ROBOT-PLANKTON: A SWARM OF MICROSCALE AQUATIC ROBOTS

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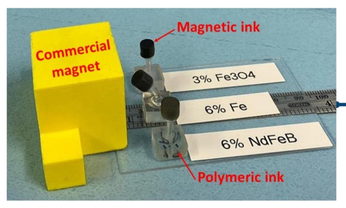
Vision: Increase micro/nano robot autonomy and functionality to solve environmental medical, and manufacturing problems

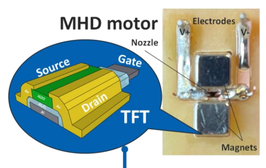
A. Advanced manufacturing of magnetic materials

To develop techniques for 3D printing of magnetic materials with sub millimeter scale resolution



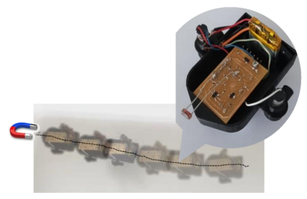
B. Complex microsystems

To develop electronic components and functional microsystems capable of interaction and manipulation of living cells



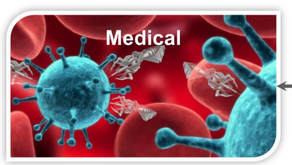
C. Microrobot swarms

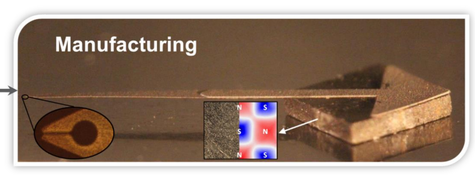
Defining a fabrication technique for a fleet of autonomous swimming microrobots

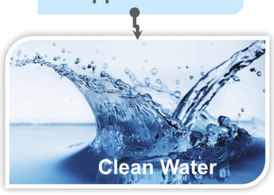


Microrobot Autonomy

Industrial applications



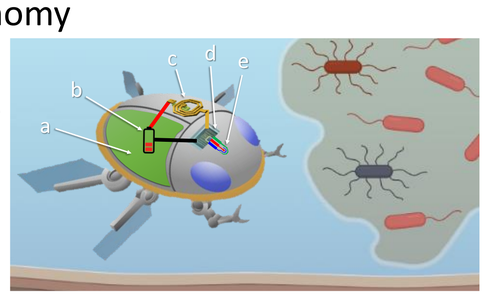




Field challenges: Minimum requirements for microorganism autonomy and survival:

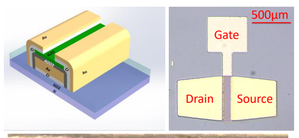
- Foraging problem in microorganisms = recharge for microrobots
- Klinotaxis / Chemotaxis / Magnetotaxis: Achieve of orientation by alternative movements towards an stimulus, chemical or magnetic signal.
- Power / mobility /control autonomy

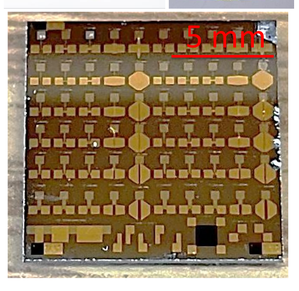
a) Body coverage for water treatment
b) Energy storage battery or super capacitor
c) Power transfer mechanism
d) Microelectronic circuitry
e) Sensor for detecting water contaminant



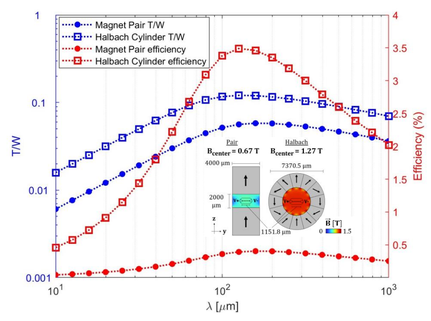
Solution: Building a swarm of functional autonomous robots, the size of plankton working together to detect and eliminate emerging contaminants in seawater by themselves, bridging the unexplored gap between microrobotics and big scale autonomous robots. We propose:

I) **Control autonomy** via sensors and microelectronic circuits using thin film transistors.

