanced fluxgate magnetometers [4,5]. Their superparamagnetic properties enhance the sensitivity and efficiency of magnetic field detection systems, making them suitable for innovative sensing technologies. The functionalization of IONPs on flexible substrates such as nylon threads further demonstrated their versatility and potential for integration into scalable sensor platforms (Fig.1c and d). Together, these studies highlight the significant contributions of nanomaterials to the advancement of quantum sensing systems. By exploiting the quantum effects inherent in AuNCs and IONPs, this work bridges the gap between fundamental nanotechnology research and practical applications, paving the way for more sustainable, precise, and adaptable solutions in diagnostics and environmental monitoring.

**Example References**

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