Keio University

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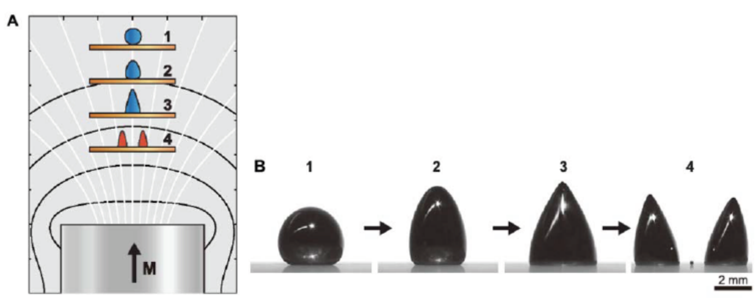
Onoe Hiroaki & Takahashi Hidetoshi's course - 2020

Biomimetic Micro/Nano Engineering
Report 4



[1]

Academic year 2019-2020
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1 Introduction

After having studied static self assembly systems, this report will be dedicated to dynamic self assembly systems. Dynamic self assembly systems are also based on the same basic factors than static self assembly, i.e. components with structures, the binding force, an environment and a driving force. However, while static self assembly systems minimize the energy and reach a stable state in terms of total energy of the systems, dynamic self assembly systems are different. Those last one typically dissipate energy to maintain the structures created, respond to external environment/energy flow and create functions. A very important feature of dynamic self assembly system is that the shape of the potential curves determining the equilibrium of the system will change depending on the energy applied or the environment. This particularity is displayed through figure 1. This figure illustrates at first that the initial state of the system is modified by the energy applied but also the left part reveals that while different energy flows are applied the equilibrium point can dynamically change. This means that it is theoretically possible to trigger, via a controlled energy flow, the behavior of the systems from one point to another, for the purpose of realising a particular action.

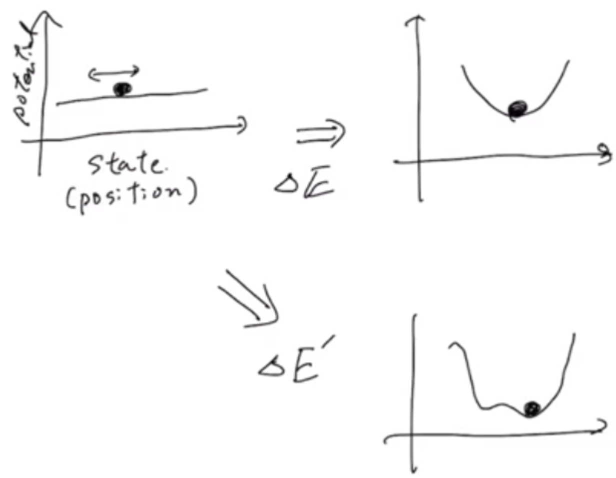

Figure 1: Dynamic self assembly systems behavior. The left part illustrates the initial system while the right part reflects the new equilibrium points caused by different energies applied

2 Assignment 1

The initial ferrofluid droplet is first used to create a static self-assembled droplet population, through successive division of the initial droplet using an external magnetic field. And then, this equilibrium can be modified by applying an oscillating magnetic field, switching the system to a dynamic dissipative system.

2.1 What are "attractive interaction" and "repulsive interaction" in the magnetic droplet pattern in the static SA mode.

2.1.1 Attractive interaction

In the static SA mode, once the droplets divide, the attractive interactions are that the daughter droplets are **attracted toward the increasing gradient of the external magnetic field** [2].

2.1.2 Repulsive interaction

In the static SA mode, the repulsive interactions are such that once the droplets divide, the daughter droplets are kinetically trapped to remain separate. This means that there is a potential energy barrier between the global one-droplet energy minimum and any multidroplet pattern [2].

This is due to **the magnetic repulsion of the droplets**. More precisely, the dipolar repulsion between the magnetized droplets. The nonwetting nature of the surface also ensures that the droplets are not connected.

