Surface Functionalization of Nanodiamonds with NV Centers as a Platform for Bioimaging and Sensing

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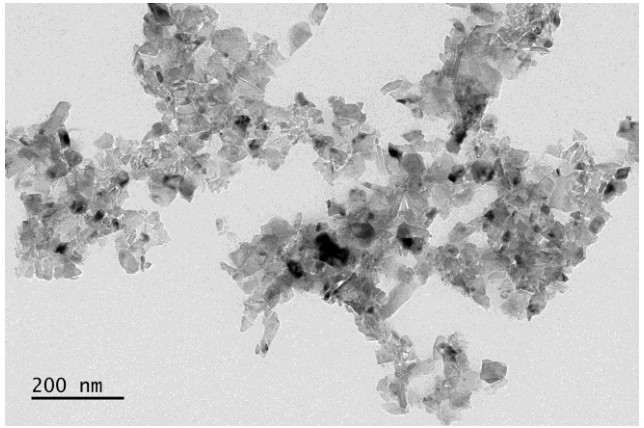
Nanodiamonds & NV Centers

➢ ***From diamond… to nanodiamond !***



Exceptional characteristics

- **Physical properties**
- **Biocompatible :** internalizable in cells
- **Optical properties** (color centers)

Nanodiamonds & NV Centers

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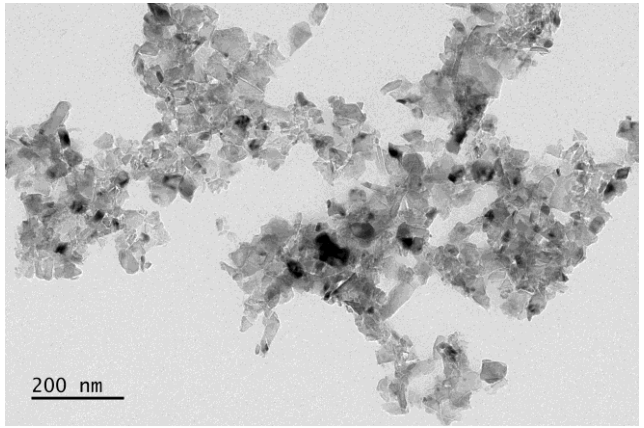
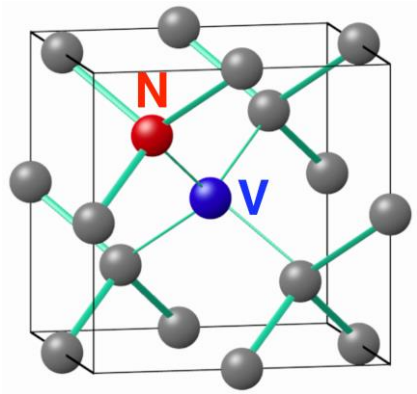
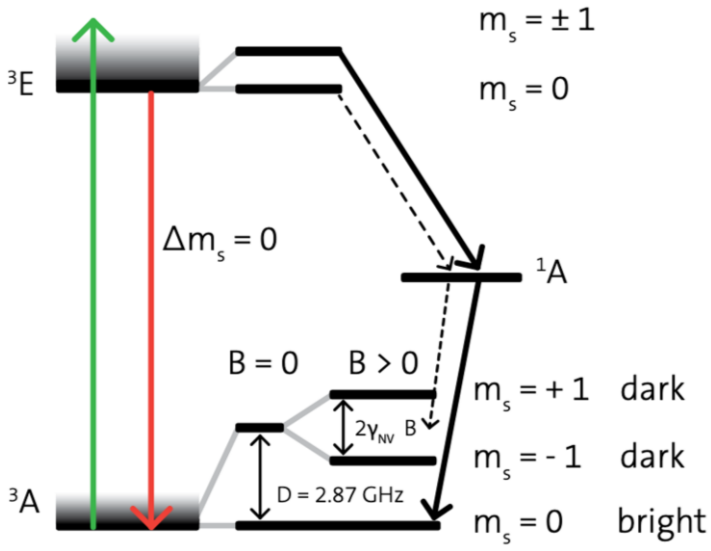


➢ ***What's a NV center ?***





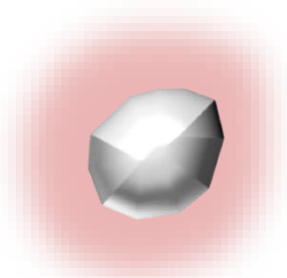
Exceptional characteristics

- **Physical properties**
- **Biocompatible :** internalizable in cells
- **Optical properties** (color centers)

→ **Stable red fluorescence** under green light excitation **(no photobleaching)**
→ Used for **bioimaging**
→ Used for **quantum sensing (pH, temperature, magnetic fields, nuclear and electron spins)**

Amplification of the fluorescence by plasmonic effect

Limitation :
NV fluorescence signal often **too weak** !



