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Nanoscale dynamics of *chlorella vulgaris* flocculation with pyridinium-modified cellulose nanocrystals

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► To cite this version:

Ayessa Pires Maciel, Wim Thielemans, Koenradd Muylaert, Cécile Formosa-Dague. Nanoscale dynamics of *chlorella vulgaris* flocculation with pyridinium-modified cellulose nanocrystals. 8th Congress of the International Society for Applied Phycology, Jun 2024, Porto, Portugal. <hal-04965799>

HAL Id: hal-04965799

<https://hal.science/hal-04965799v1>

Submitted on 25 Feb 2025

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Nanoscale dynamics of *Chlorella vulgaris* flocculation with Pyridinium-modified cellulose nanocrystals

Contact details



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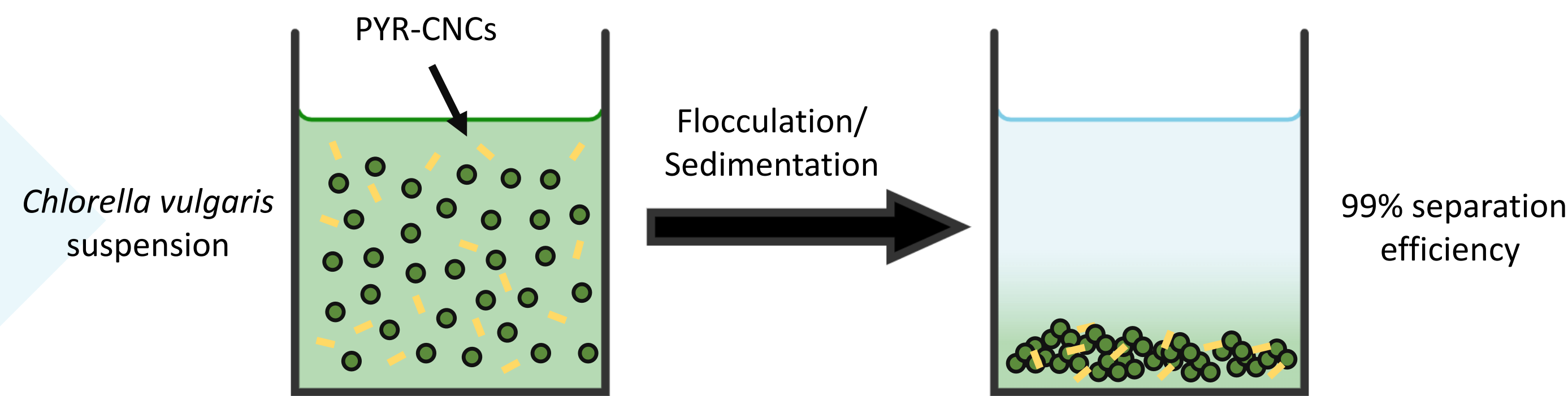
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Microalgae harvesting through flocculation

The low concentration of microalgae growth culture and their small cell size make microalgae harvesting challenging.



