

Introduction

Magnetic microrobots with neutral buoyancy are useful for 3D motion control because it eliminates the magnetic forces needed to compensate for the downward gravitational force.

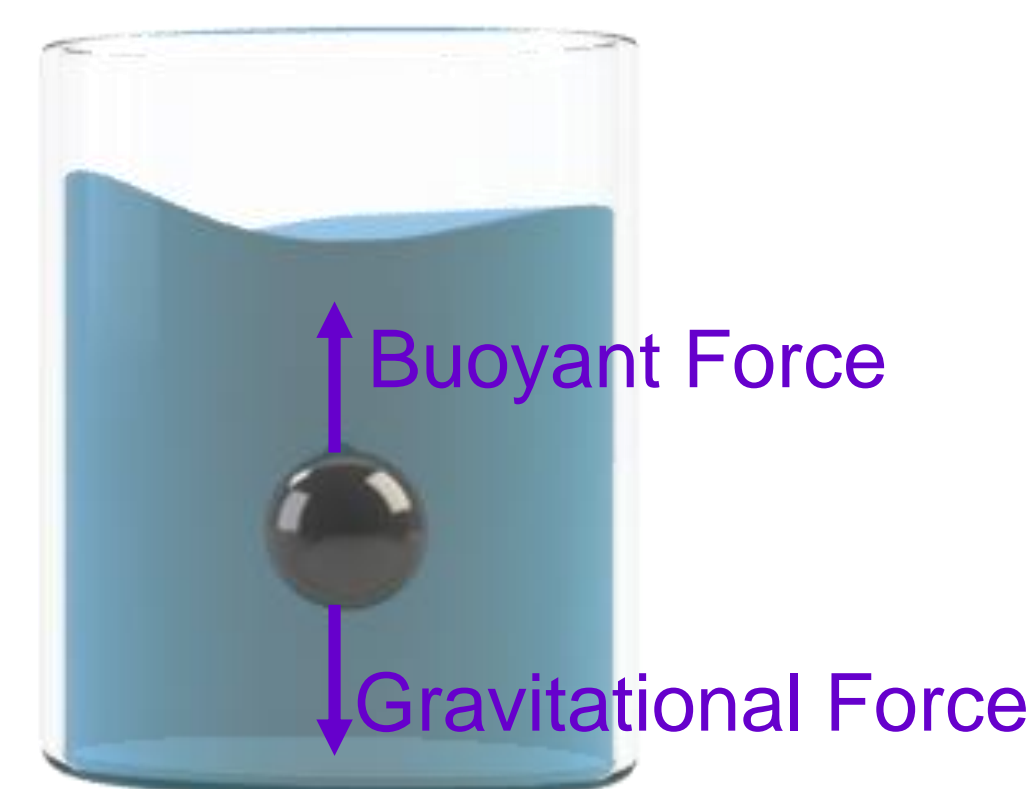


Fig. 1: Neutral Buoyancy: Buoyant Force = Gravitational force

Objective

- To develop a repeatable fabrication method that achieves a target density

Challenges

- Multi-material composition and multi-step fabrication process
- High density of magnetic particles relative to target density
- Residuals when transferring material during fabrication

Literature Review

Neutral buoyancy achieved by:

- Changing the temperature of the fluid environment
- Adjusting the concentration in the fluid environment
- Encapsulating air inside the microrobot