Bare ND

Amplification of the fluorescence by plasmonic effect

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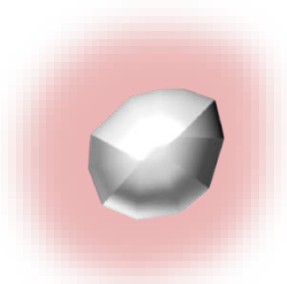
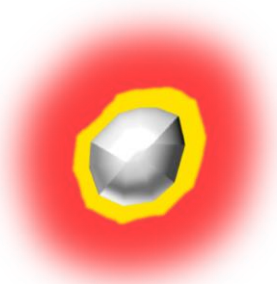


Bare ND

STRATEGY

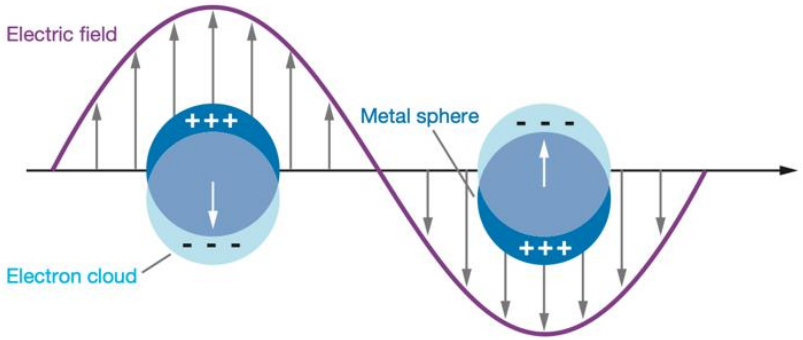
LSPR enhancement

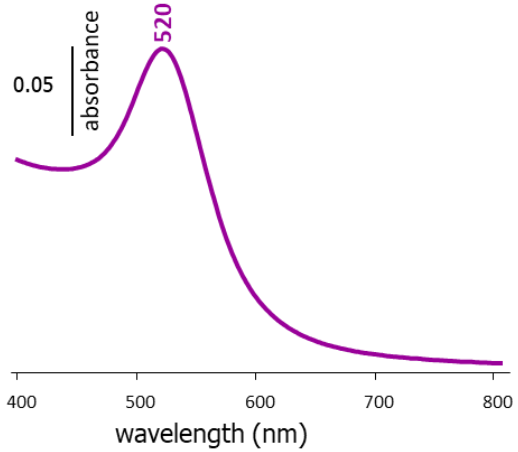


ND@Au

Development of **ND@Au nanocomposites**

→ **Localized Surface Plasmon Resonance (LSPR)**





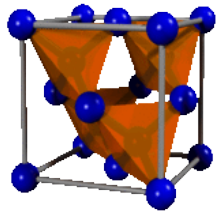
- Collective oscillation of free electrons in response to light
- **Enhancement of electromagnetic fields** at the nanoparticle surface

→Boosting fluorescence **up to 100-fold** through LSPR enhancement

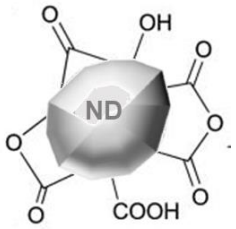
→Development of **next-gen sensors and bioimaging tools**

Why surface functionalization is essential ?

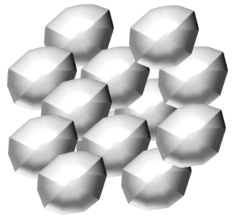
Challenges



C sp^3 = chemically inert



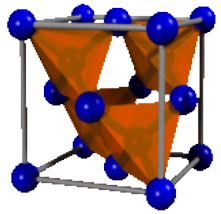
Low density of surface groups



Aggregation

Surface functionalization : 1st strategy

Challenges



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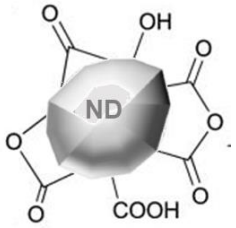

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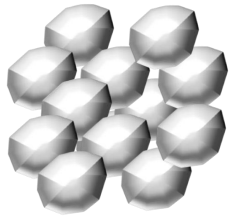
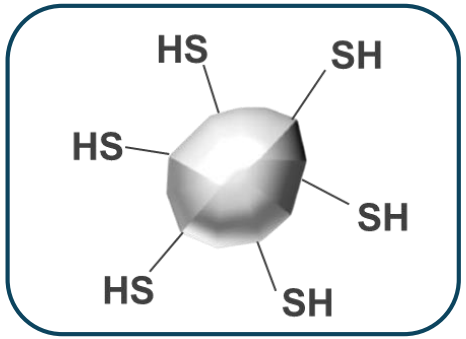


