Nano and micro robots in targeting and eliminating biofilm infections: From mechanical matrix disruption to targeted drug delivery and detection

Supervisor: Dr. Hossein Fazeli

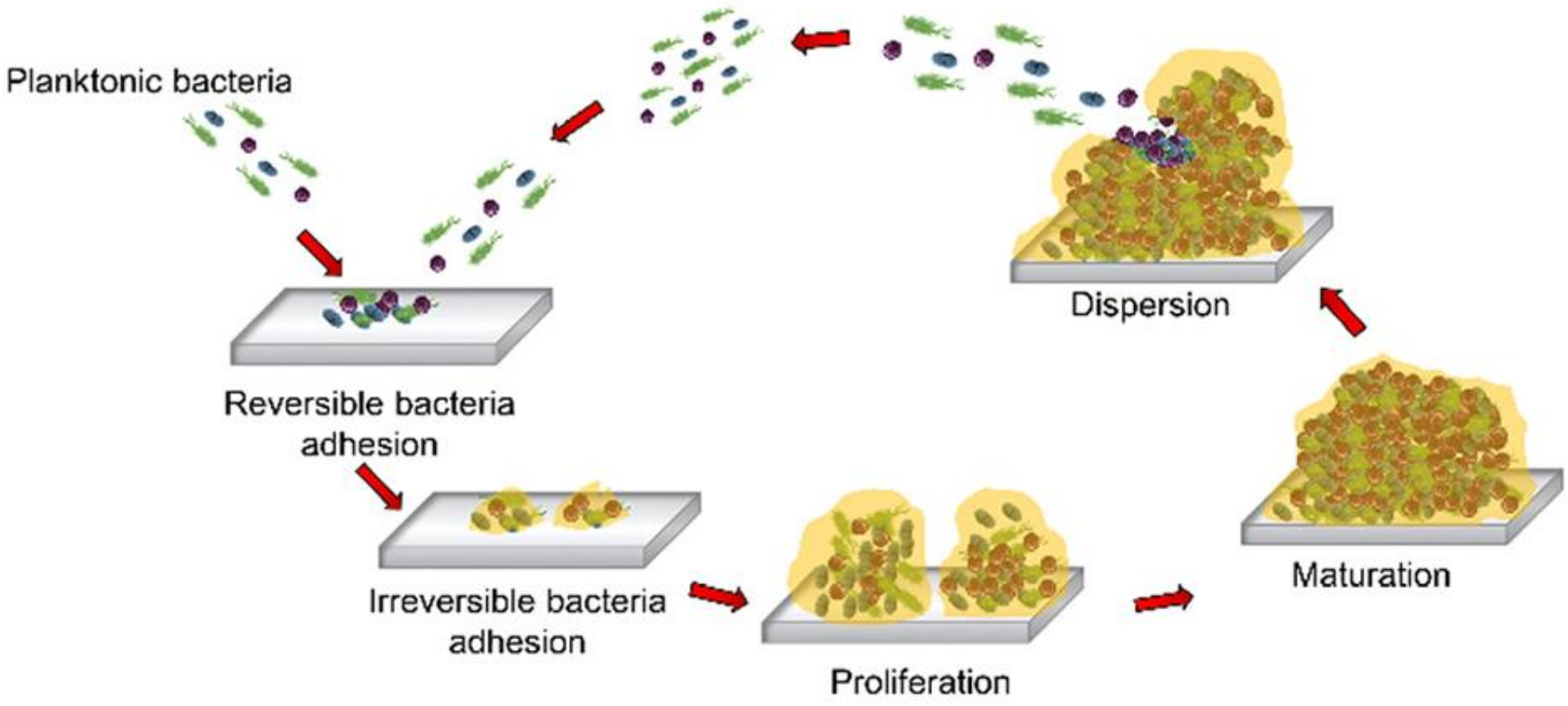
Presentor: Mohsen Alizadeh

Outline

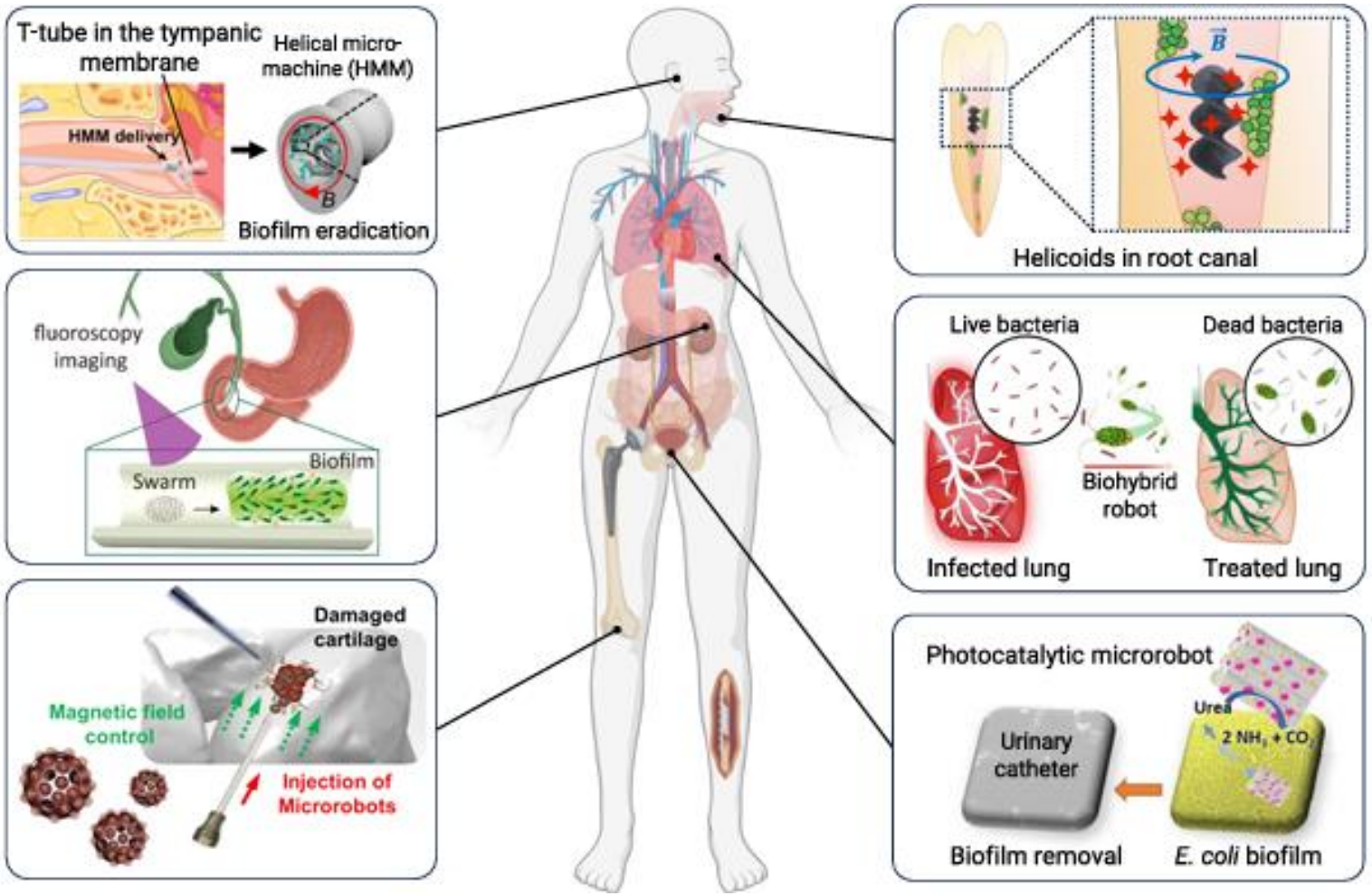


- Biofilm structure and challenges in its treatment
- Introduction of nano and micro robots as a new diagnostic-therapeutic method
