Magneto-catalytic Janus micromotors for selective inactivation of bacteria biofilms

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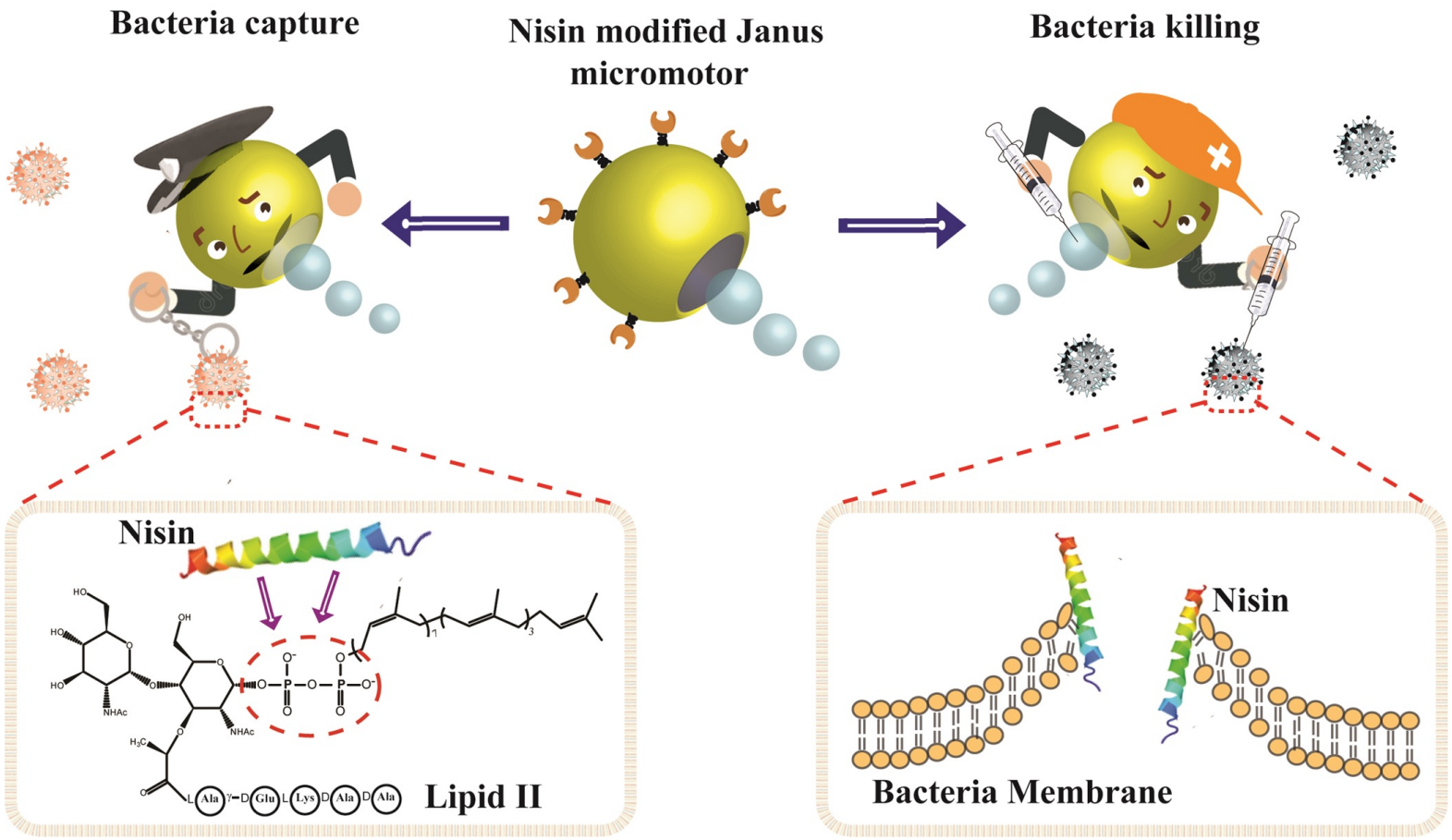
Universidad de Alcalá

MINYNANOTECH
Analytical Miniaturization and Nanotechnology

Magneto-catalytic Janus micromotors for selective inactivation of bacteria biofilms



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Abstract:. Herein we will describe the preparation of graphene oxide (GO)/PtNPs/Fe_2O_3) Janus micromotors for highly selective capture/inactivation of gram-positive bacteria units and biofilms. The strategy is based on the combination of a lanbiotic (Nisin) with Janus micromotors. Such peptide can bind to lipid II unit of the bacteria membranes, damaging its morphology and releasing its contents. The micromotors possess adaptative propulsion mechanisms, including catalytic mode (PtNPs) in peroxide solutions or magnetic actuation (fuel free) by the action of an external magnetic field. The enhanced movement and localized delivery of the micromotors (both in catalytic and magnetic actuated mode) results in a 2-fold increase of the capture/killing ability towards *Staphylococcus Aureus* bacteria in raw media (juice, serum and tap water samples), as compared with free Nisin and static counterparts. Unlike previous micromotors based strategies, this approach displays higher selectivity towards a type of bacteria along with enhanced stability, prolonged use and adaptative propulsion modes, holding considerable promise to treat methicillin resistant antibiotic infections, for environmental remediation or food safety, among other applications.

Keywords: Janus, peptide, bacteria, biofilm

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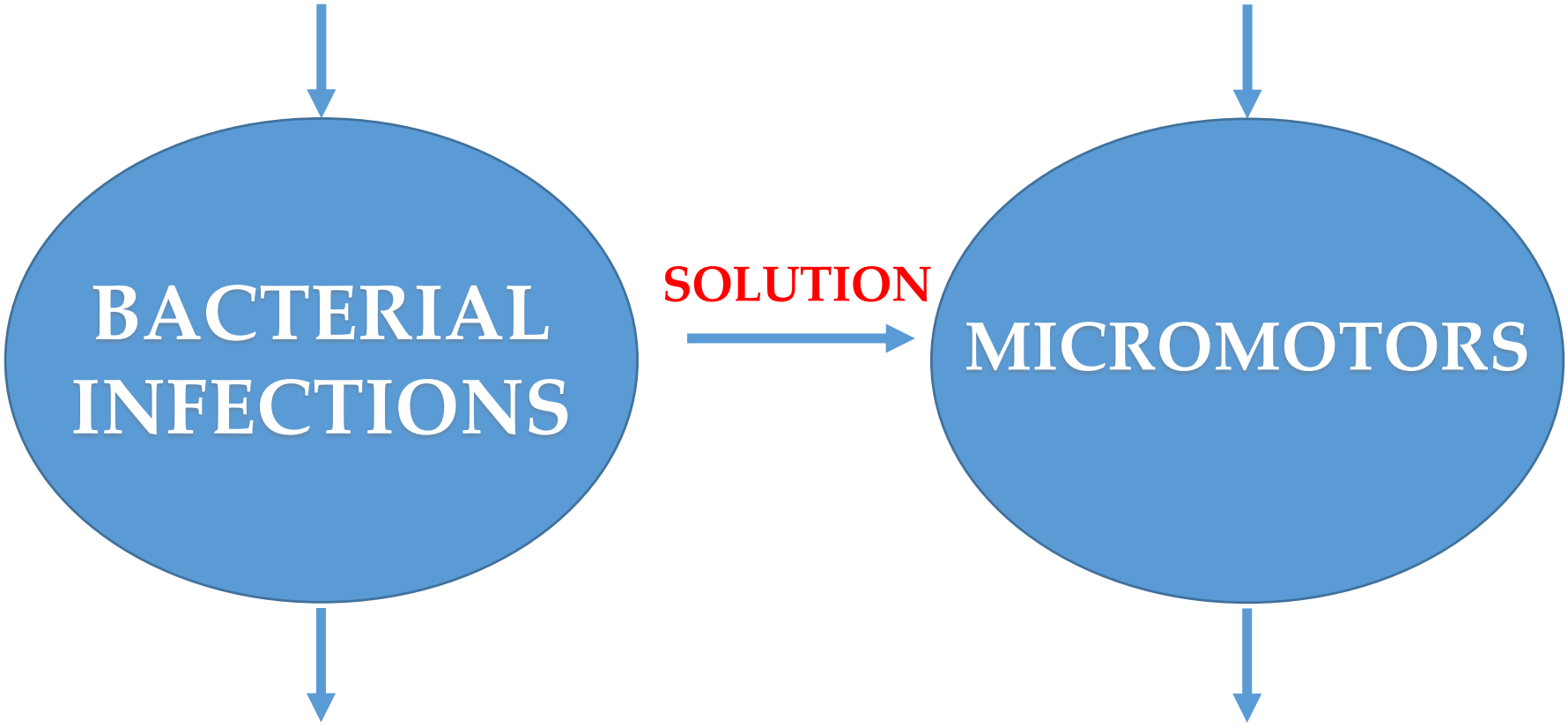
Introduction