Aggregation

Surface functionalization

Provide chemical versatility
Introduce anchoring sites for Au deposition

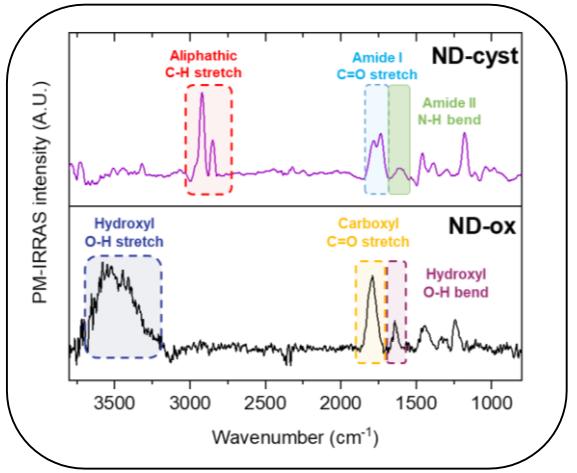
Strategy 1



Cysteamine grafting

ND-COOH $\xrightarrow[\text{EtOH}]{\text{EDC/NHS}}$ **ND**-CO-NHS $\xrightarrow[\text{EtOH}]{\mathbf{H_2N}\text{-}(CH_2)_2\text{-}\mathbf{SH}}$ **ND**-CO-NH-$(CH_2)_2$-**SH**

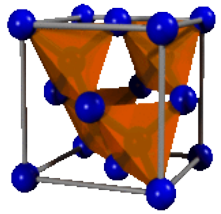
→ Functionalization with **cysteamine (thiol groups)**
→ Activation of oxidized NDs carboxyl groups with **EDC/NHS** reaction



Characterization with XPS, PM-IRRAS, Zeta potential…

Surface functionalization : 2nd strategy

Challenges



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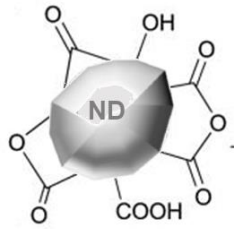

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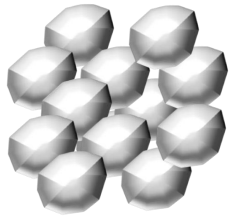
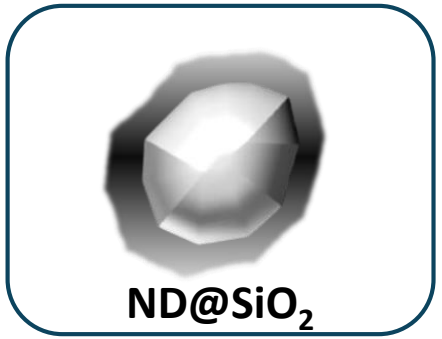


Aggregation

Surface functionalization

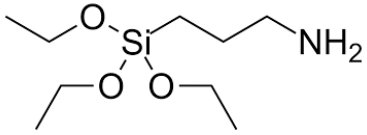
Provide chemical versatility and ensure colloidal stability
Control ND-Au spacing to avoid quenching of the fluorescence

Strategy 2

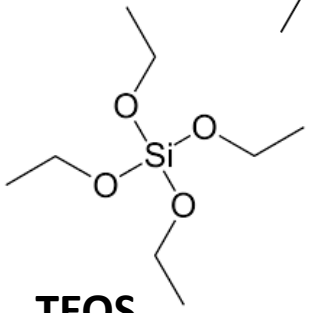


Silica coating

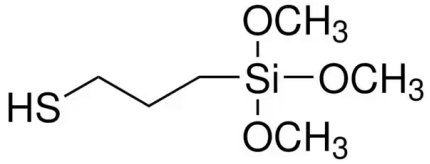
→ Formation of **tunable silica shell** (SiO_2) around NDs with a **sol-gel process**
→ Condensation of silane precursors with hydroxyl groups at the surface



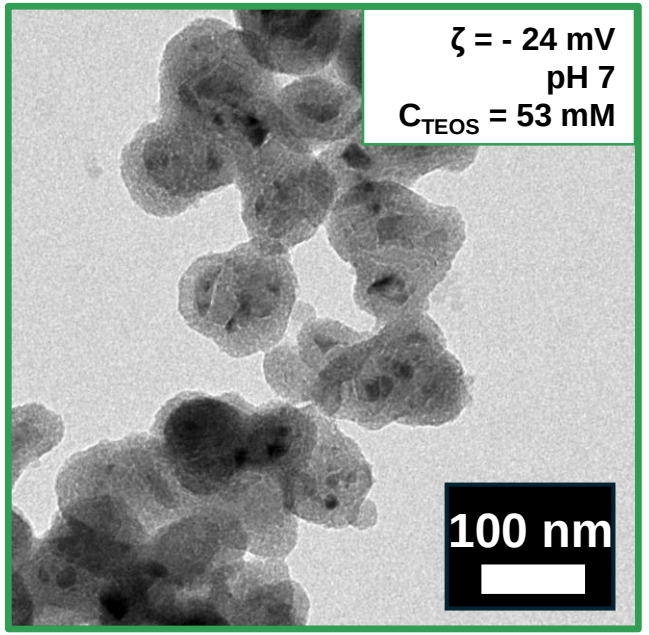
APTES



TEOS



MPTMS



Shell thickness e = 11.8 ± 2.4 nm

Scheme of my project

Development of different nanocomposites

ND@Au

ND@SIO_2@Au

With various shell morphologies

Smooth
(uniform plasmonic field)

Hollow shell
(tunability of distance)

Spiky
(localized “hot spots”)

Evaluation of optical and quantum properties
(ODMR, fluorescence spectroscopy tests)
Applications

Acknowledgments

Thank you for your attention!