- How to target and mechanically and chemically destroy biofilm
- Laboratory studies conducted to evaluate the ability of these robots to destroy and treat biofilm
- Medical applications, benefits and challenges of transferring this technology to human treatment

Why is biofilm a medical problem?

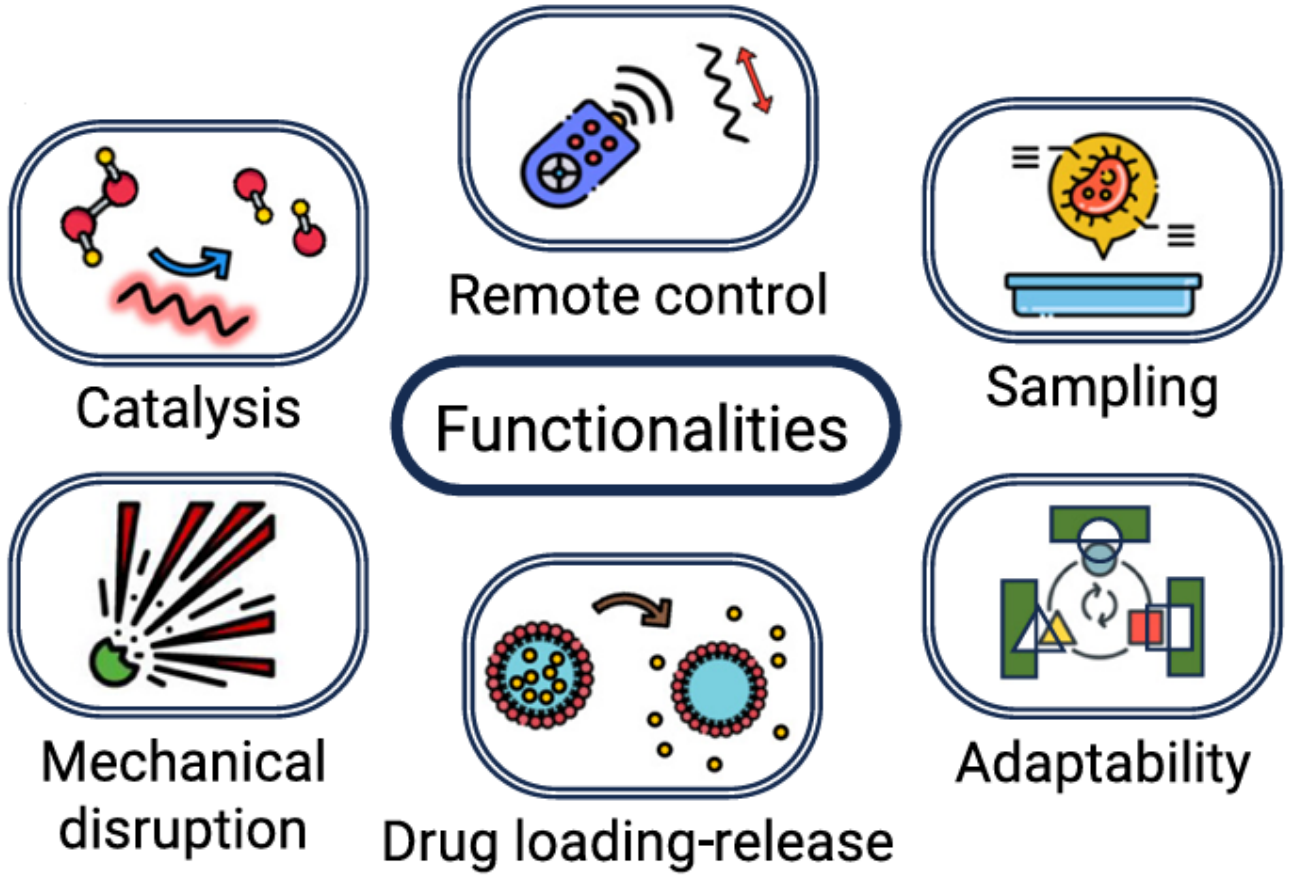


Limitations of conventional treatments



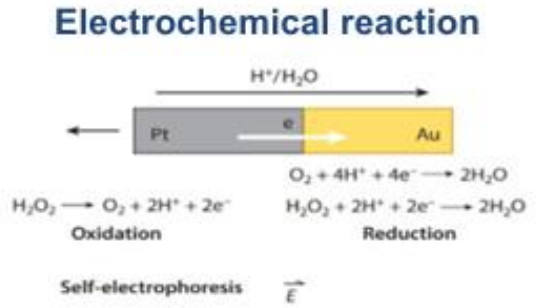
What is an anti-biofilm robot?