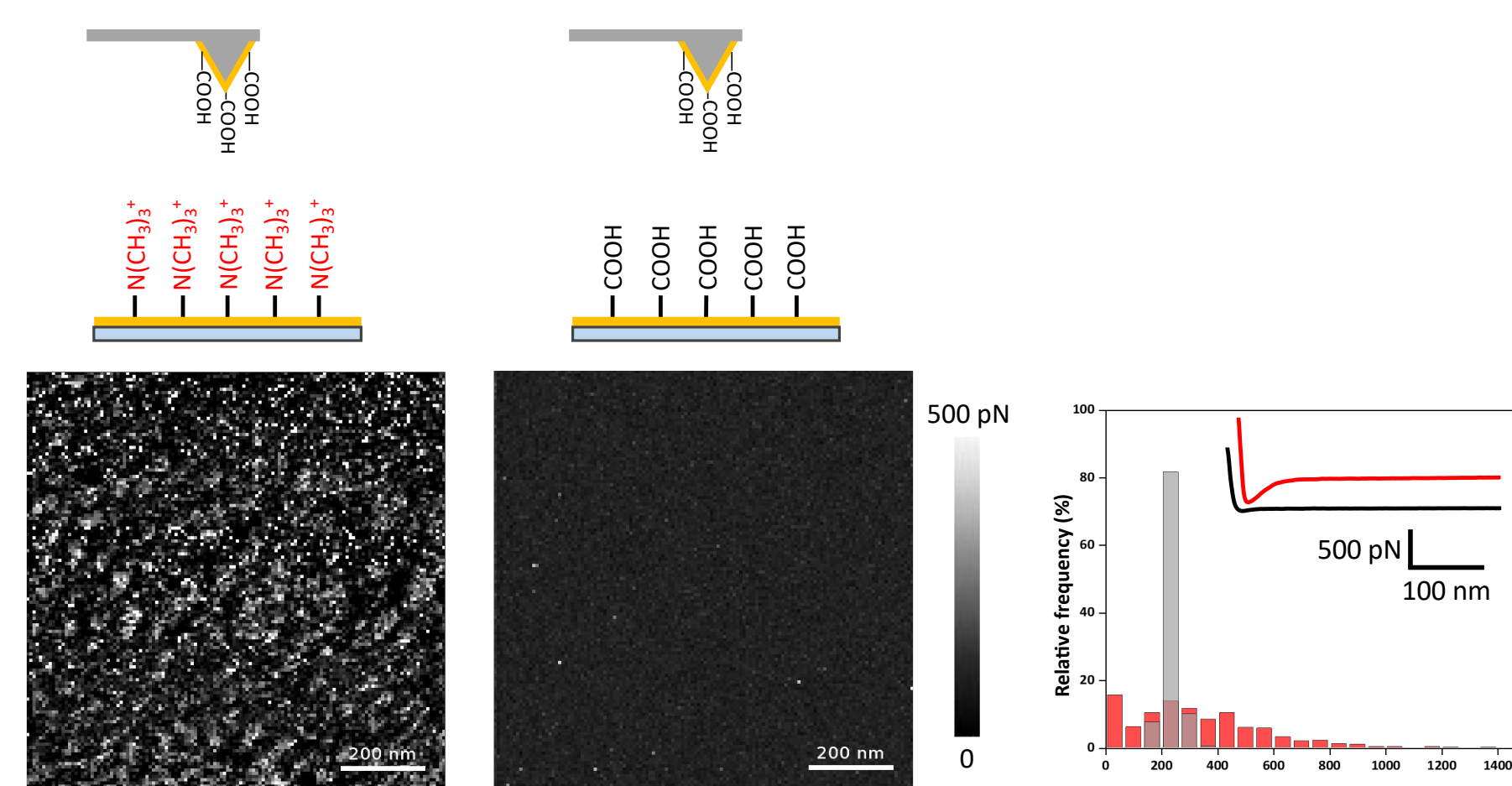
The separation efficiency in harvesting processes could be greatly improved by turning individual cells into aggregates or flocs.

Atomic force microscopy as a tool to understand the molecular mechanisms underlying flocculation

- **Why?** Understanding the dynamics involved in the flocculation process is crucial for the potential extension of its application and optimization on a larger scale.
- **How?** Applying a chemical force microscopy methodology to investigate interactions between negatively charged AFM tips and *C. vulgaris* cells in the presence of PYR-CNCs flocculants to gain insights into the flocculation mechanism.

