Manipulation of Convection Using Infrared Light Emitted from Human Hand

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ABSTRACT

Convection control plays an important role in heat transfer regulation, bio/chemical sensing, phase separation, etc. Traditional systems with engineered sources require extra energy for convection manipulation. We've developed a method to wirelessly control liquid convection by using the human hand as a sustainable infrared source to create patterns and move objects by changing the ways of hand placement. This approach offers a low-cost, energy-efficient alternative for convection control, with potential applications in bio/chemical sensing and separation.

KEY WORDS

Human hand, Infrared radiation, Convection controlling system

1. INTRODUCTION

Convection, a common phenomenon in nature and engineering for energy and mass transfer, is often caused by temperature gradients in liquids. While research still relies on artificial energy sources to control convection, these add extra energy consumption. Natural energy sources, like human hands, offer the benefits of zero additional energy use and sustainability. Our team has shown that using hands as natural IR light sources can enhance sustainability and intelligent control in engineered systems for sign language recognition[1] and human-machine interaction[2].

In this study, we demonstrate using the human hand as a natural, sustainable IR light source for intelligently manipulating convection. By moving the hand, we can create both static complex patterns and dynamically control convection. Additionally, we leverage the mass transfer characteristics of convection to control the movement of floating "boats," as well as for bio/chemical sensing and separation.

2. RESULTS AND DISCUSSTION

2.1 Generation of single convection using human hand

The human hand, acting as an incoherent infrared (IR) energy source at around 310 K with an emissivity of 0.98, emits IR radiation primarily between 4 μm and 16 μm[3]. In our study, we placed a hand covered with aluminum foil (with a 4 cm x 4 cm open window) on the left side of a quartz container with half-filled deionized water. Polystyrene (PS) nanoparticles, averaging 206 nm in size, were used to track liquid flow movements. These particles began moving within 5 S (response time) and established full convection within 6 minutes (cycle time) (Figure 1(a)).

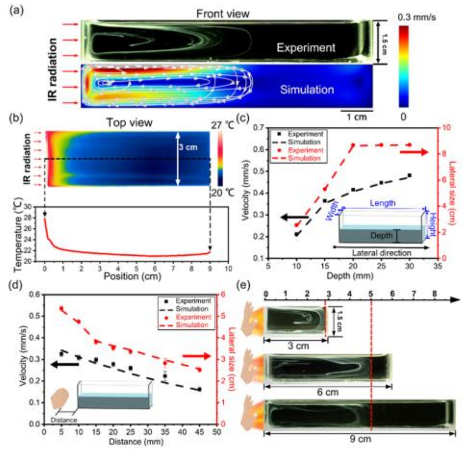

Figure 1. The generation of the convection by hand. (a) Generation of the convection; (b) The temperature distribution of the convection; The change of velocity and lateral size of the convection with the change of (c) the depth of the water and (d) the distance between the hand and the container. (e) The optical images of convection patterns formed in the containers with different lengths.

Using an IR camera (FLIR T640), we visualized the water's temperature distribution, revealing that the left side of the container was warmer than the right (Figure 1(b)). We further analyzed factors affecting convection generation, such as liquid depth, hand-to-container distance, and length of the container. Convection velocity and lateral size increased with water depth (Figure 1(c)). The velocity and size of convection decreased with increasing distance between the hand and the container (Figure 1(d)). The container's length limited the convection's lateral size, which affect the formation of convection. In small containers, the convection's lateral size was restricted by the container's length, but in larger containers, the container's length did not influence convection generation (Figure 1(e)).

2.2 Static and dynamic generation of complex convection patterns via hands.

With the demonstration of the generation of convection inside the fluid by the IR radiation from the hand, we further explore the use of hand to generate convections with different complex patterns. By placing both hands symmetrically or asymmetrically on opposite sides of the container, we produced different static convection patterns (Figure 2(a)(b)). Additionally, using individual fingers and various ways of hand placement also resulted in complex convection patterns (Figure 2(c)).

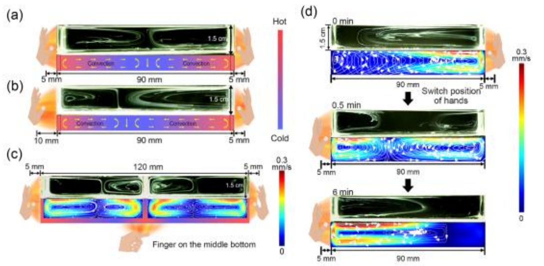

Figure 2. Static and dynamic formation of the convections with complex patterns. (a-b) Symmetric and asymmetric convection patterns; (c) Complex convection patterns; (d) Dynamic convection patterns formed by switching positions of the hand.

We also designed experiments for dynamic convection control by human hand (Figure 2(d)). Initially, the hand was placed on the right side of the container, causing stable convection there. After switching the hand to the left, the IR radiation moved to the left, leading to a decrease temperature gradient on the right side and the formation of a new gradient on the left. Switching the position of hand triggered a new convection on the left while the convection on the right side is still exist due to the residual heat.

2.3 Demonstrations of the potential applications of the hand-controlled convection.

By taking the advantage of the dynamic control of the localized convections, the sustainable and flexible control of the floating "boat" at the liquid-air surface was further demonstrated in this study (Figure 3(a)).

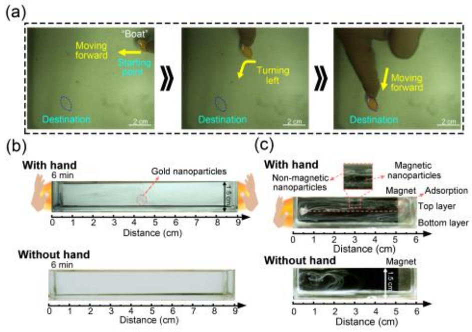

Figure 3. Demonstrations of the potential applications of the hand-controlled convection. (a) Controlling the floating "boat" at will. (b) With the hand-generated convection, the chloroauric acid could react with ascorbic acid in 6 minutes and form the gold nanoparticles. (c) With hand-controlled convection, the mixed magnetic and non-magnetic nanoparticles could be separated.

Based on the mass transfer of the convection, we thus demonstrated the potential applications in sensing and separation systems. As a proof-of-concept demonstration, we ran an experiment for the rapid detection of chloroauric acid aided by the hand-induced convection, which accelerated this process (Figure 3(b)). For the separation system, the convection could transport the mixtures (the magnetic PS nanoparticles and the non-magnetic PS nanoparticles) to the target, where placed a magnet, for separation by the liquid flow. The bottom layer of convection, flowing back to the opposite side of the target, contained only non-magnetic PS nanoparticles after the magnetic PS nanoparticles were separated (Figure 3(c)).

3. CONCLUSION

In our study, we utilize the human hand as a natural IR radiation source to control convection at will. The experiment results showed that the velocity and lateral size of convection increased with deeper water and closer hand-to-container distance. Complex manipulation of the convection, both static and dynamic, can be realized with the use of human hand as IR light source. Additionally, we demonstrated the use of the generated convection for the controlled movement of a floating "boat", as well as for bio/chemical sensing and separation.

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