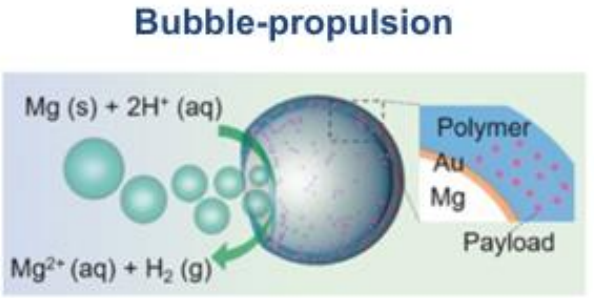
- Can move to the biofilm site in a controlled manner
- Can perform at least one therapeutic or diagnostic function

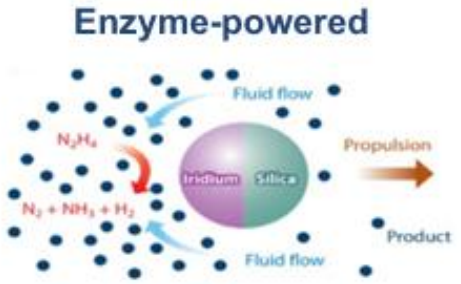


Types of robots based on their movement method

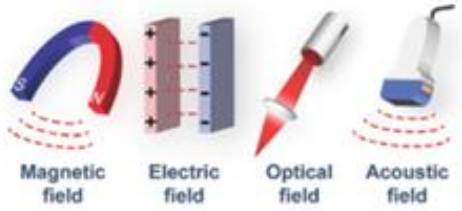
1. Catalytic
2. Biological
3. Optical
4. Magnetic

