

DNA Autonomous Joint for Micro Self-assembly

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Abstract

In this research, we developed a novel DNA autonomous joint to achieve location-selective self-assembly of various kinds of individual parts. It is hypothesized that various kinds of parts made from heterogeneous materials can be simultaneously fabricated using the hybridization process underlying single- to double-stranded DNA conversion.

1 Introduction

Self-assembly is an attractive approach for carrying out multi-batch processes involving the fabrication of micro parts. It is a better alternative to the serial robotic assembly approach for MEMS fabrication. Self-assembly processes require a driving force such as capillary forces, gravity, and electric fields to guide the micro parts to their appropriate position on a micrometer scale. However, with this process, it is difficult to fabricate different kinds of parts simultaneously in parallel batches because the driving force is not selective about the location of the micro parts on the platform.

It has been hypothesized that the use of DNA hybridization for guiding self-assembly processes would enable the selective placement of parts [1], [2]. So far, it has been difficult to precisely position parts that are micro meter scale in length.

2 Concept of DNA autonomous joint

In this research, we developed a novel DNA autonomous joint to achieve location-selective self-assembly of various kinds of individual parts. It is hypothesized that various kinds of parts made from heterogeneous materials can be simultaneously fabricated using the hybridization process of single- to double-stranded DNA.

Micro parts coated with single-strand oligonucleotides can automatically find the location of the complementary bond on the substrate. If the sequences of oligonucleotides coated on the micro parts complement those of the oligonucleotides coated to the substrate, the micro parts can identify the locations on the substrate to which they must attach. This implies that the parallel batch fabrication of micro parts using various sequences of single-strand oligonucleotides can be considered as DNA autonomous joint.

In order to locate micrometer-scale parts on the substrate, very high density DNA patterns are required to be formed on both the micro parts and the substrate. The high-density pattern of the oligonucleotides significantly enhances the binding force between the parts and the substrates. Photolithography can be applied to form the high-density oligonucleotide pattern [3].

During the hybridization procedure, the binding force of the DNA works to determine and maintain the position of the micro parts. The micro parts are finally fixed into position by electrostatic, capillary, and intermolecular forces. The DNA only functions as a temporary joint to select the location of the micro parts. After the micro parts are attached, it is possible to remove the DNA by annealing.

3 Experimental procedures

In order to verify the feasibility of the automatic positioning by DNA autonomous joint, we performed an adhesion experiment for correctly positioning 1- μm micro beads on an oligonucleotide-patterned substrate.

The surface of the substrate is coated with four types of the single-stranded, artificially synthesized oligonucleotides. The oligonucleotide sequences, which are patterned on a substrate, are A25 (25 base of adenine), T25 (25 base of thymine), C25 (25 base of cytosine), and G25 (25 of guanine). The oligonucleotide-patterned areas are 100- μm -diameter circular spots of A25, T25, C25, and G25. Spots coated with the same sequence of oligonucleotides are arranged in a grid pattern comprising 4 columns and 30 rows; the column pitch in the pattern is 600 μm , and the row-pitch is 300 μm

Biotinylated single-stranded oligonucleotides are coated to the bead surfaces via avidin-biotin bonds. The micro beads are allowed to settle on the substrate surface in the absence of any flow, and then the surplus micro beads are detached from the substrate surface by a flushing process. The locations of the micro beads are then observed by optical microscopy.

4 Experimental results

Fundamental experiments are performed to verify the feasibility of the selective positioning of micro parts by DNA autonomous joint. Micro beads coated with oligonucleotides of A25 and C25 are prepared as benchmark samples. Two types of micro beads are dispersed in a lithium chloride/phosphate-buffered saline /bovine serum albumin buffer, and then the substrate surface is immersed in this buffer. Figure 1 shows the selective positioning of the oligonucleotide-coated beads on the spots coated with A25, T25, C25, and G25. In the case of the positioning of the beads coated with A25, the lines of T25 become visible on the substrate, as shown in Fig. 1 (a). As shown in Fig. 1 (b), the lines of G25 also become visible after the selective positioning of the beads coated with C25. Hence, A25- and C25-coated micro beads are selectively positioned on the T25 and G25 spots, respectively.

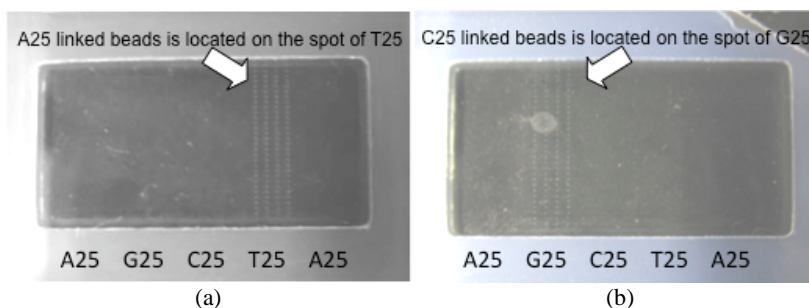


Figure 1: Selective positioning of micro beads coated with oligonucleotides A25 (a) and C25 (b).

Micro-bead adhesion is quantified by the number of beads attached to the oligonucleotide spots on the substrate, as shown in Figure 2. Both types of beads—the beads coated with A25 and those coated with—C25 are effectively positioned on the substrate sites having complementary oligonucleotides.

5 Conclusion

Fundamental experiments were performed to verify the feasibility of selective positioning of micro parts by DNA autonomous joint. Beads of 1- μm diameter were selectively positioned on spots on the substrates having complementary oligonucleotides sequences. It is hypothesized that various kinds of parts made from heterogeneous materials can be simultaneously fabricated using the hybridization process of single- to double-stranded DNA.

Acknowledgement

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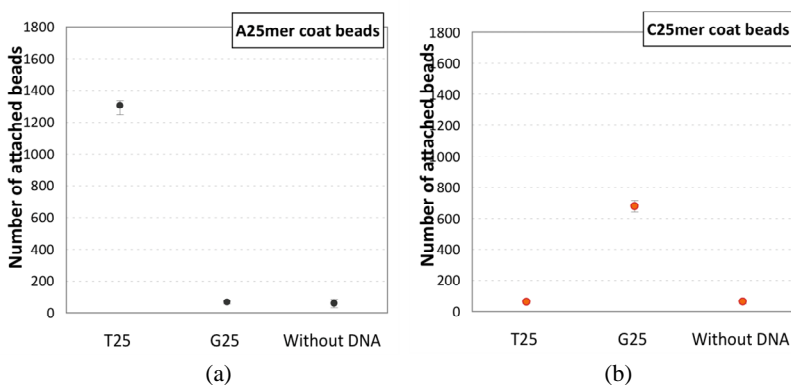


Figure 2: Evaluation of the micro beads selectively positioned because of specific bonding of DNA autonomous joint: (a) beads coated with A25 and (b) beads coated with C25.