2.2 Explain why the droplet patterns change when they are dragged back and forth (in the dynamic SA mode).

The switch from the static SA mode to the dynamic SA is due to the energy input in the system, which allows to move the state away from the previously established minimum. In other word, it is the previously covered case, shown in figure 1, about the potential curve. The phenomenon in the droplet system is displayed on figure 2 [2].

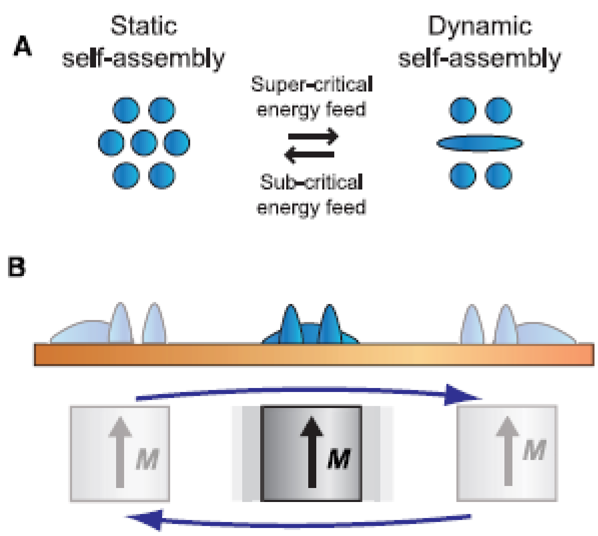

Figure 2: Dynamic self assembly systems behavior in the droplet system while critical energy is fed to the system such that the equilibrium is moved away from a minimum [2]

3 Assignment 2

3.1 Do you think that "dynamic self-assembly systems" could be engineered products for supporting our life in the future?

My opinion is nuanced. I think that the development of this technology as engineered products wouldn't be a possibility in the near future. As explained during the course, this field is very new. Furthermore, the functions achievable are either very basic such as the magnetic droplets, or require too much money such are in the swarm robotics case, also the systems are not miniaturized enough, to be applied to medicine by example.

However, in a distant future, if the systems are able to perform more complex tasks, on a smaller scale and at a smaller costs, this technology could be very interesting for designing systems with complex shapes, behavior or functions. These would use a rather simple energy input (magnetic field, ...) and then realize by itself the complex arrangement or response, decreasing the complexity of some operation (maybe not even understandable/feasible using the state-of-the-art sciences). Particularly, the dynamic feature would allow us to trigger the system's response in real time.

The example I would like to give is the application of such systems to surgery. While performing reconstructive surgery, or in treating wounds and cancers, it would be possible to control, in real time, the dispatch of some proteins, macromolecules or chemical compounds at a targeted location of the body. On top of that, surgeons and/or engineers could dynamically control the so created systems. It could help to reduce the invasive nature of surgery or allow a more precise action than the human's ones.

4 Conclusion

In this report, the dynamic self-assembly systems where at first studied through magnetic droplets patterns being modified at first to produce a static SA mode and then by adding an oscillating magnetic field removing the system from its stable minimum. The interesting point being that the pattern of the droplet can be dynamically modified by a special energy flow. Finally, the report ended on a personal reflection about the future uses of self-assembly systems in our society. This part concluded that even though those would be hard to put into effect on a close future basis, if improvements were made on the designs, those could be useful to perform rather difficult task quite easily by example in the surgery field.

References

[1] Onoe Hiroaki & Takahashi Hidetoshi's slides of "biomimetic micro/nano engineering" course. Course #4, slide #12.

[2] Jaakko V. I. Timonen, Mika Latikka, Ludwik Leibler, Robin H. A. Ras, and Olli Ikkala. Switchable static and dynamic self-assembly of magnetic droplets on superhydrophobic surfaces. *SCIENCE VOL 341*, pages 255–256, 19 July 2013.