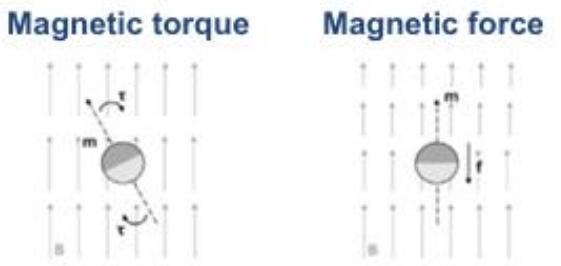




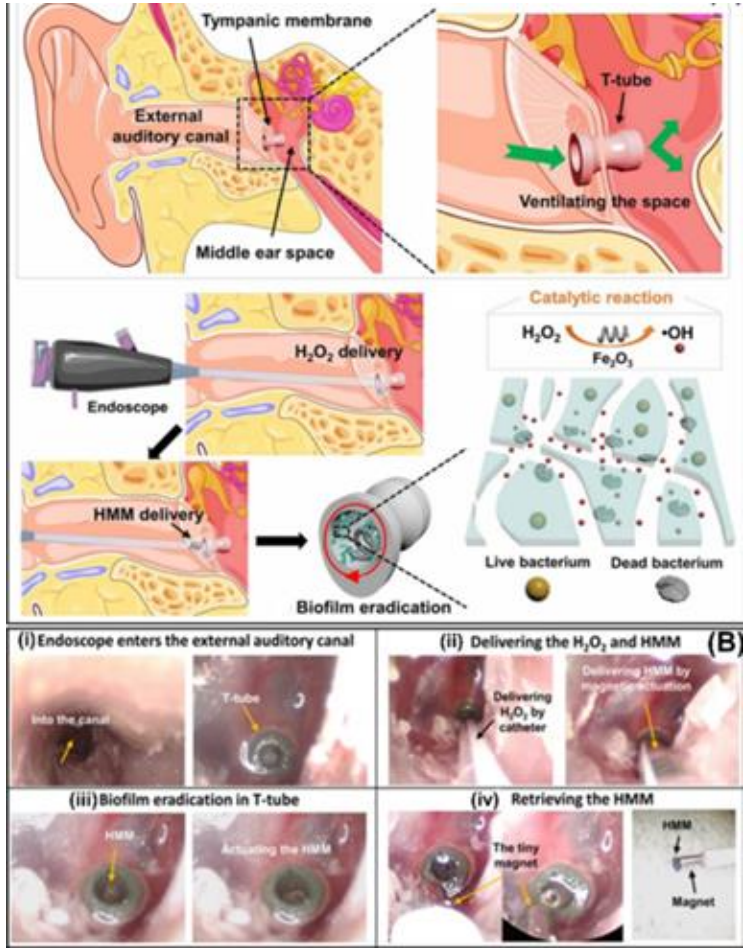


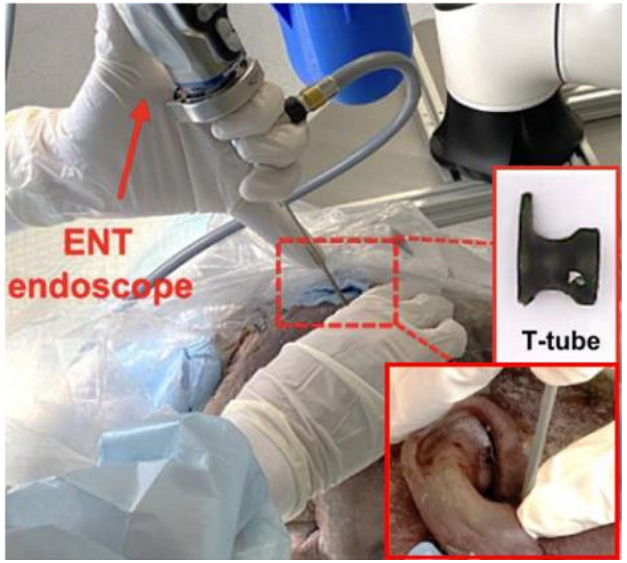


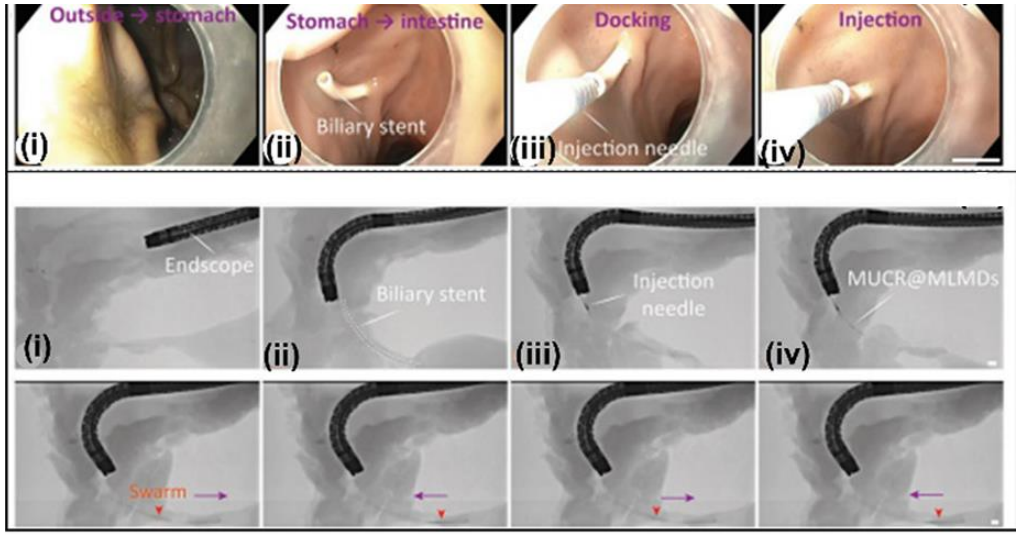




Mechanism of action of anti-biofilm: First step; reaching the site of infection

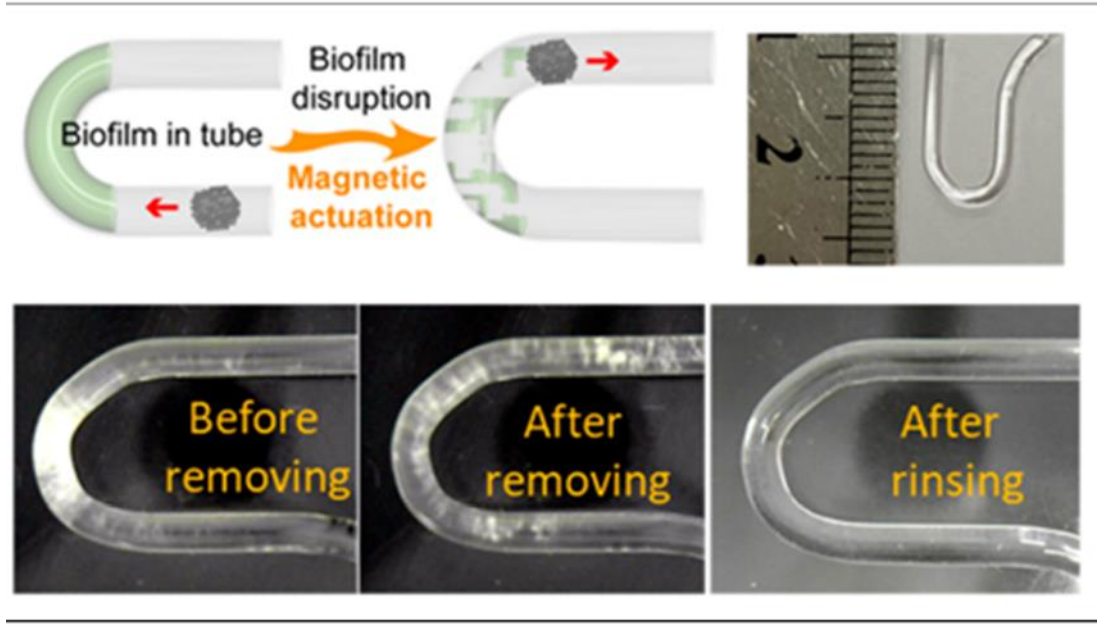




