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Title	光誘起形超高速DNA二重鎖侵入法の開発とその応用
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Abstract

In this dissertation, I investigated the engineering of novel photochemical strategies for the sequence-specific recognition and manipulation of double-stranded DNA. Accessing genetic information within the stable DNA double helix remains a primary challenge in molecular biology due to the significant thermodynamic and kinetic barriers presented by Watson-Crick base pairing. While existing technologies like PNA and LNA can invade the duplex, they often require prolonged incubation times, elevated temperatures, or complex designs to achieve high efficiency.

The research centers on the application of 3-cyanovinylcarbazole nucleoside, ^{CNV}K, an ultra-fast photo-cross-linker capable of forming a covalent bond with a complementary pyrimidine base within one second of UV irradiation at 366 nm. First, focusing on Photo-induced Double Duplex Invasion (pDDI), a pair of invasion probes containing both ^{CNV}K and 5-cyanouridine (^{C}U) was utilized as the photo-cross-linker and photo-cross-linking inhibitor. The result showed successful invasion of the probes. However, with the unexpected discovery of the invasion difference between the paired Forward and Reverse probe, we speculate the possibility of achieving Photo-induced Duplex Invasion (pDI) with a single invasion probe. With a systematic analysis via Job's plots , we confirmed the invasion independence of the paired invasion probes. This discovery led to the development of Photo-induced Duplex Invasion (pDI). And the result showed that pDI achieved superior invasion efficiencies, exceeding 90% in just 60 seconds of photo-irradiation.

Finally, we further applied the photochemical principles to dynamic DNA nanotechnology by constructing a Photo-induced DNA Memory Gate. Driven by toehold-mediated strand displacement (TMSD), this device utilizes the rapid cross-linking of ^{CNV}K to lock the gate into specific "Written" or "Blocked" states based on the order of data inputs. By converting reversible equilibrium reactions into irreversible kinetic traps, this motif overcomes the inherent instability of traditional DNA logic circuits.

Overall, this work establishes ^{CNV}K -mediated photo-cross-linking as a versatile kinetic driver for DNA manipulation. These findings lay the groundwork for a new class of photo-antigene therapeutics and stateful molecular robotics capable of recording complex biological events with high spatiotemporal precision.

Keywords: 3-cyanovinylcarbazole nucleoside, photo-cross-linker, double-duplex invasion, duplex-invasion, DNA logic circuit, DNA computing