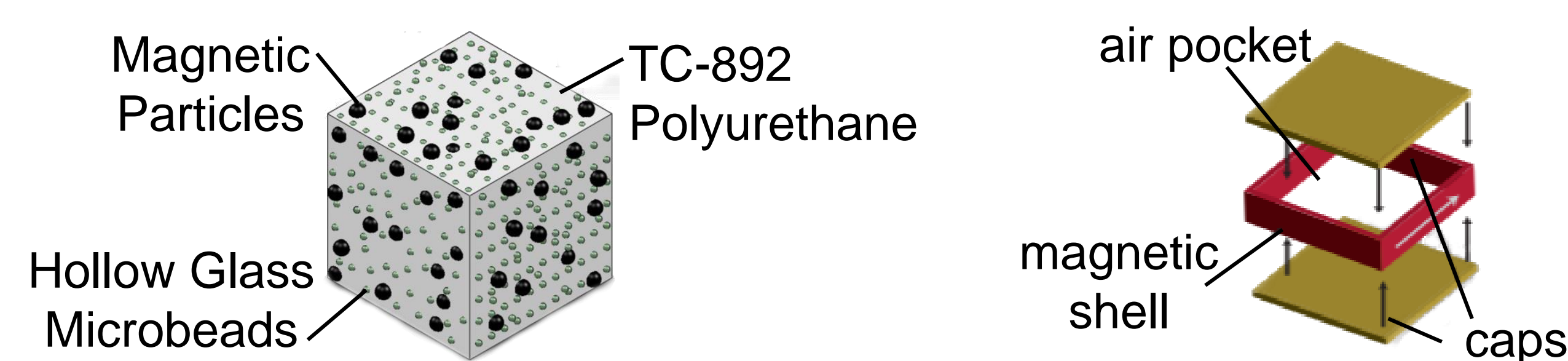


Fig. 2: (left) Schematic of cubic structure with hollow glass beads, (right) schematic of air cavity inside microrobot. P. Jena, et al. (2012)