Tip functionalization validation

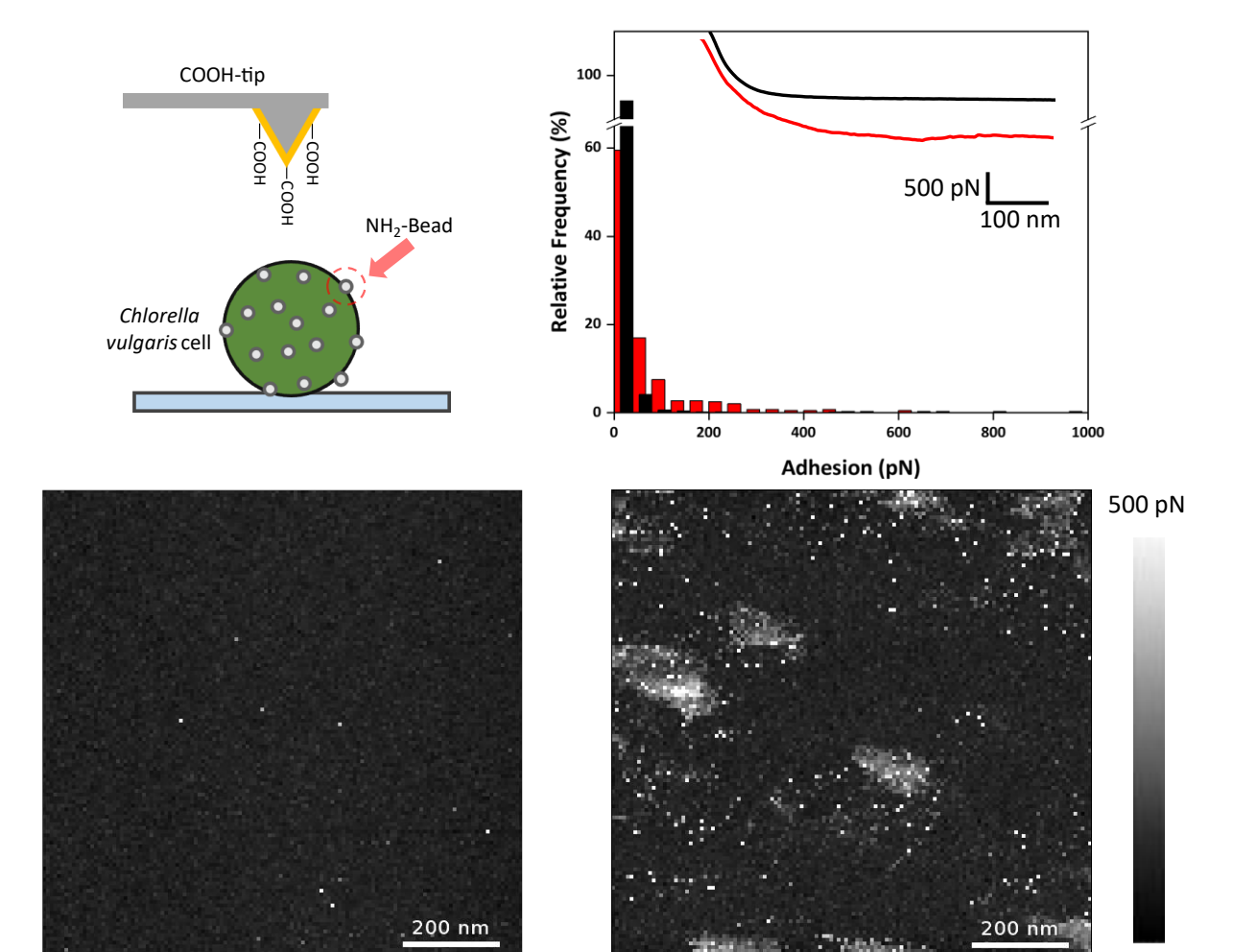
AFM measurements between COOH-functionalized probes and gold surfaces coated with either cationic or anionic groups.



The results provide evidence of the tip's anionic character.

Methodology test

AFM measurements were performed with the COOH-coated tip on *C. vulgaris* cells incubated with 100-120 nm diameter amine-modified beads.

