Structural Optimization of Self-Propelled Microrobots

Over the past decade, external actuation of man-made robots at the nano- and micro-scales have shown potential to revolutionize medicine and technology. It is possible to direct and/or drive these robots via the action of a magnetic field without the need of onboard power supply and control system. In this project, we will focus on the structural optimization of the microjets to maximuze their speed in low-Reynolds number regime.

Objective

The locomotion mechanism of catalytic tubular microjets is governed by several aspects such as catalytic decomposition of hydrogen peroxide into oxygen, diffusion, movement of the oxygen bubble in the microjet, bubble ejection, and interaction with the environment. In this project, we will optimize the structure of the microjet (length, cone angle, and concentration of the solution) to find the optimal paramagnetic space of maximum swimming speed.

Tasks

- Modeling of the microjet shown in Fig. 1;
- Optimization of the structure of the microjet;
- Development of a simple self-propelled microrobot that resembles the self-propulsion approach shown in Fig. 1.

Materials

- 4 electromagnetic coils are available in MNRLab;
- 4 electric drivers;
- Motion control systems;
- A numerical model of the microjet is available;
- A feature tracking algorithm.

PREREQUISITES

Students are expected to have a working knowledge of control theory, differential equations, linear systems, statics, kinematic and dynamics. Familiarity with programming, especially with Matlab and C++.

OTHER NOTES

This project will involve a weekly meeting with the instructors and progress reports have to be prepared. All reports should be written in academic paper format.

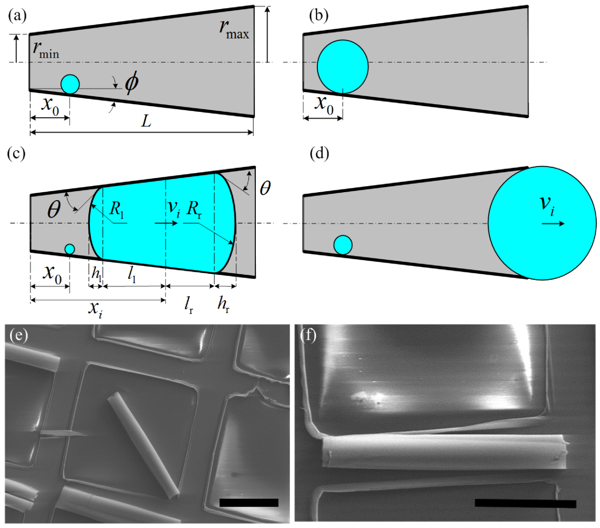

Figure 1. Schematic representation of a catalytic tubular microjet. (a) The microjet has length L, minimum radius r_{min}, maximum radius r_{max}, conical angle ϕ, liquid-platinum contact angle θ. (b) First bubble nucleates and grows at position x_0. (c and d) Second bubble nucleates and grows at position x_0. The first bubble moves at speed v_i towards the wider microjet end with ejection frequency f and radius r_e, to initiate unidirectional microjet motion along opposite direction. The bubble shape is geometrically described by two spherical caps (left and right) of radii R_l and R_r, and heights h_l and h_r and two cones of length l_l and l_r. (e) Ti/Fe/Pt rolled-up microtubes. scale bar is 25 μm. (f) The jet is prepared with a composition of the nanomembranes of Ti (5 nm), Fe (5 nm), and Pt (3 nm). Scale bar is 50 μm.

1. References

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[2] S. Fournier-Bidoz, A. C. Arsenault, I. Manners, and G. A. Ozin, "Synthetic self-propelled nanorotors," *Chemical Communication*, vol. 4, pp. 441-443, November 2004.

[3] J. R. Howse, R. A. L. Jones, A. J. Ryan, T. Gough, R. Vafabakhsh, and R. Golestanian, "Self-Motile colloidal particles: from directed propulsion to random walk," *Physical Review Letters*, Vol. 99, (048102), July 2007.