10 global causes of death
~750,000 deaths worldwide

Enhanced fluid mixing
Localized delivery
Functionalization



New ways of treatment: decrease mortality rate!

Lower treatment times
Efficiency!

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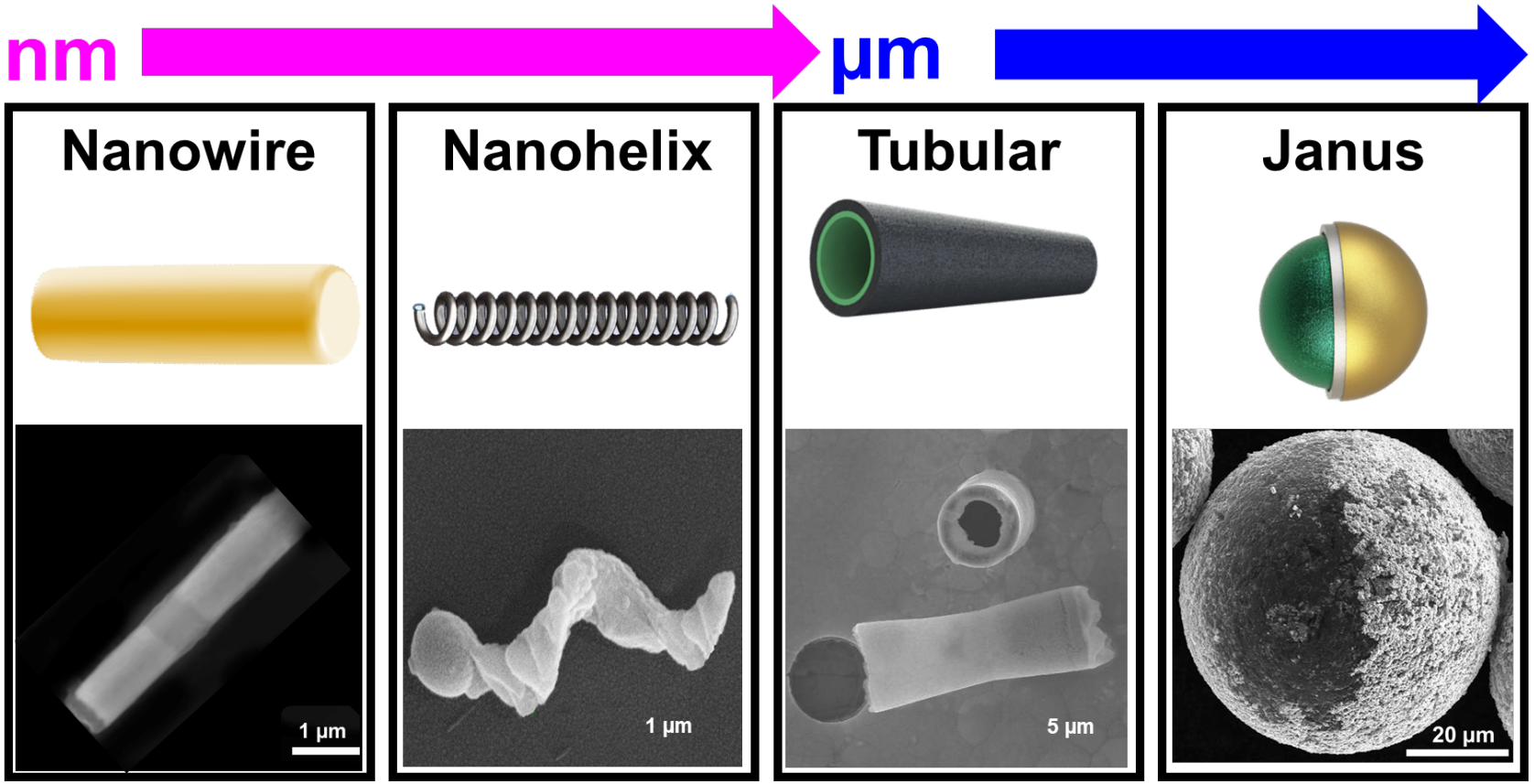
Introduction

MICROMOTORS

Nanoscale devices designed to perform selected mechanical movements in response to specific stimuli. ***Can convert energy into mechanical movement***



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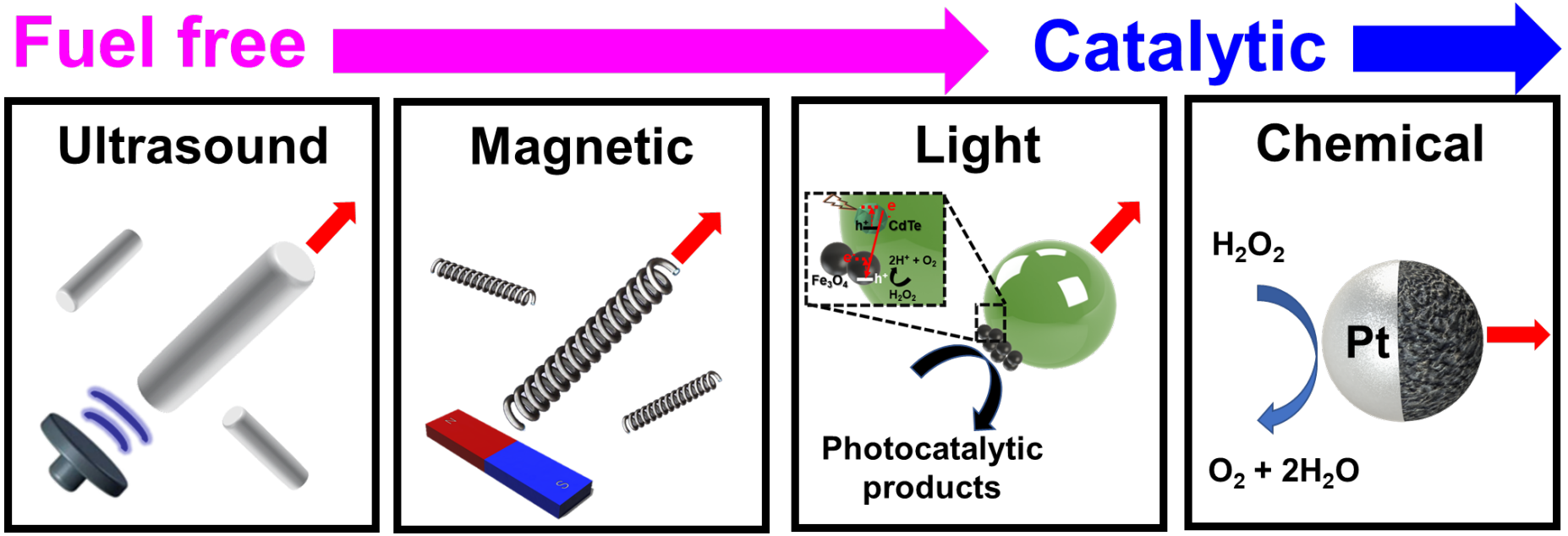
Introduction