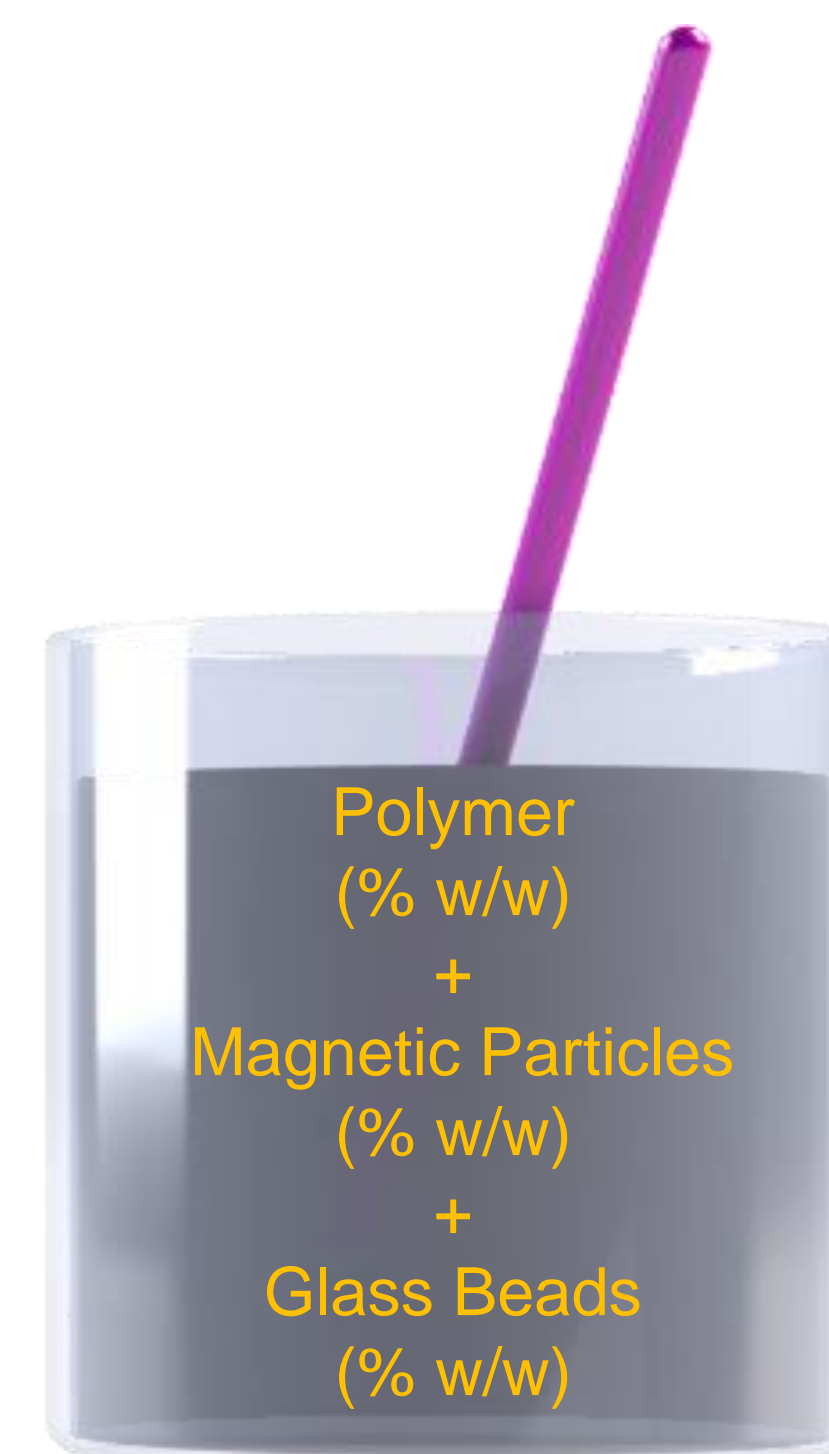
Fabrication

Material

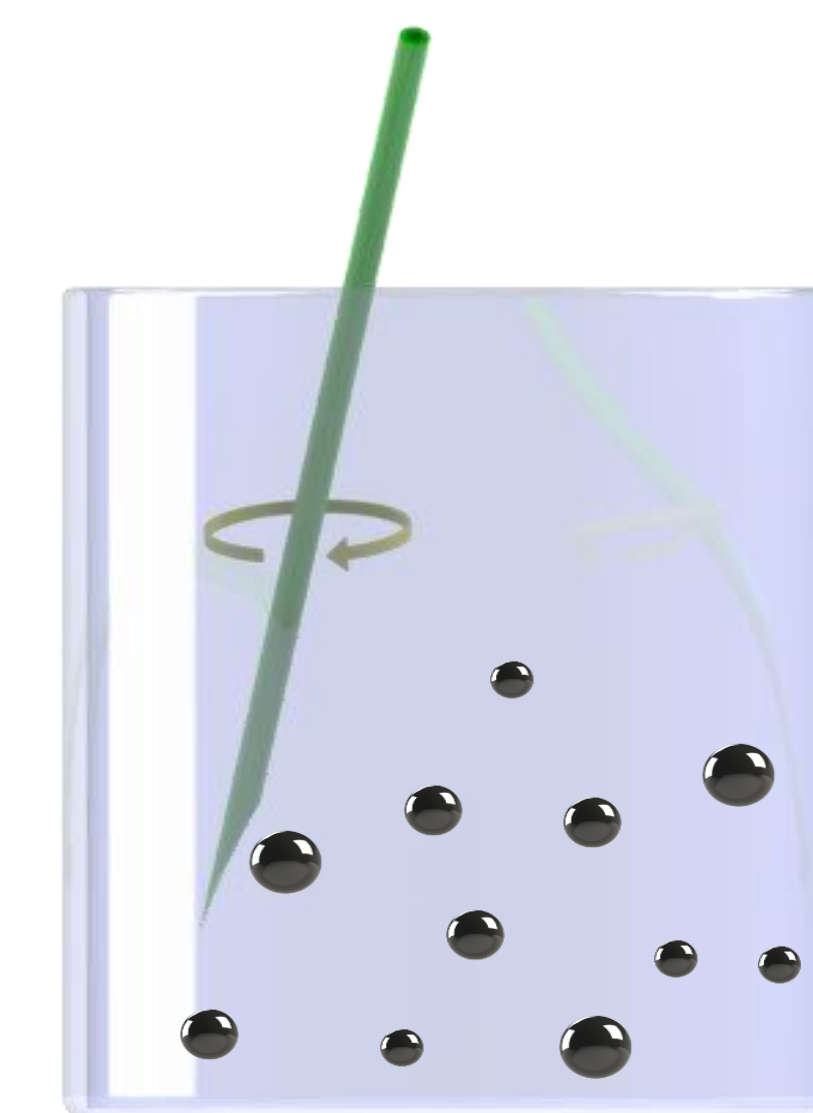
- Polyurethane polymer mixed with permanent magnetic particles and hollow glass beads