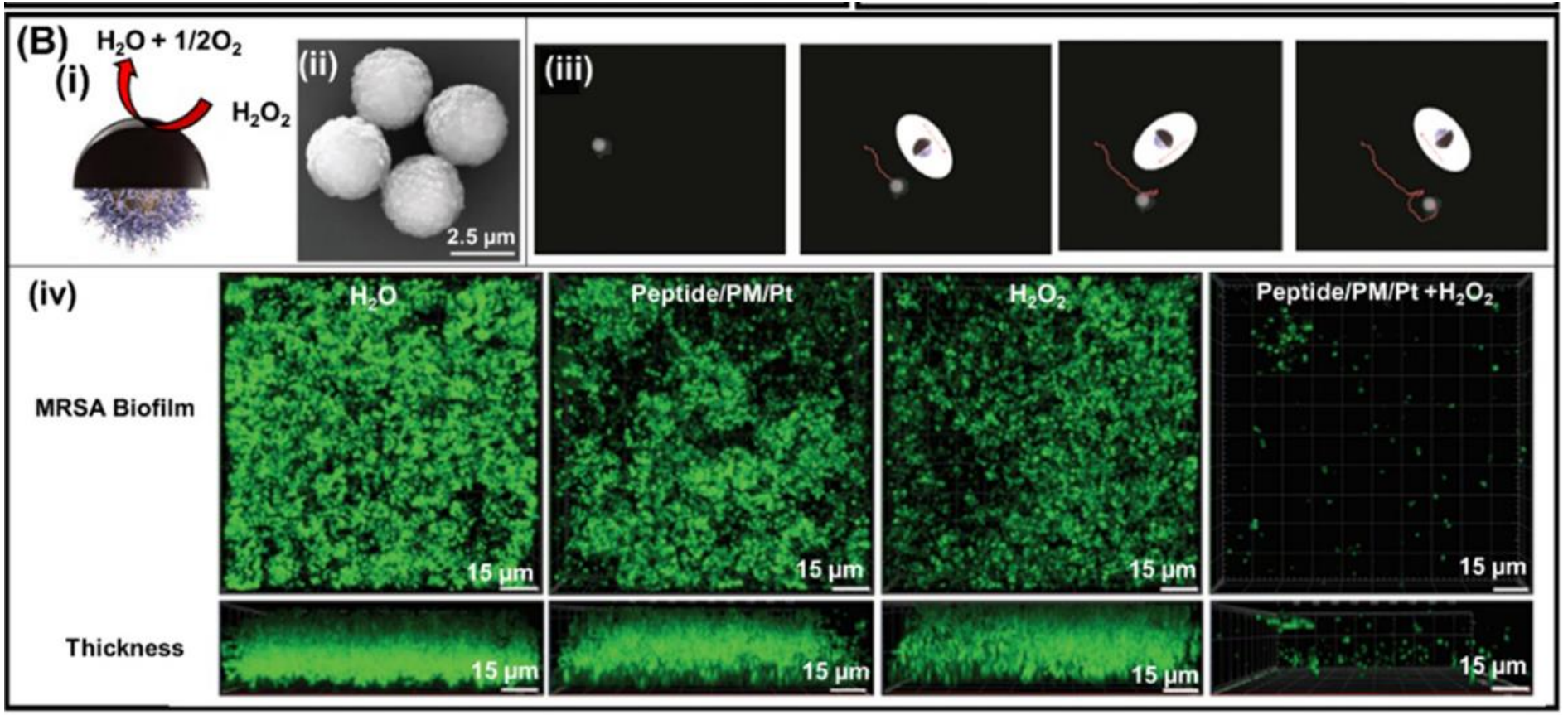


Anti-biofilm mechanism of action: Step 2: Breakdown of the EPS matrix and killing bacteria

- Bursting oxygen bubbles
- Rotating, rolling or spiraling motion
- Heat generation
- Local antibiotic release
- Delivery of antibacterial peptides