PROPULSION MODES



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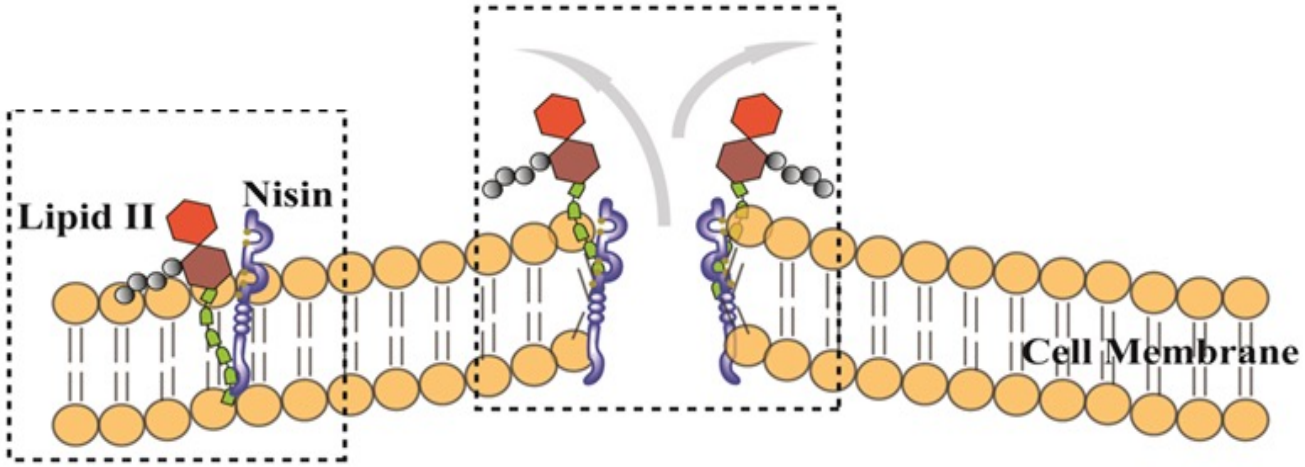
Introduction

LANBIOTICS → NISIN

Peptides with methyl-lanthionine residues and antimicrobial activity



Selective for gram-positive bacteria inactivation:
highest efficiency for multidrug resistance bacteria killing!

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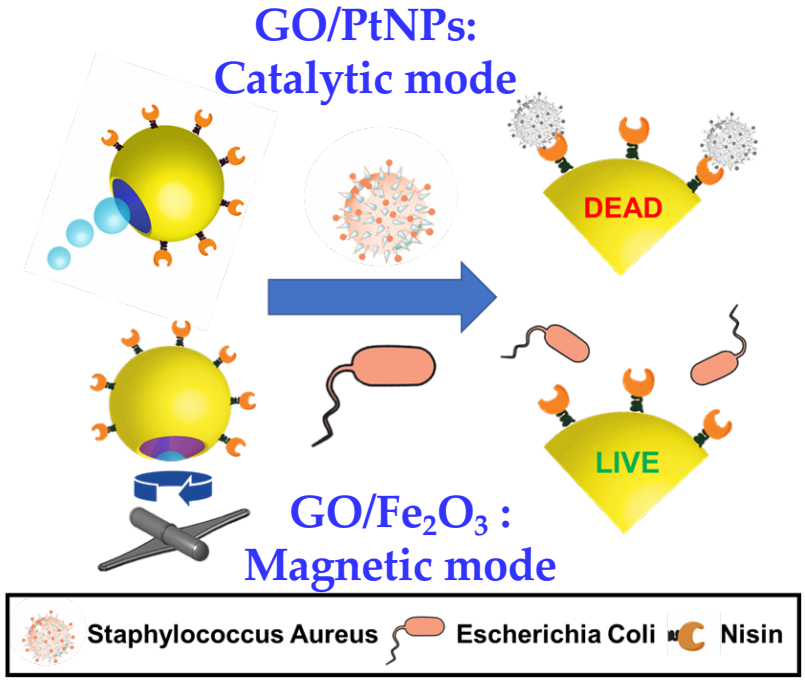
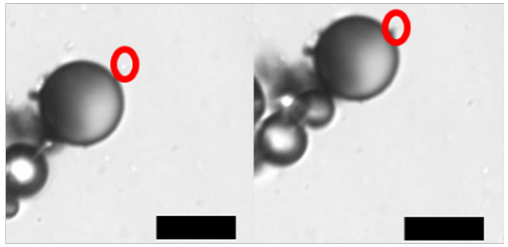
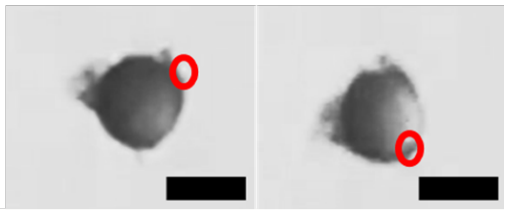
Results and Discussion