Method

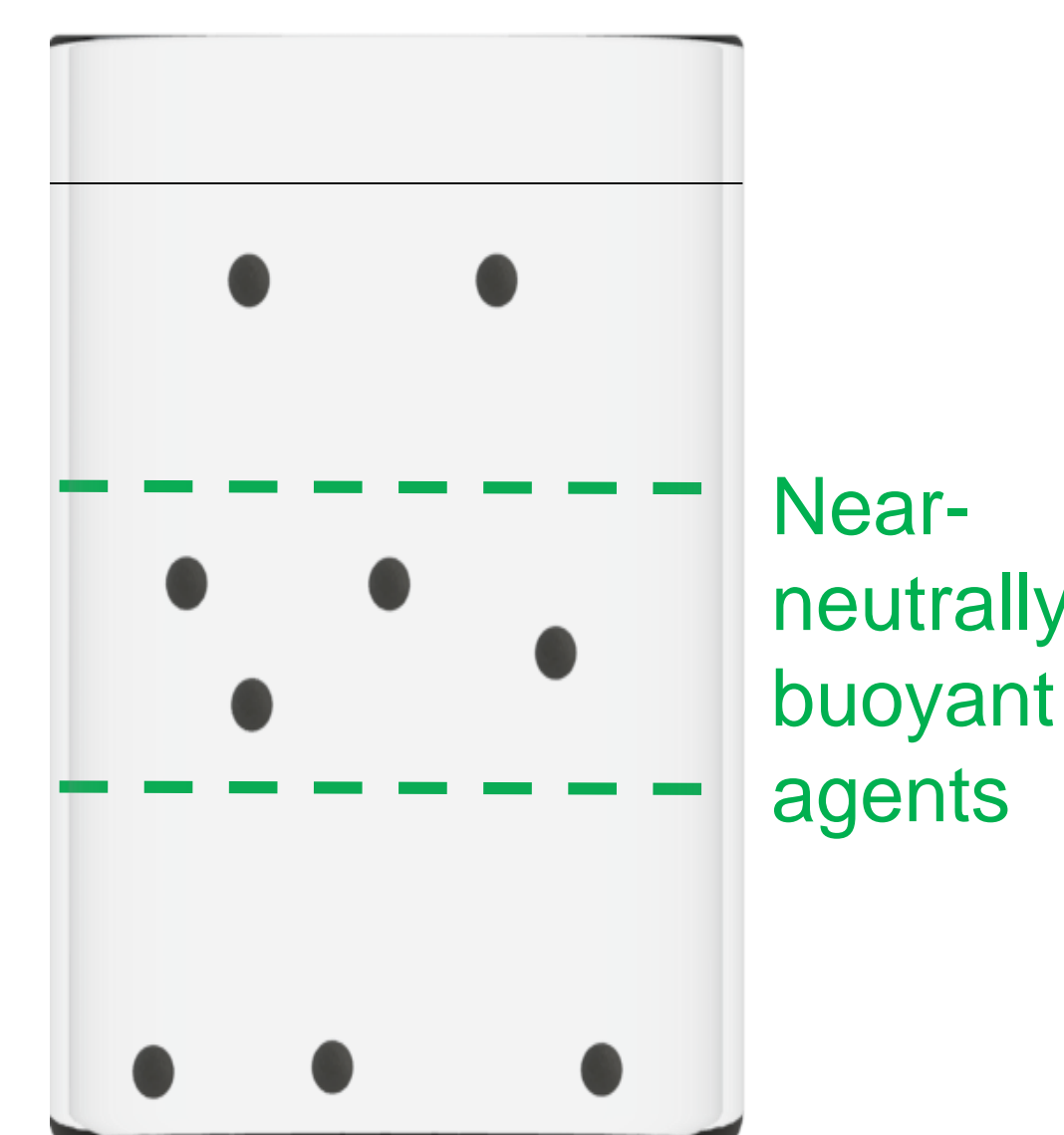
1. Mixture Fabrication



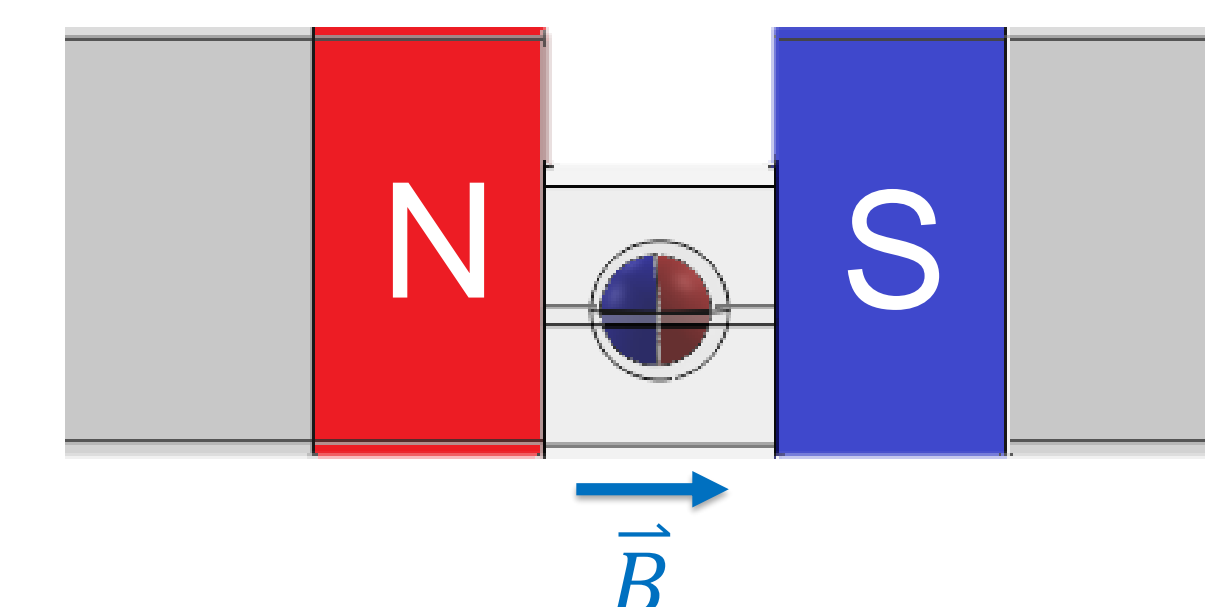
2. Injection into Fluid



3. Filtering



4. Magnetization



References

- [1] P. Jena, E. Diller, J. Giltinan and M. Sitti, "Neutrally Buoyant Microrobots for Enhanced 3D Control", *International Conference on Intelligent Robots and Systems, workshop on Magnetically Actuated Multiscale Medical Robots*, 2012.
- [2] M. Salehizadeh and E. Diller, "Two-Agent Formation Control of Magnetic Microrobots in Two Dimensions," *Journal of Micro-Bio Robotics*, vol. 12, no. 1, pp. 9–19, 2017.

Results

Preliminary results suggest a repeatable method to fabricate near-neutrally buoyant microrobots. However, it requires experimentally tuning the mass ratios to the target density.