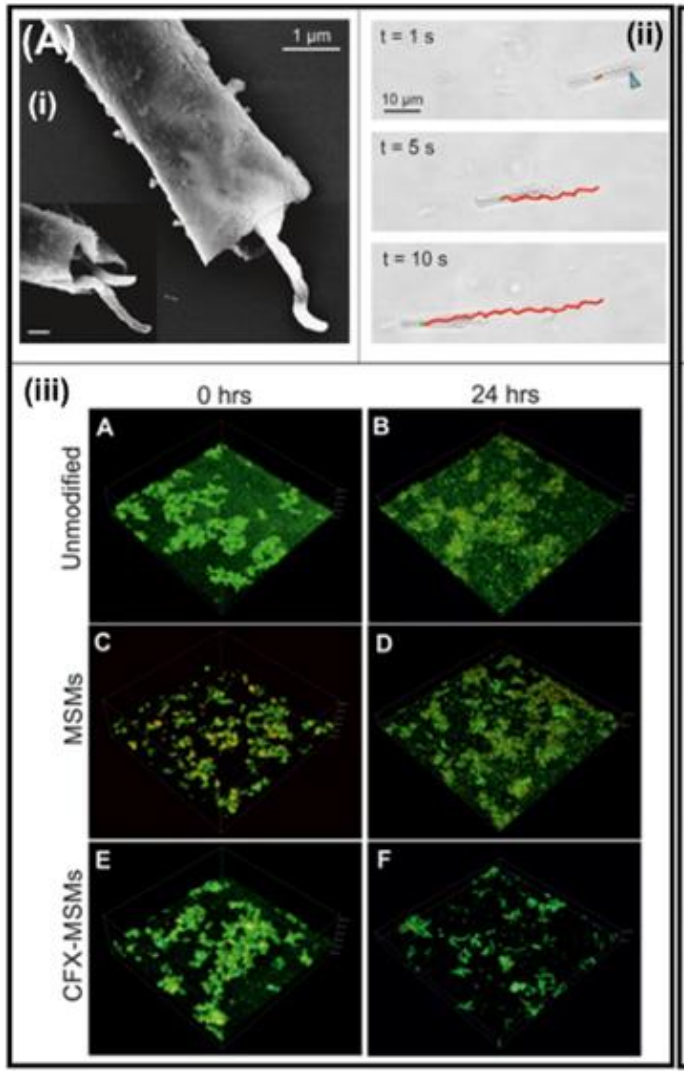


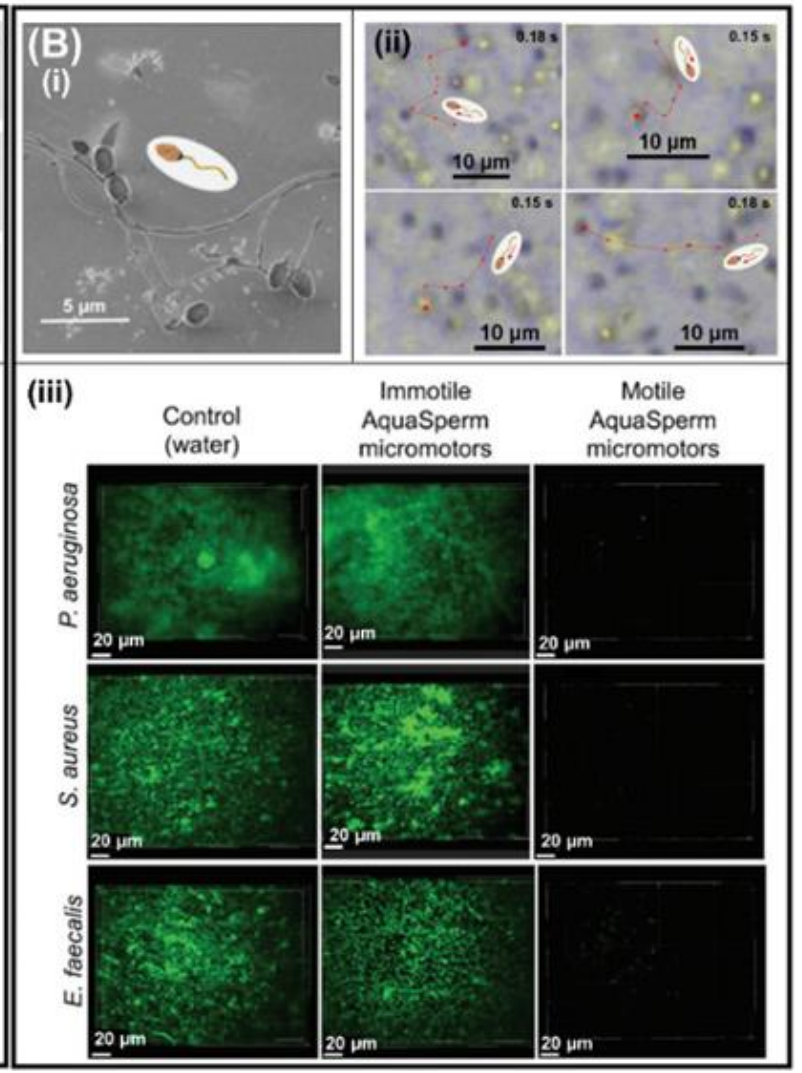
Selected Studies: Catalytic Robot



Selected Studies: Biological robots

Magnetospirillum gryphiswaldens





Catfish aqua sperm cells

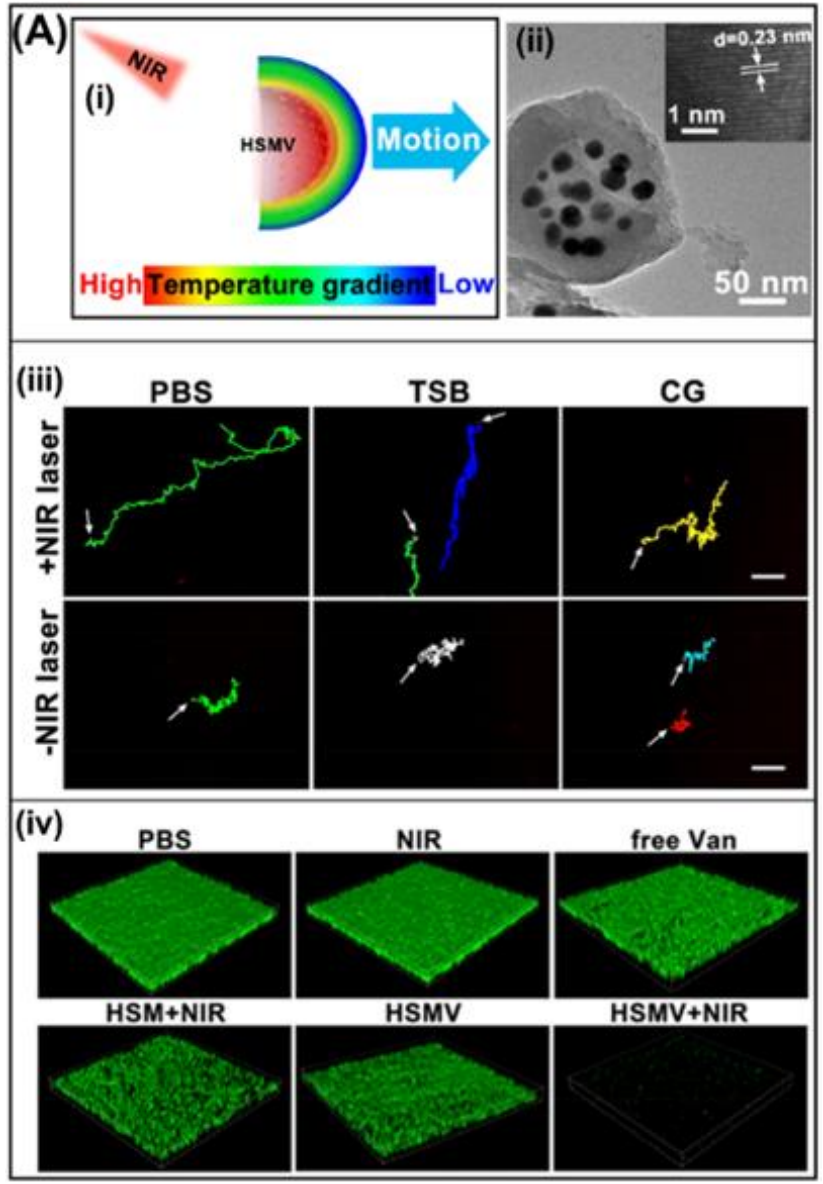
Selected Studies: Light-driven robots

NIR-activated nanoswimmers (HSMV)