DUAL PROPELLED LANBIOTIC BASED JANUS MICROMOTORS FOR SELECTIVE BACTERIA INACTIVATION AND BIOFILM KILLING

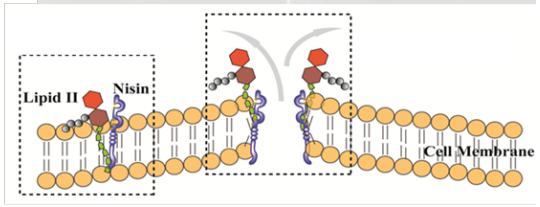


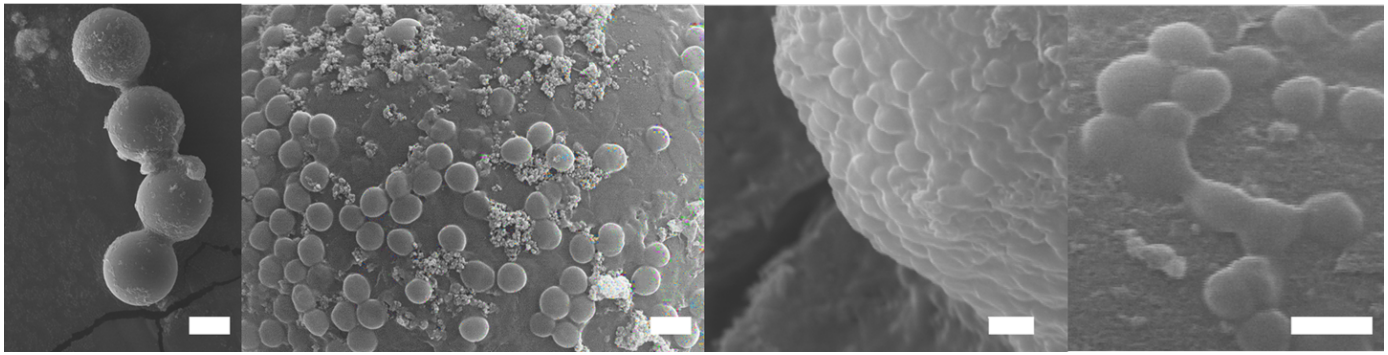


Bubble mode



Magnetic mode





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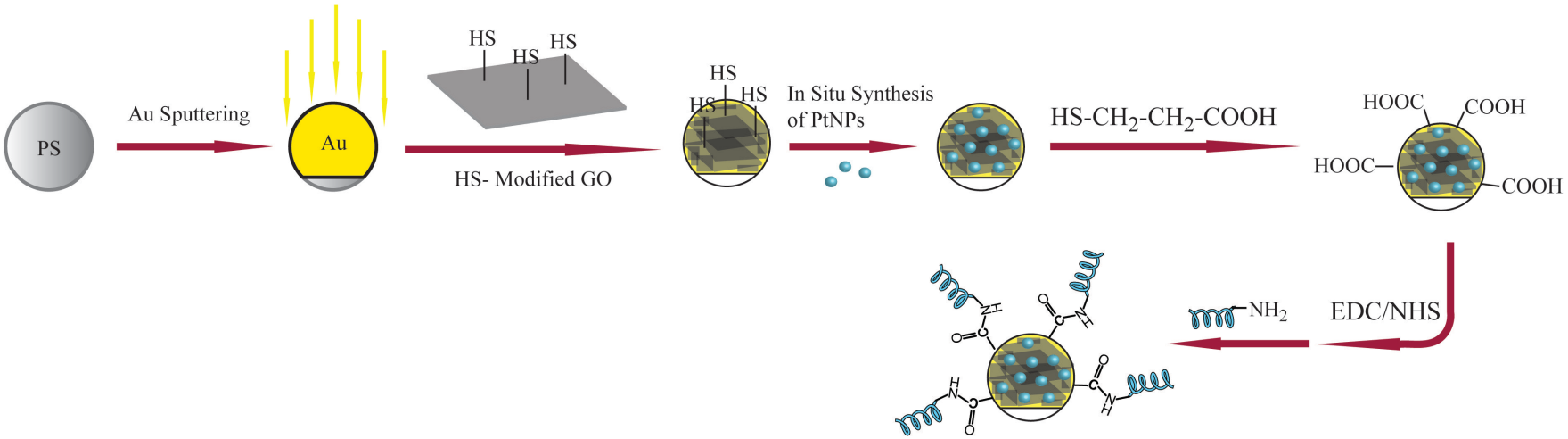
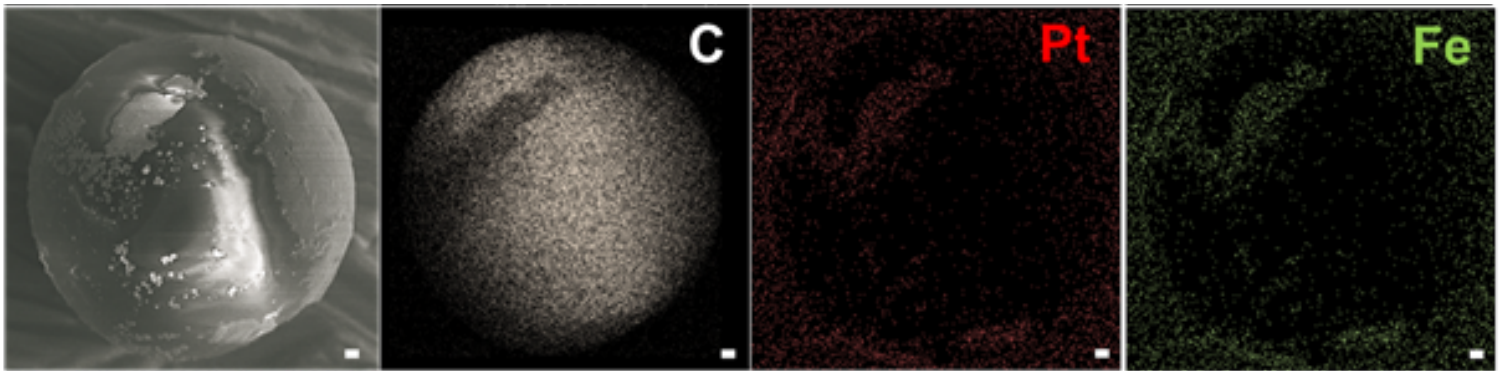
Results and Discussion