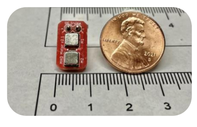




III) **Functionality** via minimalistic and low-complexity robots (Braitenberg vehicles) for klinotaxis

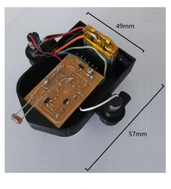


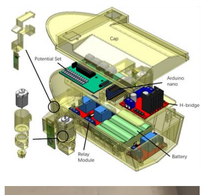
II) **Mobility autonomy** using magneto hydrodynamic actuators



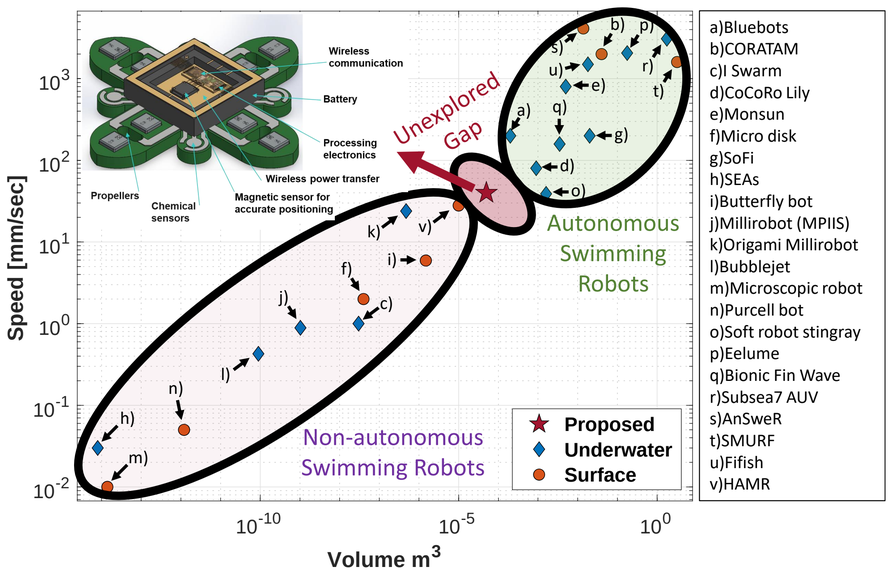
Magnetic gradients **Chemical gradients**

Robotic Boat





Underwater Robot



a)Bluebots
b)CORATAM
c)I Swarm
d)CoCoRo Lily
e)Monsun
f)Micro disk
g)SoFi
h)SEAs
i)Butterfly bot
j)Millirobot (MPIIS)
k)Origami Millirobot
l)Bubblejet
m)Microscopic robot
n)Purcell bot
o)Soft robot stingray
p)Eelume
q)Bionic Fin Wave
r)Subsea7 AUV
s)AnSweR
t)SMURF
u)Fifish
v)HAMR

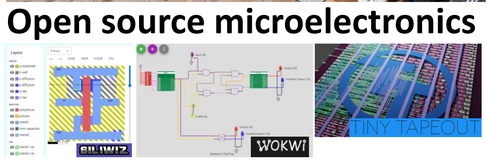
Scientific Impact: This work intends to bridge the gap (red region) between autonomous swimming robots (red region) and non-autonomous swimming robots also know and tethered microrobots (purple region) in the field of aquatic surface and underwater robotic swarms. Insert depicts proposed swimming microrobot with magneto hydrodynamic propulsion capabilities.

Broader impact: Imminent need to address clean and wastewater problems from innovative angles.

- Clean water: sustainable development goal, UN 2030.
- ~80% of world's industrial and municipal wastewater is released untreated to the environment.
- Providing access to clean water is considered one of the grand challenges for engineering according to the National Academy of Engineering.
- Emerging contaminants are polluting especially North and Latin America (one-third of world water resources).

We aim to build a cost-effective swarm microrobot testbench that researchers and curious minds (even high school students) can use in the future to evaluate their own technologies.

Open source microelectronics



Research and education:

- **Design of autonomous robots course:** ~200 students have participated in courses lead by PI. Final competitions (left) designing autonomous swimming robots for rescue.
- **Entry level VLSI training camps:** Multisite Workshop modality using open-source libraries for 130 nm CMOS ASIC foundry process (e-fabless/ Google/Skywater 130nm Open PDK). Latin American pilot (September 2023, sponsored by EDS-IEEE) will reach ~246 people from 13 countries, in 3 languages (Eng, Spa, Port). Specialized circuits for microrobots will be publicly available for laboratory practices in courses at universities and colleges.