Composition: Mesoporous silica, gold nanoparticles, and vancomycin

Activation: Near-infrared light induces motion and local heating

Mechanism: Photothermal treatment combined with vancomycin release

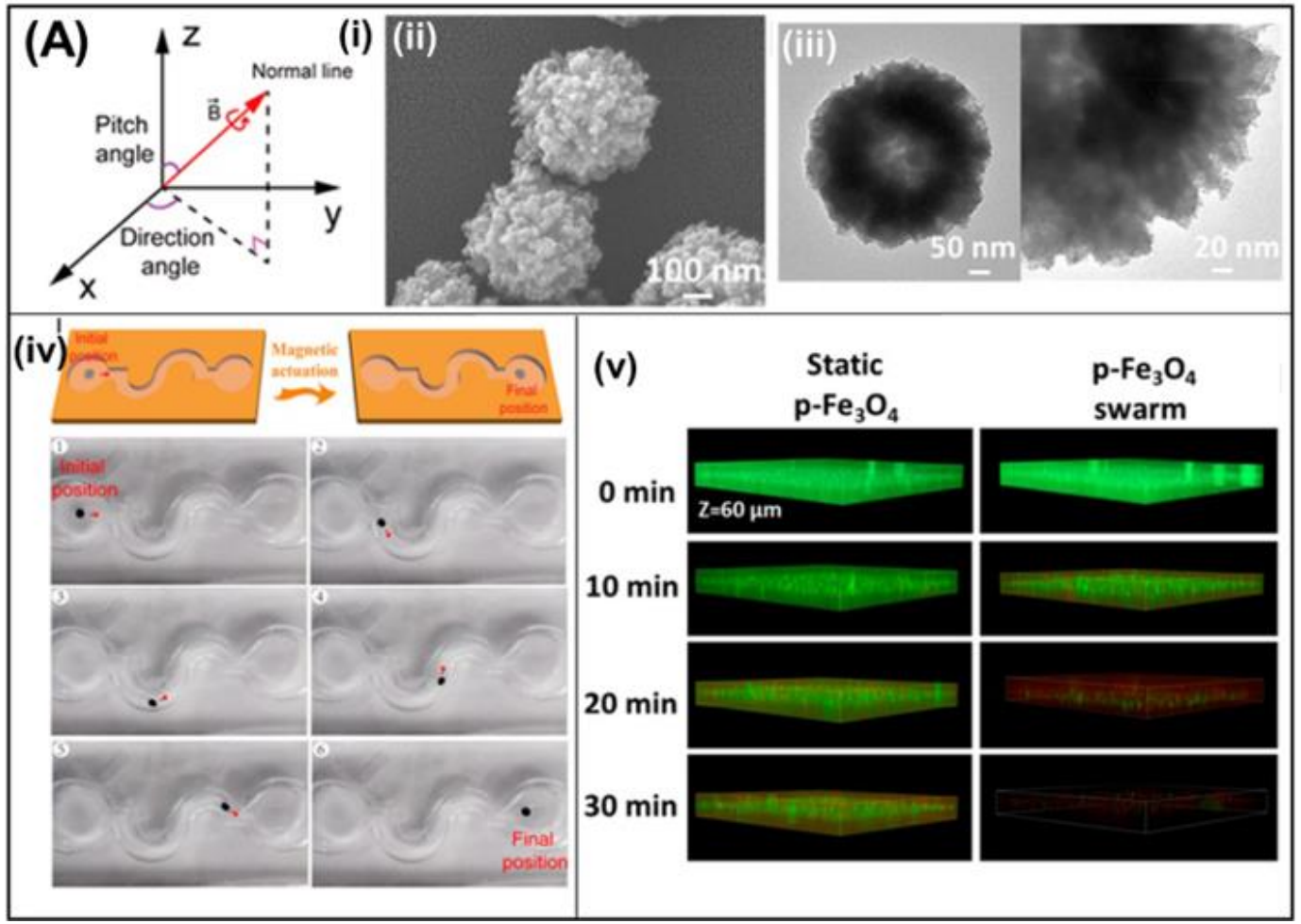


Selected Studies: Magnetically driven robots

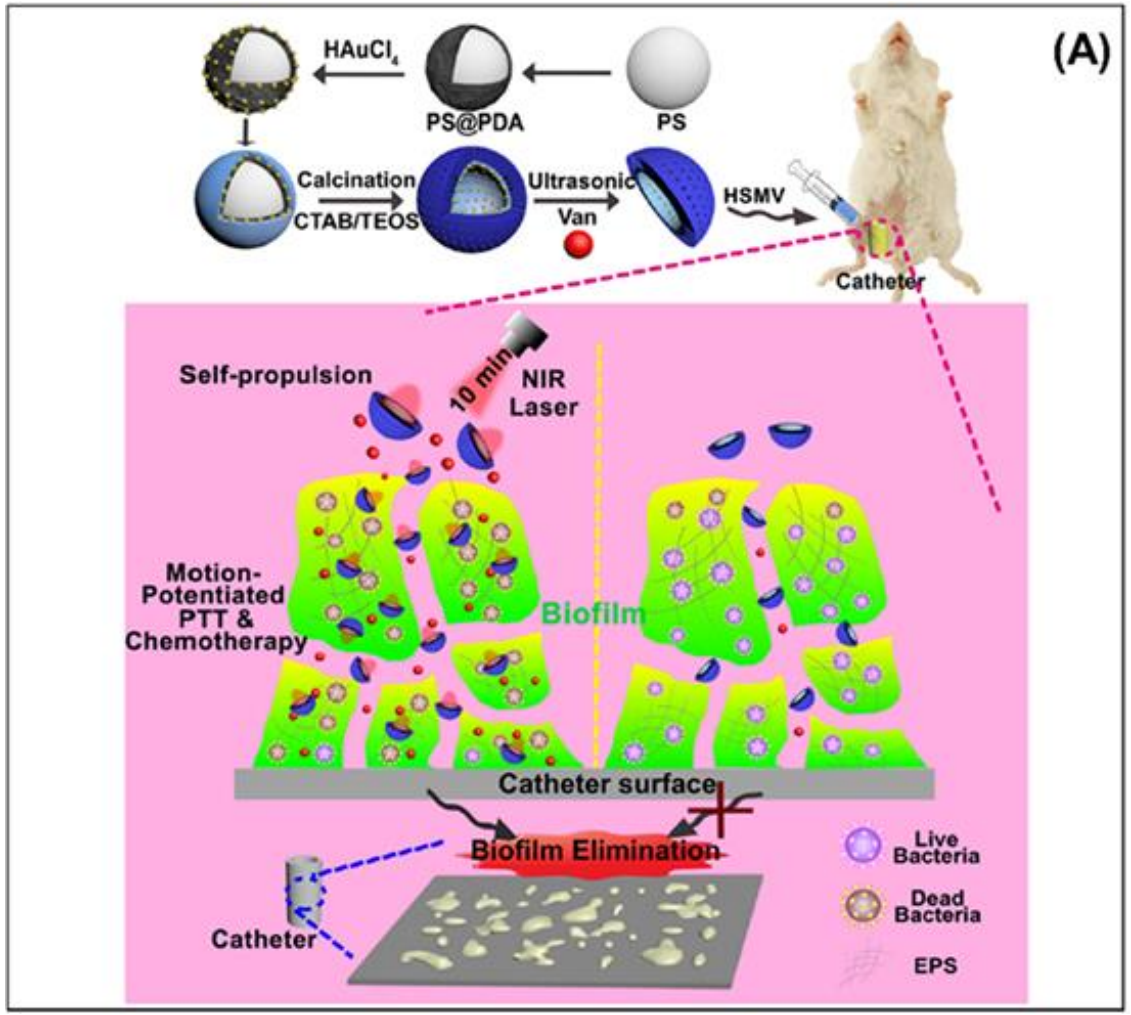
Composition: Porous iron oxide (Fe_3O_4) particles