MICROMOTOR SYNTHESIS: SELF-ASSEMBLY



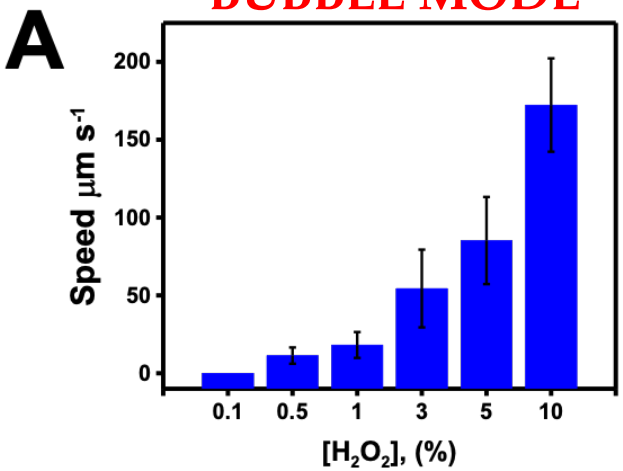
MORPHOLOGY: SEM AND EDX



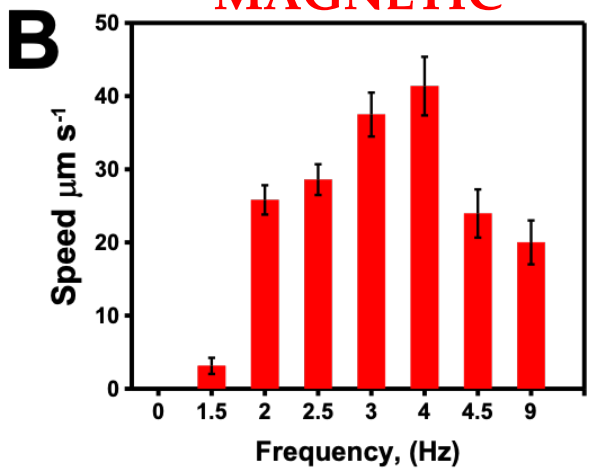
Results and Discussion

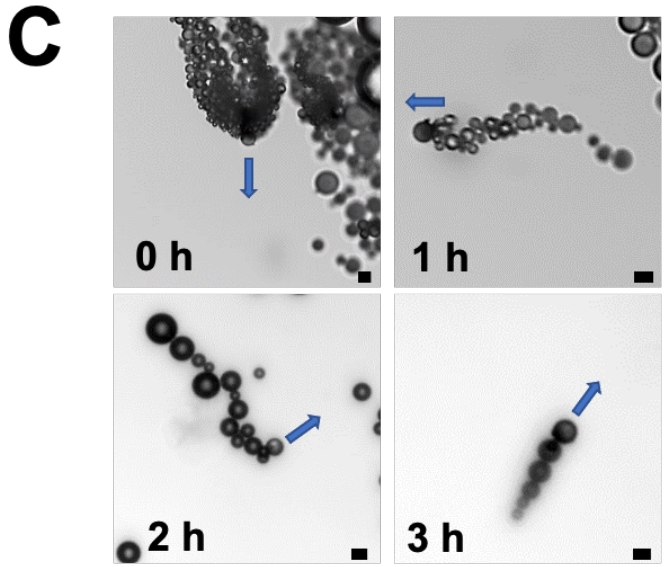
MICROMOTOR PROPULSION

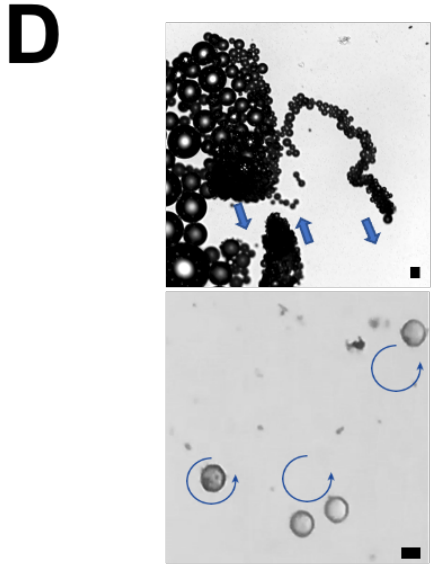
BUBBLE MODE



MAGNETIC







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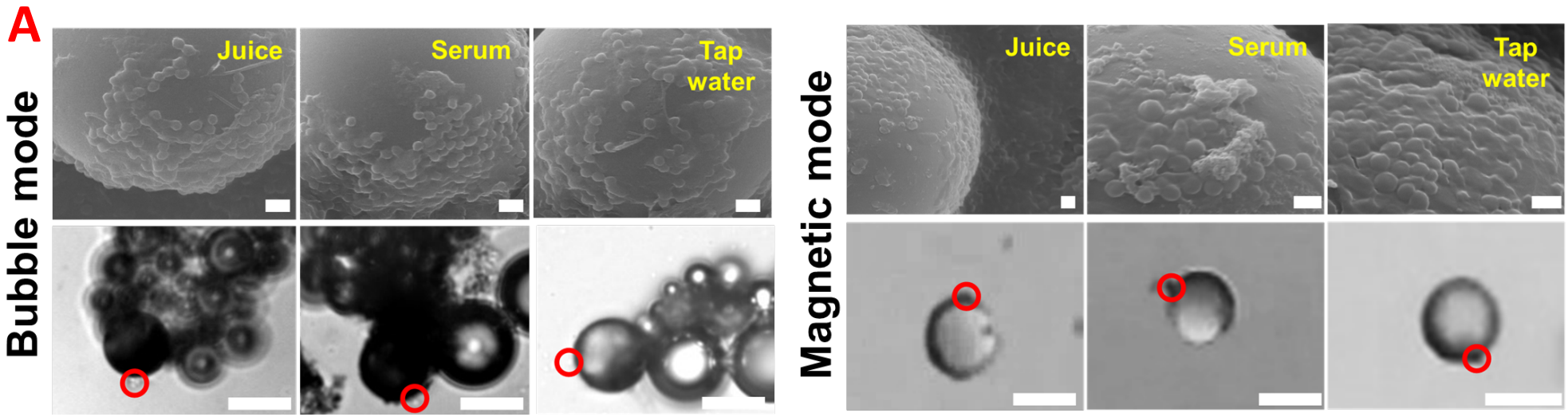
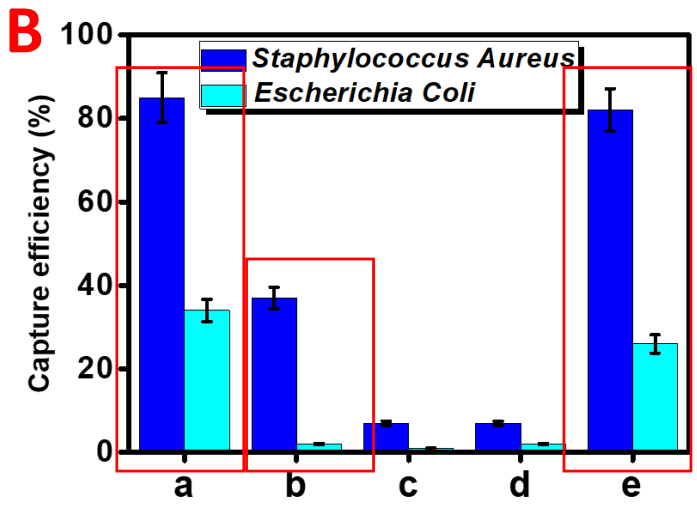
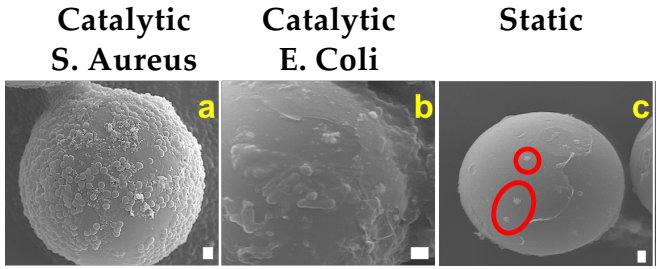
Results and Discussion

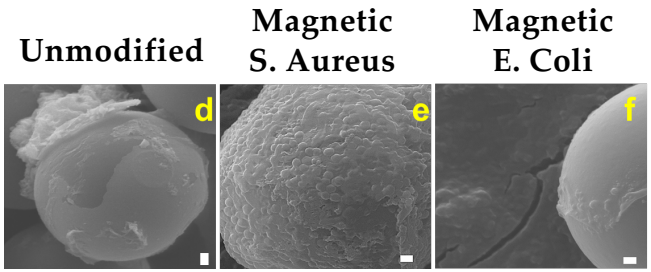
Enhanced bacteria capture in complex raw media with high efficiency







