Development of a Self-Propelled Microrobot using Calcium Carbonate and Vinegar Fuel

Remember what happens when we put an egg in a bowl and pour vinegar until the egg is covered. Bubbles will appear after a few moments. Egg shells contain calcium carbonate ($CaCO_3$). It reacts with the vinegar's active ingredient, i.e., acetic acid (CH_3COOH). This reaction generates a salt called calcium ethanoate, some water, and bubbly carbon dioxide gas. Now let us break the shell of the egg into small fragments and observe the behaviour of these fragments under a microscope. We expect that the ejecting carbon dioxide bubbles would provide a propulsive force that would enable the fragment to move.

Objective

In this project, we will develop a self-propelled microrobot using fragments of calcium carbonate ($CaCO_3$). These fragments will be contained inside vinegar fuel to generate bubbly carbon dioxide gas. The propulsive force associated with the ejection of the gas would enable the fragment to move and achieve self-propulsion. This idea is similar to the chemical reaction between the Ti/Fe/Pt rolled-up microtubes (Fig. 1) and the surrounding hydrogen peroxide solution.

Tasks

- Development of a self-propelled microrobot similar to the microjet (in the concept) shown in Fig. 1;
- Integration of fragments of calcium carbonate to a magnetic material to achieve self-propulsion and direction control using external magnetic fields.

Materials

- An electromagnetic system with an array of 4 orthogonal coils;
- 4 electric drivers and a control system;
- A microscopic system and iron oxide nanoparticles.

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.

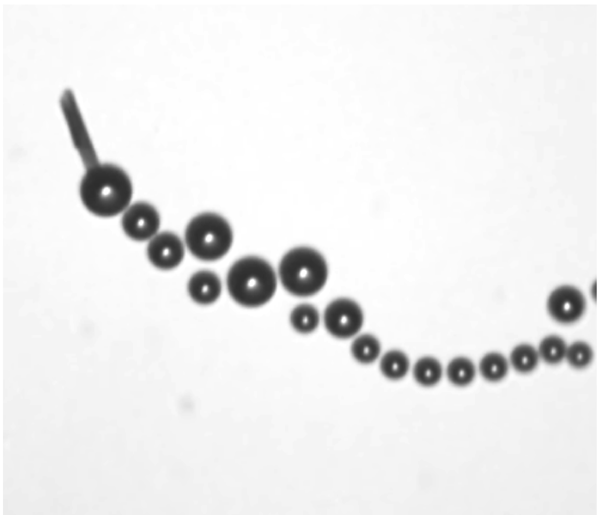

Figure 1. Ti/Fe/Pt rolled-up microtubes achieve self-propulsion in hydrogen peroxide solution [1]. The catalytic decomposition of the solution into water and oxygen bubbles. The bubbles provide thrust force and enable self-propulsion, whereas the iron layer of the microtube enables directional control under the influence of external fields.

1. References

[1] I. S. M. Khalil, V. Magdanz, S. O. Sanchez, O. G. Schmidt, and S. Misra, "The control of self-propelled microjets inside a microchannel with time-varying flow rates" *IEEE Transactions on Robotics*, vol. 30, no. 1, pp. 49-58, February 2014.

[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.

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