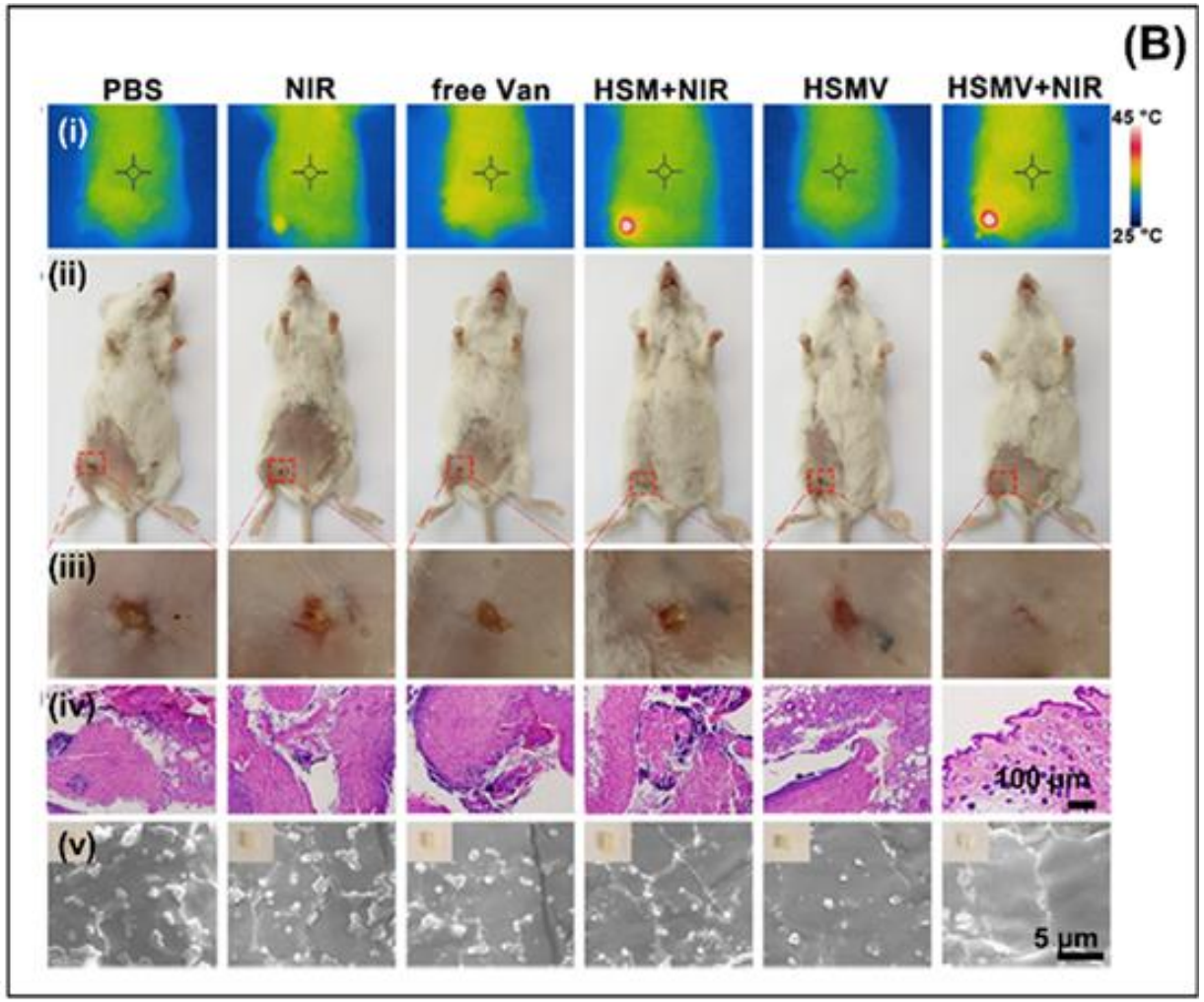
Actuation: Controlled swarm motion under a rotating magnetic field

Mechanism: Mechanical disruption of EPS + Fenton reaction mediated ROS generation



In vivo biofilm treatment





Advantages	Limitations and Challenges
Access to narrow and difficult spaces; such as root canals, catheters, ear tubes, and stents	The biocompatibility and long-term toxicity of some materials are still not fully understood
Remote control, especially with magnetic fields	Control equipment, especially magnetic systems, can be large and complex.
Simultaneous physical and chemical degradation of EPS matrix	Many studies are still conducted in vitro, in animal models, or ex vivo
Local drug delivery; reducing drug contact with healthy tissues	Tracking robots in the body is difficult, especially at the nanoscale
Multi-purpose capability: biofilm removal, bacteria killing, sampling and diagnosis	Mass production, sterilization, cost, and obtaining clinical approval are challenging

Reference

I. Chemical multiscale robotics for bacterial biofilm treatment (2024)

II. Targeting biofilm infections in humans using small scale robotics (2024)

Thank you for your attention