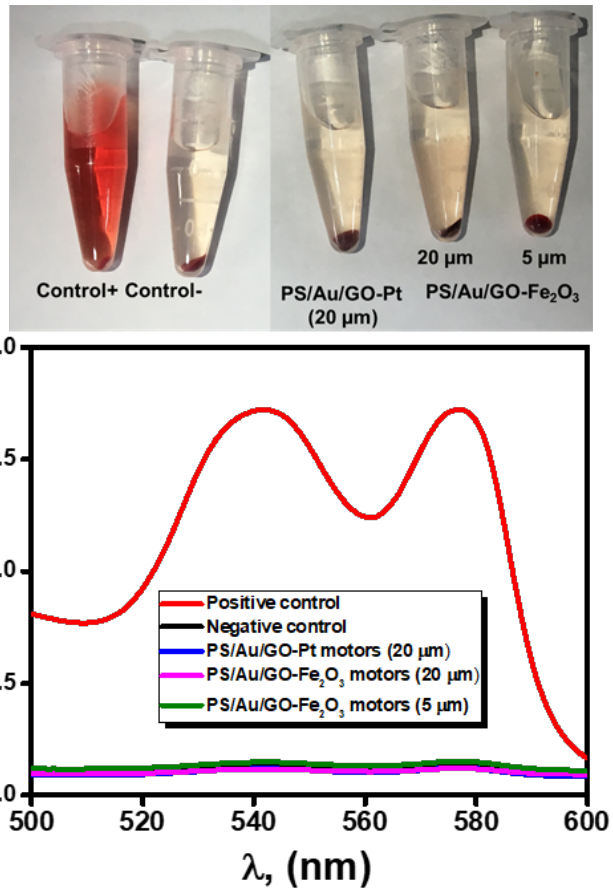
a) moving (catalytic mode);
b) static
c) Unmodified catalytic
d) unmodified magnetic
e) moving (magnetic mode).



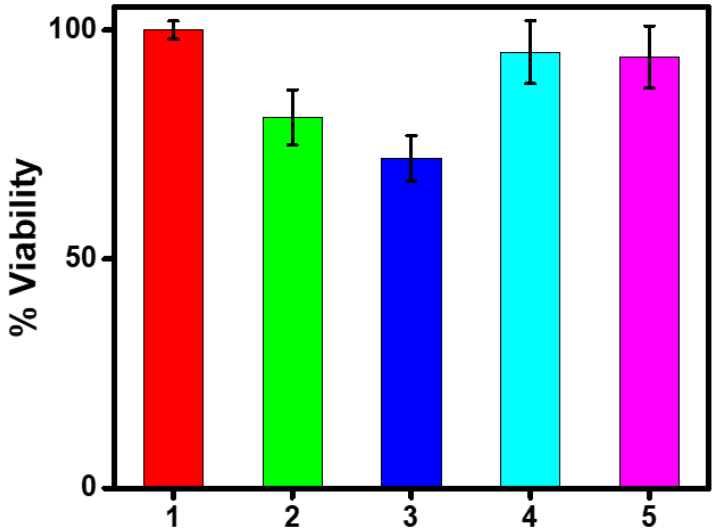
Results and Discussion

Biocompatibility and efficient movement against blood flows in magnetic mode: great potential for in-vivo applications

Hemocompatibility



MTT



1)control ; 2)20µm PS-Au; 3)20µm Nisin Pt motor; 4)20µm Nisin Fe_2O_3 motors ; 5)5 µm Nisin modified Fe_2O_3 motors

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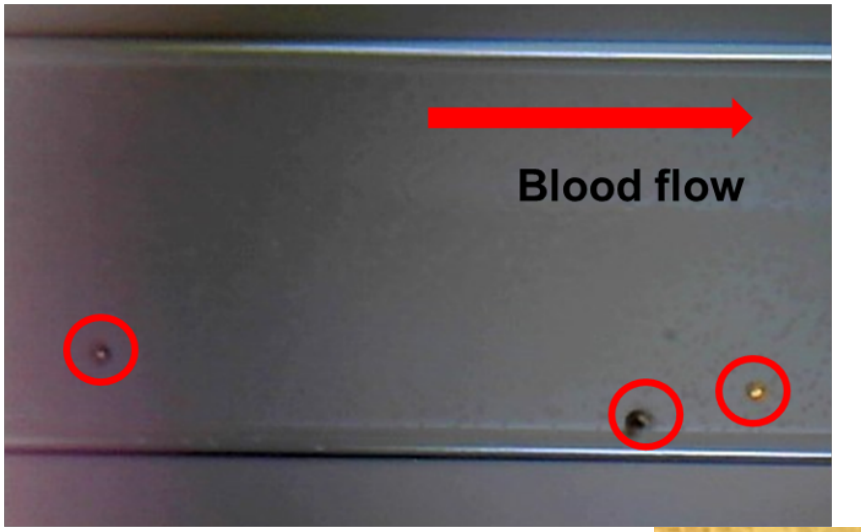
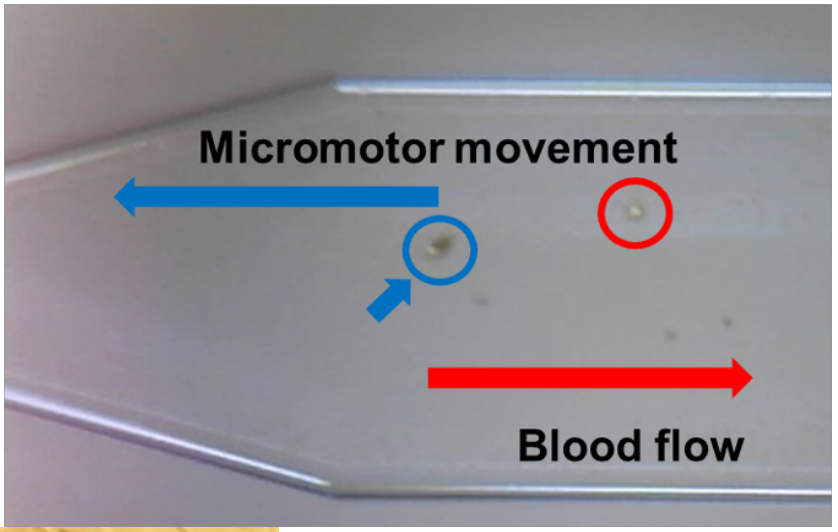
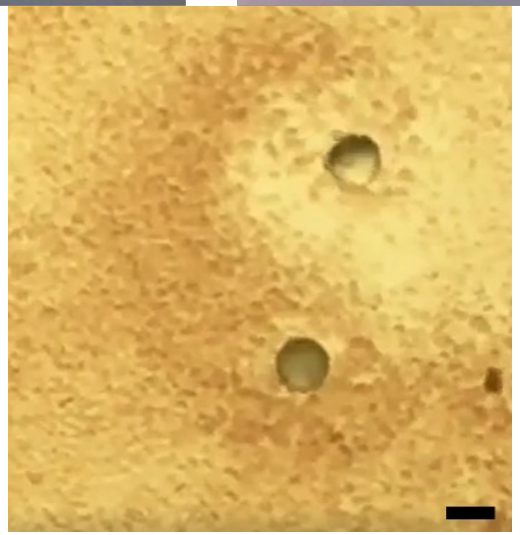
Results and Discussion

