20p-C4-4

Controlled-release of single-stranded DNA based on photothermal effect using BHQ

Atsushi Onishi, Yusuke Ogura, Jun Tanida

Graduate School of Information Science and Technology, Osaka University
E-mail: a-onishi@ist.osaka-u.ac.jp

1. Introduction

Fluorescence resonance energy transfer (FRET) is a phenomenon associated with fluorescent molecules within a nanometer order of the separation distance. FRET signals can be controlled and modulated with variations, positions, and energy states of the fluorescent molecules in a nanometer-scaled volume. Use of FRET is a fundamental technique to construct nanoscale information processing systems. A good example of the devices utilizing the technique is a DNA-controlled FRET switch [1].

We have demonstrated DNA scaffold logic as a scheme for executing DNA logical operations. This scheme is based on positioning of fluorescent molecules on a single-stranded DNA as a scaffold and forming a FRET signal cascade as a logical gate [2]. To date, the FRET signal from the tail of the fluorescent molecular cascade was used to report the operation result. However, if a physical response to the operation result on site is achieved, it becomes useful to control surrounding molecules. This study aims at demonstrating release of a single-stranded DNA with the thermal energy emitting from a molecule and embedding a physical response in the DNA scaffold logic.

2. Methods for controlled-release of DNA with BHQ

Black hole quenchers (BHQs) are molecules accepting energy from many kinds of fluorescent molecules as donors. BHQs are generally used to report the state of molecules in the FRET system. In this work we apply BHQs to controlled release of DNA strands. When an excited BHQ returns to the ground state via a non-radiative process, it generates a large amount of heat owing to its high absorption capacity [3].

As the temperature rises, a double-stranded DNA is denatured into two single strands; namely, a strand is released from the other. Figure 1 shows the scheme of controlled release of a DNA strand by the photothermal effect. A couple of complementary strands are prepared; one includes two BHQs, and the other is considered as a target strand to be released. The excitation light irradiates the BHQs directly, and then the generated heat releases the target strand.

3. Experimental results

A couple of 10-base DNA strands were prepared for experimental verification. Absorbance of 260-nm wavelength, which reflects the state of DNA strands owing to the hyperchromic effect, was measured under repeated irradiation. The excitation light was emitted from a semiconductor laser (wavelength: 531nm) and the excitation power was 100 mW. The concentration of DNA was 20 μM. Figure 2 shows the time course of the absorbance. The absorbance is high during the light irradiation for 2 minutes. This indicates that a single-stranded DNA is released by the excitation of BHQs. In contrast, the absorbance decreases after stopping the irradiation, which suggests strand recombination. These results demonstrate controlled-release of a single-stranded DNA based on photothermal effect of BHQs.

In conclusion, release of a single-stranded DNA is achievable with the heat generated by deactivation of excited BHQs. The method can be embedded into the DNA scaffold logic for further applications.

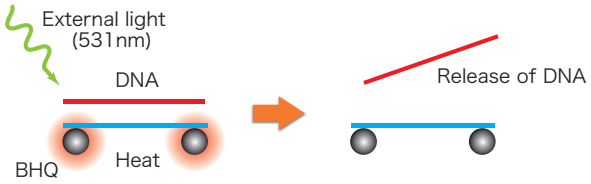

Fig. 1. Controlled-release of DNA using BHQs.

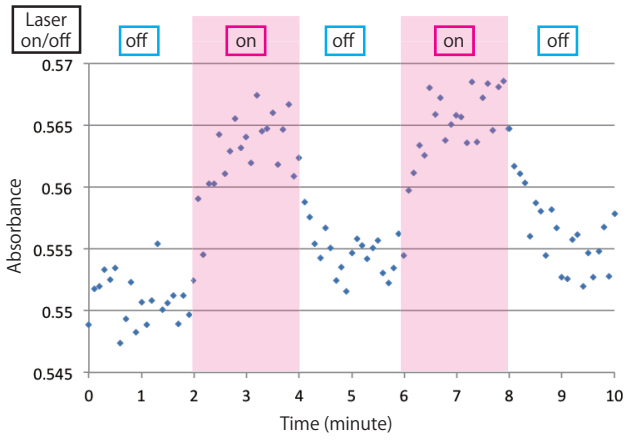

Fig. 2. Change of absorption (dots) during repetition of irradiation with excitation light.

References

[1] S. Uphoff *et al.*, Nature Methods, **7**, 831 (2010).
[2] T. Nishimura *et al.*, Appl. Phys. Let., **101**, 233703 (2012).
[3] A. Gaiduk *et al.*, Science, **330**, 353 (2010).