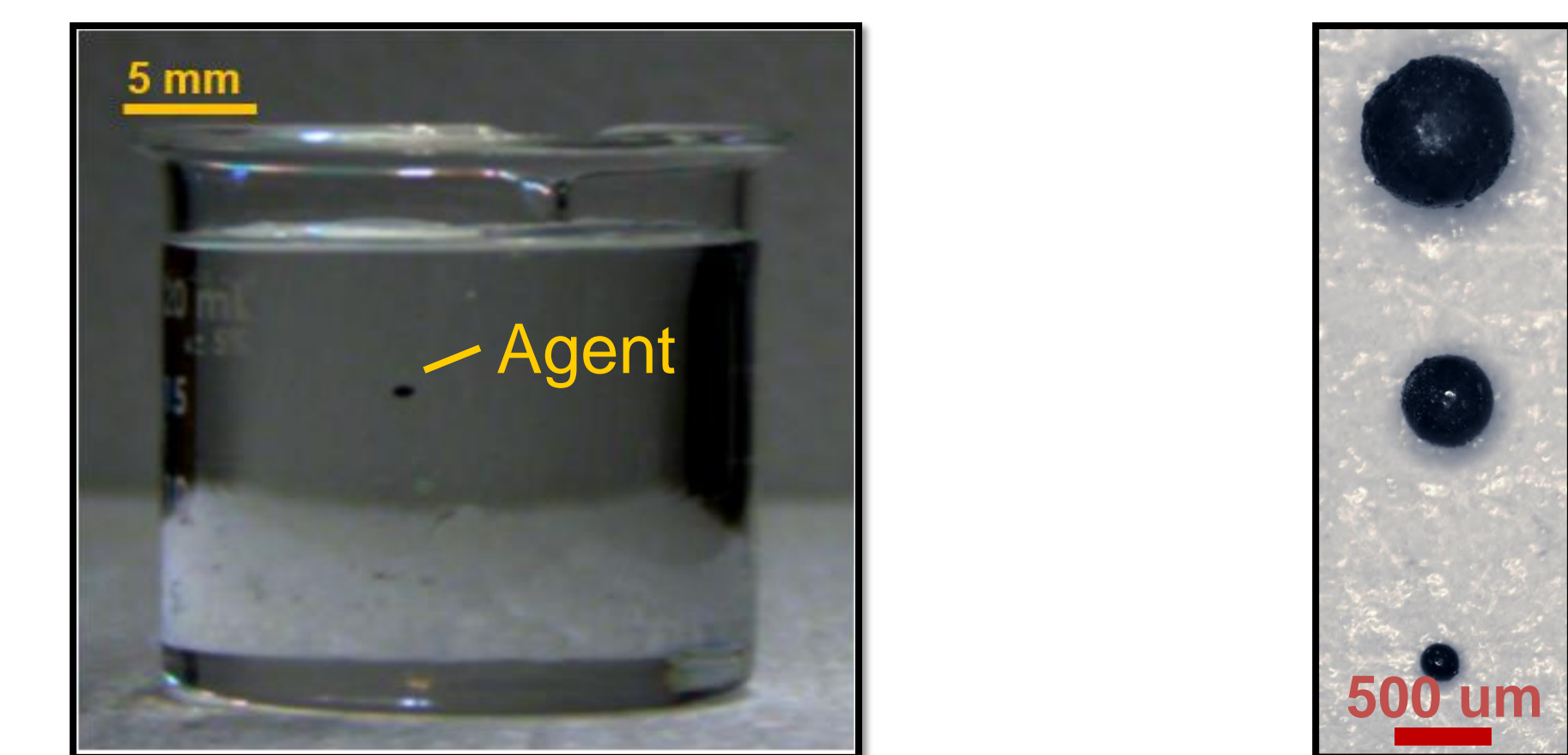


Fig. 3: (left) Neutrally buoyant microsphere in glycerol, (right) microspheres with different spherical sizes

Properties

| Property | Value |
|--|----------|
| $\Delta 1$ mm Time in Glycerol Verification Test | ~ 2 mins |
| Percentage Error with Corrective Factor | < 3% |

Conclusion

Near-neutrally buoyant microspheres achieved by controlling mass ratios using a repeatable fabrication process.