Movement in blood and against blood flood in magnetic mode







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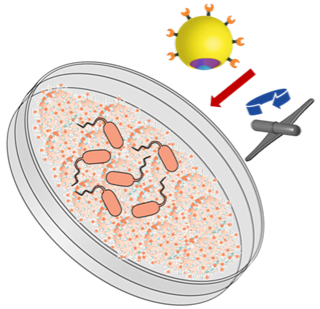
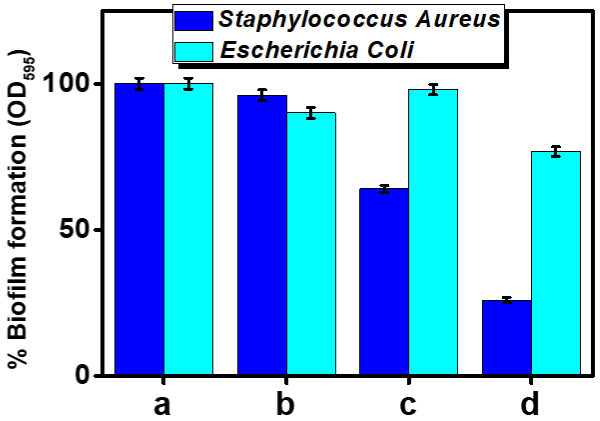
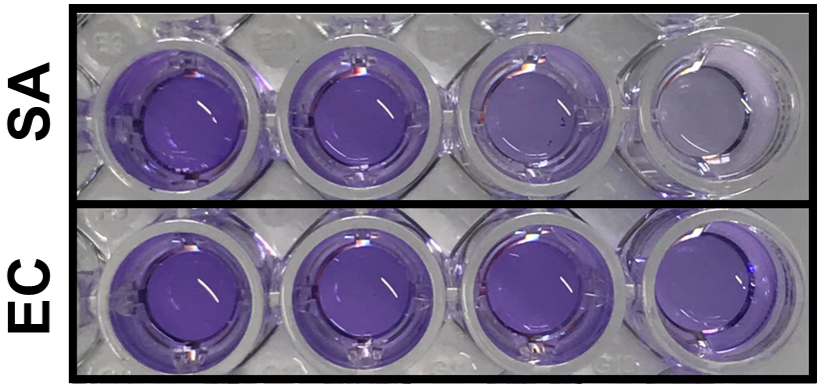
Results and Discussion

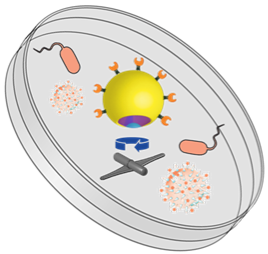
Selective inactivation of biofilms



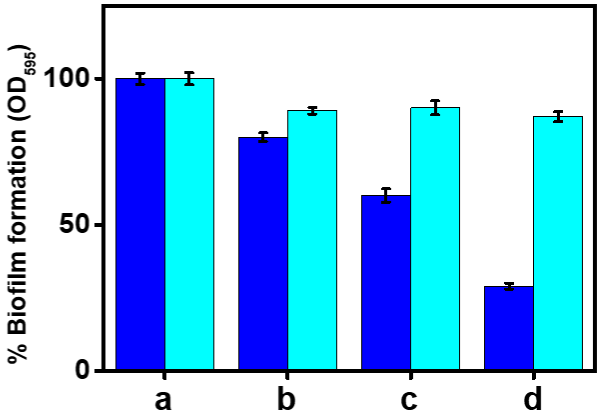
Fast killing

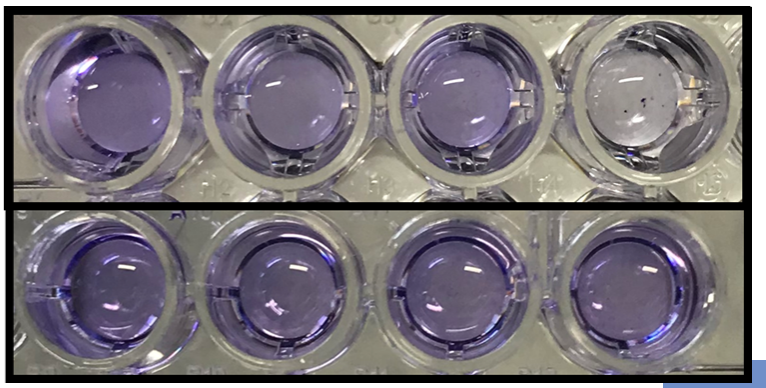






Long-term inactivation





a) Initial; b) unmodified moving; c) static modified motor; d) modified moving motor

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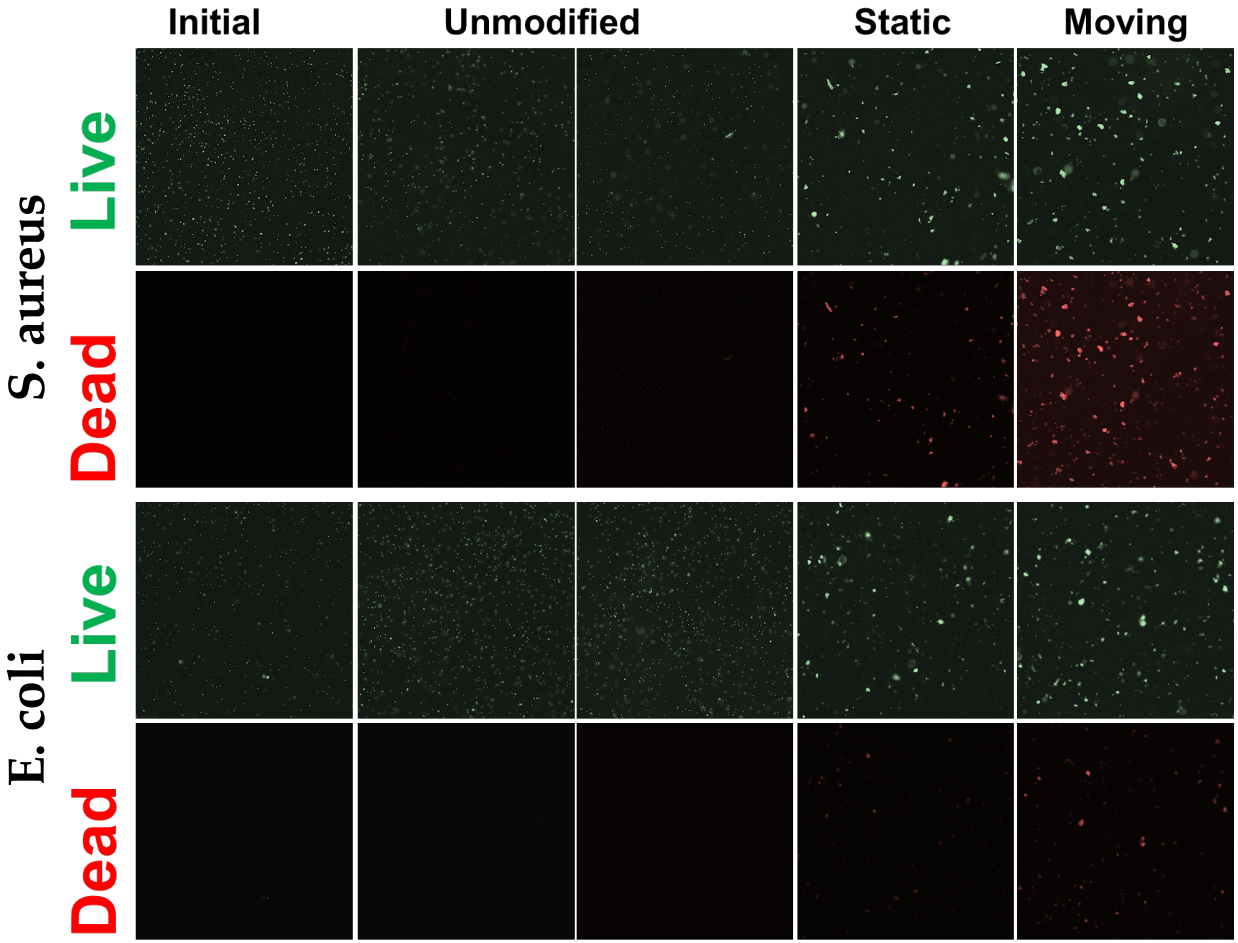
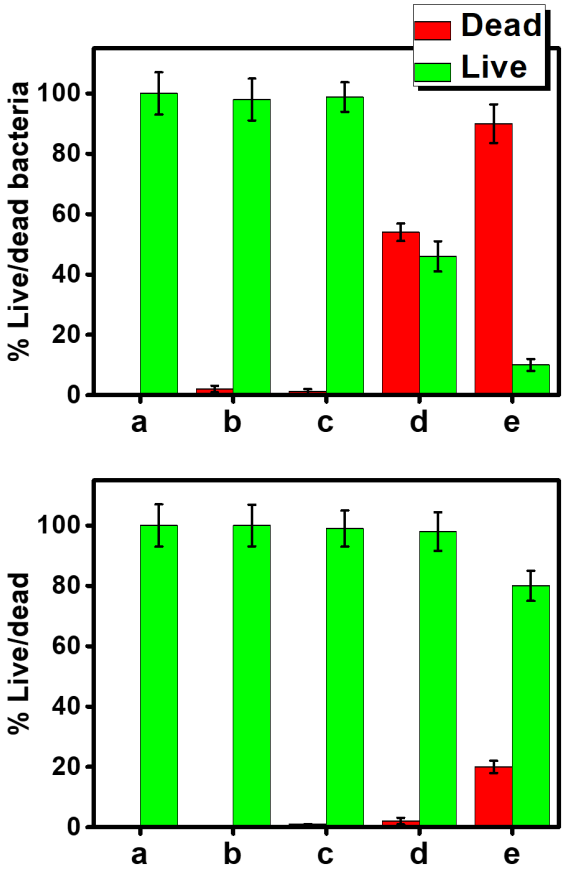
Results and Discussion