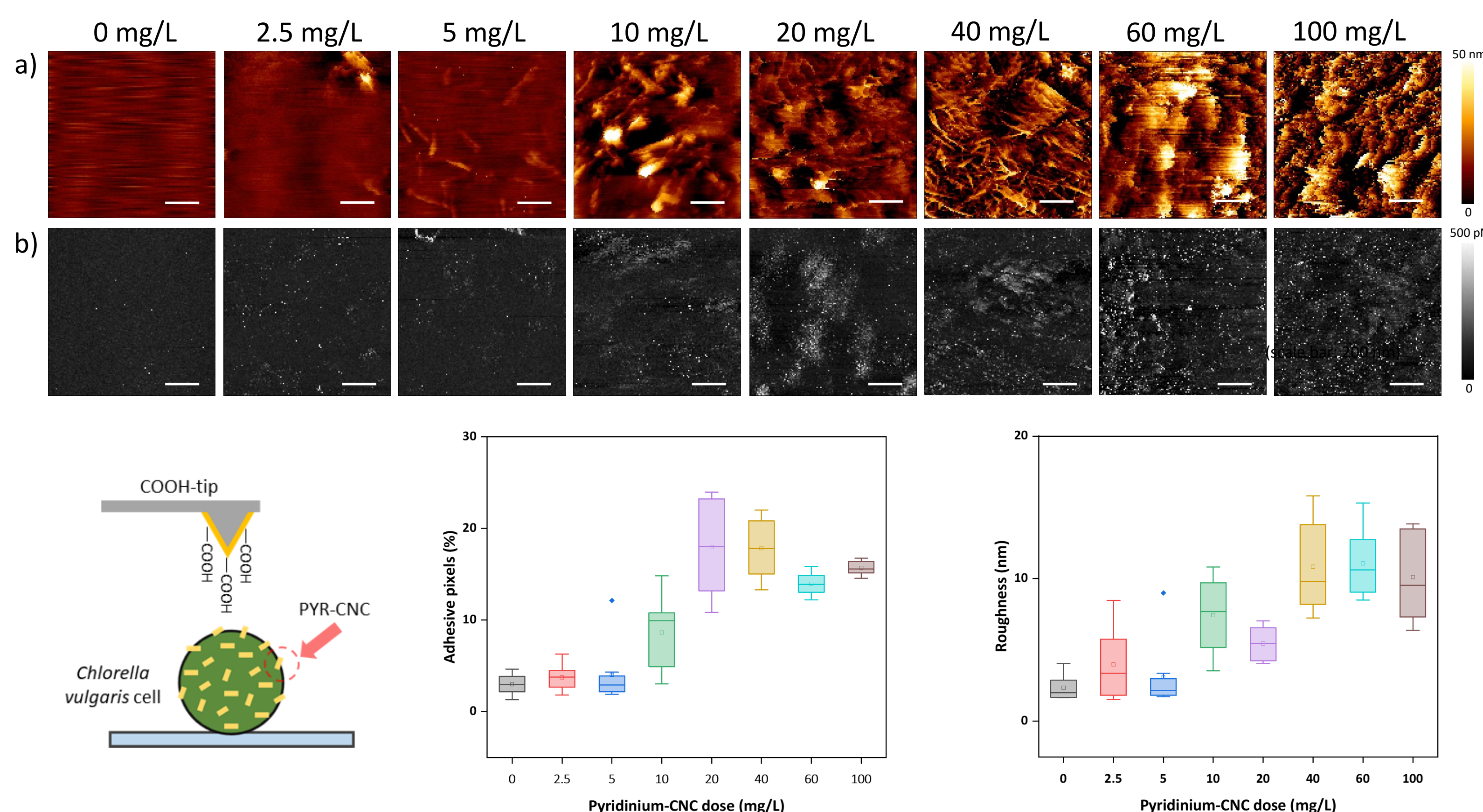


The results show that our system can detect nanosized cationic particles over the negatively charged cell surface.

Dynamics involved in the flocculation process

The methodology applied to microalgae cells flocculated with PYR-CNCs unveils details of the flocculants' spatial distribution across the cell surface at varying concentrations.

a) topographic images, b) adhesion maps (scale bar: 200 nm).



Results summary

- a** *Chlorella vulgaris* cells 0 mg/L PYR-CNC
 - Cells are stable in suspension mainly due to their negative surface charge, which prevents them from aggregating;
 - This character is confirmed by the minimum adhesion observed, presenting only $3.0 \pm 1.1\%$ adhesive pixels.
- b** Optimal flocculant dose 20 mg/L PYR-CNC
 - Flocculation efficiency of 99% is achieved with the increase of surface roughness from 2.3 ± 0.9 nm to 5.4 ± 1.2 nm, confirming the flocculant attachment over the cell surface;
 - The increase of adhesive pixels to $18.0 \pm 5.4\%$ proves that full coverage of the cell surface with flocculant is not necessary to induce flocculation. Instead, it occurs through the formation of cationic patches.
- c** Flocculant saturation > 60 mg/L PYR-CNC
 - The roughness values reach a plateau around 10 nm, indicating saturation of the flocculant on the cell surface;
 - Drop in flocculation efficiency due to increased coverage of CNCs on the cell surface; the cells become positively charged, generating repulsive electrostatic forces that re-stabilize the suspension.