Future Works

- Multi-Agent Formation
- Functional Microgrippers

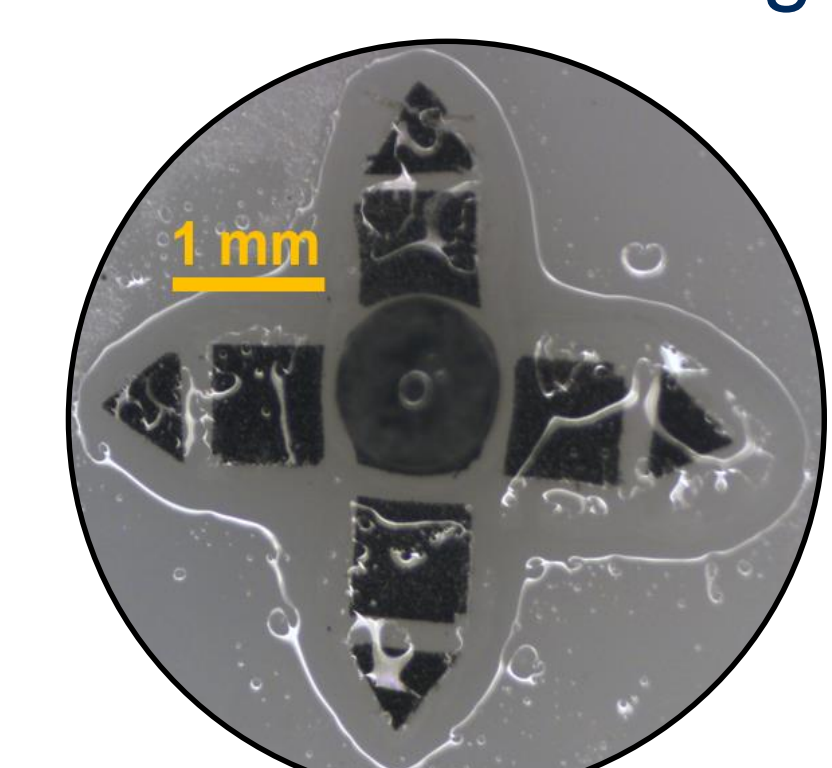
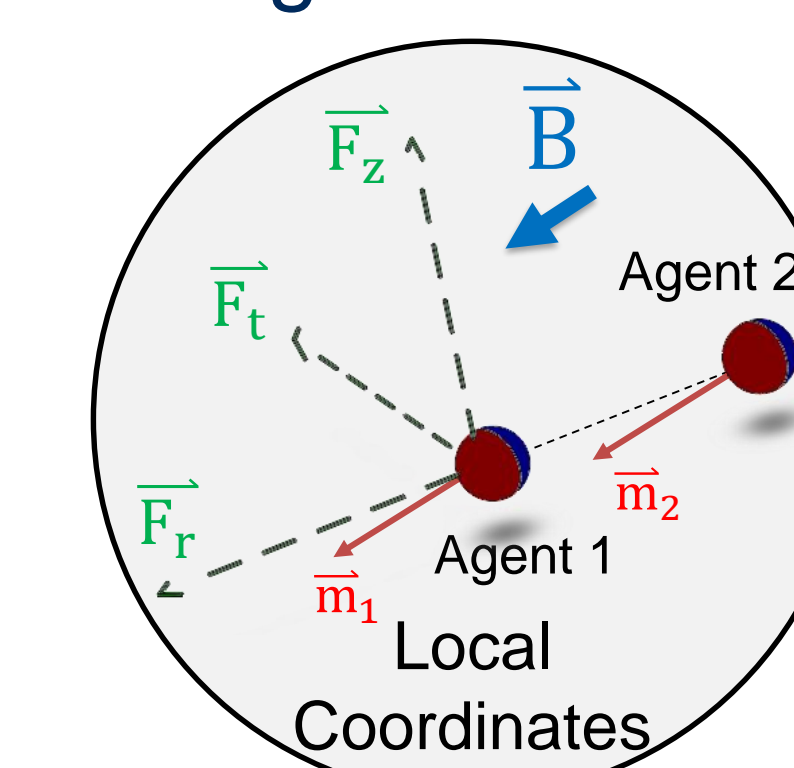


Fig. 4: (left) Inter-agent forces (shown on agent 1 only) and magnetic moments
Fig. 5: (right) One functional microgripper with microsphere backpack