Selective bacteria inactivation (magnetic mode)





a)initial; b) unmodified moving motor, c) unmodified motors with free peptide, d) static modified motors, e) moving modified motor

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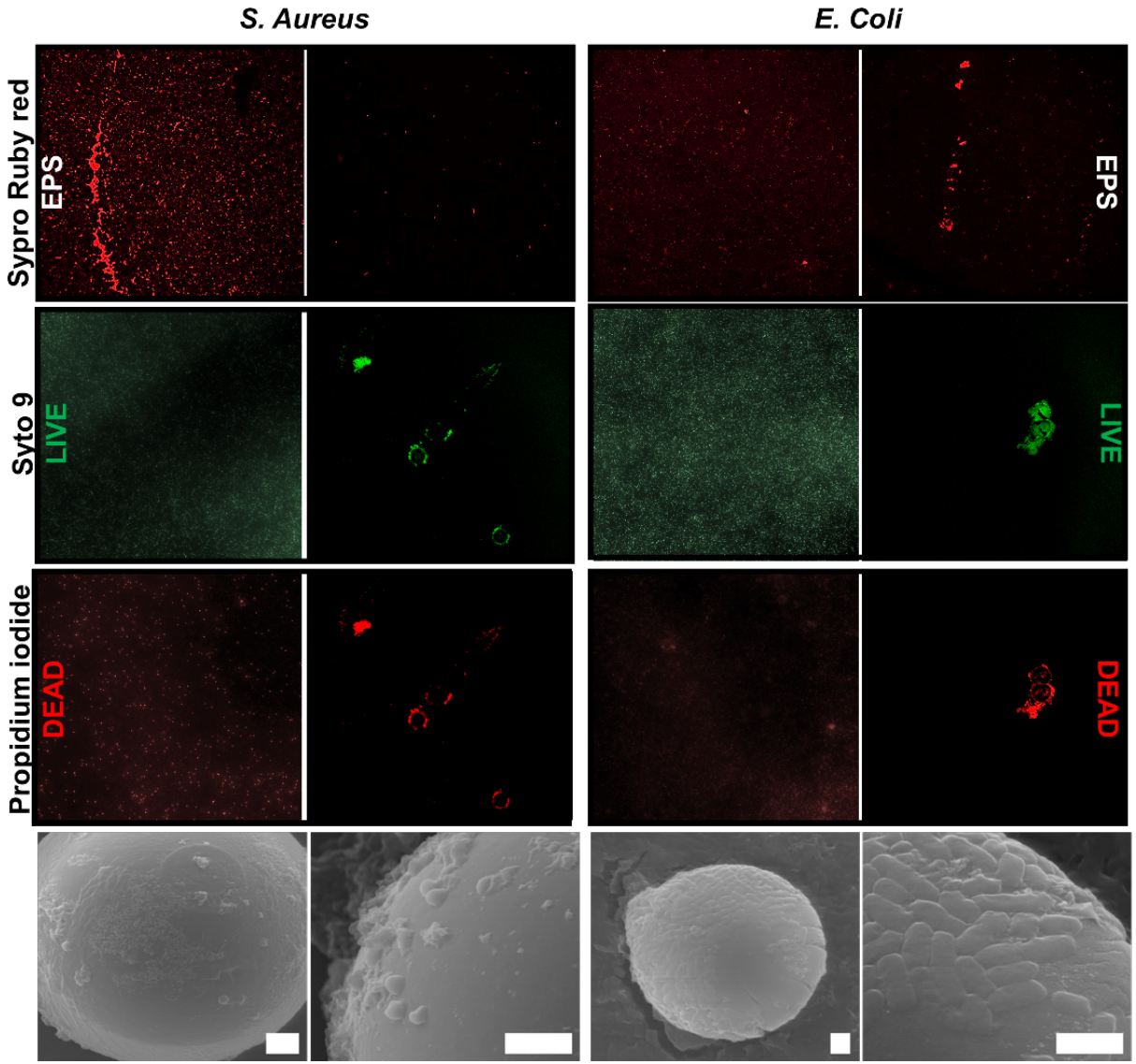
Results and Discussion

Selective extracellular polymeric substances (biofilm) deactivation



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Conclusions

- First combination of self-propelled micromotors with lanbiotics.

- Specific interaction of amine groups in Nisin molecule with the pyrophosphate groups of the lipid II molecules in the membrane of gram-positive bacteria result in a damage and killing.

- The strategy does not require additional pre-treatment of the bacteria or sample purification, allowing for its usage in raw complex samples, which is a major advantage over other micromotors strategies based on labile receptors (such as antibiotics or biological components).

- The presence of two engines (catalytic and magnetic) in the micromotors allow for an adaptative behavior to tailor each application.

- Accelerated kinetics for improved capture (as reflected by the 83% capture efficiency percentages of moving micromotors towards Staphylococcus Aureus) and prolonged contact for fast inactivation.

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Acknowledgments

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