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Design of multiple efficient molecular logic devices based on molecular systems containing bovine serum albumin and 5-sulfosalicylic acid

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ABSTRACT

Several logic gates, which are commonly designed with DNA or organic molecules, rely on only one output mode. Here, a new molecular device was designed and constructed by combining bovine serum albumin and 5-sulfosalicylic acid. When MoO_4^{2-}, Tris(hydroxymethyl)aminomethane, $EDTAH_2Na_2$, Al^{3+}, Trichloroacetic acid are used as inputs, changes in the fluorescent intensity at 350 nm and 406 nm were observed via FRET. Four molecular devices as a half-adder and three digital logic circuits were successfully constructed on the unimolecular platform by employing emission properties at different wavelengths as outputs. The advantage of the combined system was that many different functional molecular devices could be designed and assembled by employing protein and various organic molecules in aqueous solution.

1. Introduction

Fluorescent probes can serve as molecular logic gates, as firstly demonstrated by De Silva [1]. In the past two decades, excellent work has been devoted to the development of molecular logic gates, such as logic gate [2–7], half-adder or half-subtractor [8–13], full-adder or full-subtractor [14,15], digital logic circuit [16–21], logic memory [22,23], and molecular keypad lock [24]. In these molecular devices previously published, most of the logic systems rely on deoxyribonucleic acid (DNA) or multi-step compound organic molecules. Moreover, most of these logic systems can generate only one output. Our previous study showed that the stability of the bovine serum albumin (BSA) solution lasts only ~ 5 days; however, the compound system of BSA and the small organic molecule is stable for more than 30 days at room temperature [25]. Moreover, we found that the logic gates or molecular devices can be constructed by combining BSA and organic fluorescence molecules [26,27]. In this work, we have developed a new digital logic by combining BSA and 5-sulfosalicylic acid (5-SSA) based on Förster resonance energy transfer (FRET) in aqueous solution. MoO_4^{2-}, Tris (hydroxymethyl)aminomethane (Tris), $EDTAH_2Na_2$, Al^{3+}, trichloroacetic acid (TCA) have been used as inputs, and then the input orders have been switched to obtain a half-subtractor and three digital logic circuits. The logic device schematic consisting of BSA and 5-SSA is illustrated in Fig. 1.

2. Material and methods

2.1. Materials

BSA solution (1.0×10^{-4} mol/L) was prepared in a Na_2HPO_4/NaH_2PO_4 buffer solution (pH 6.8). The pH of the buffer solution was adjusted using HCl or NaOH solutions. All the chemicals were commercial analytical reagents.

2.2. Fluorescence spectroscopy measurements

Fluorescence spectra were recorded on a Perkin–Elmer LS45 spectrophotometer with the temperature maintained constant using circulating water. Fluorescence spectra were obtained at wavelengths ranging from 300 to 500 nm and excitation wavelength (λ) of 280 nm.

3. Results and discussion

3.1. Analysis of the interaction between BSA and 5-SSA

The interaction between BSA and 5-SSA has been investigated in a Na_2HPO_4/NaH_2PO_4 buffer solution (pH 6.8) via fluorescence spectroscopy (Figure S1). The fluorescence emission spectra (λ_e = 280 nm) of the different concentrations of 5-SSA with BSA have been recorded at wavelengths ranging from 300 to 400 nm at different temperatures. We have obtained the Stern–Volmer quenching curve showing a good

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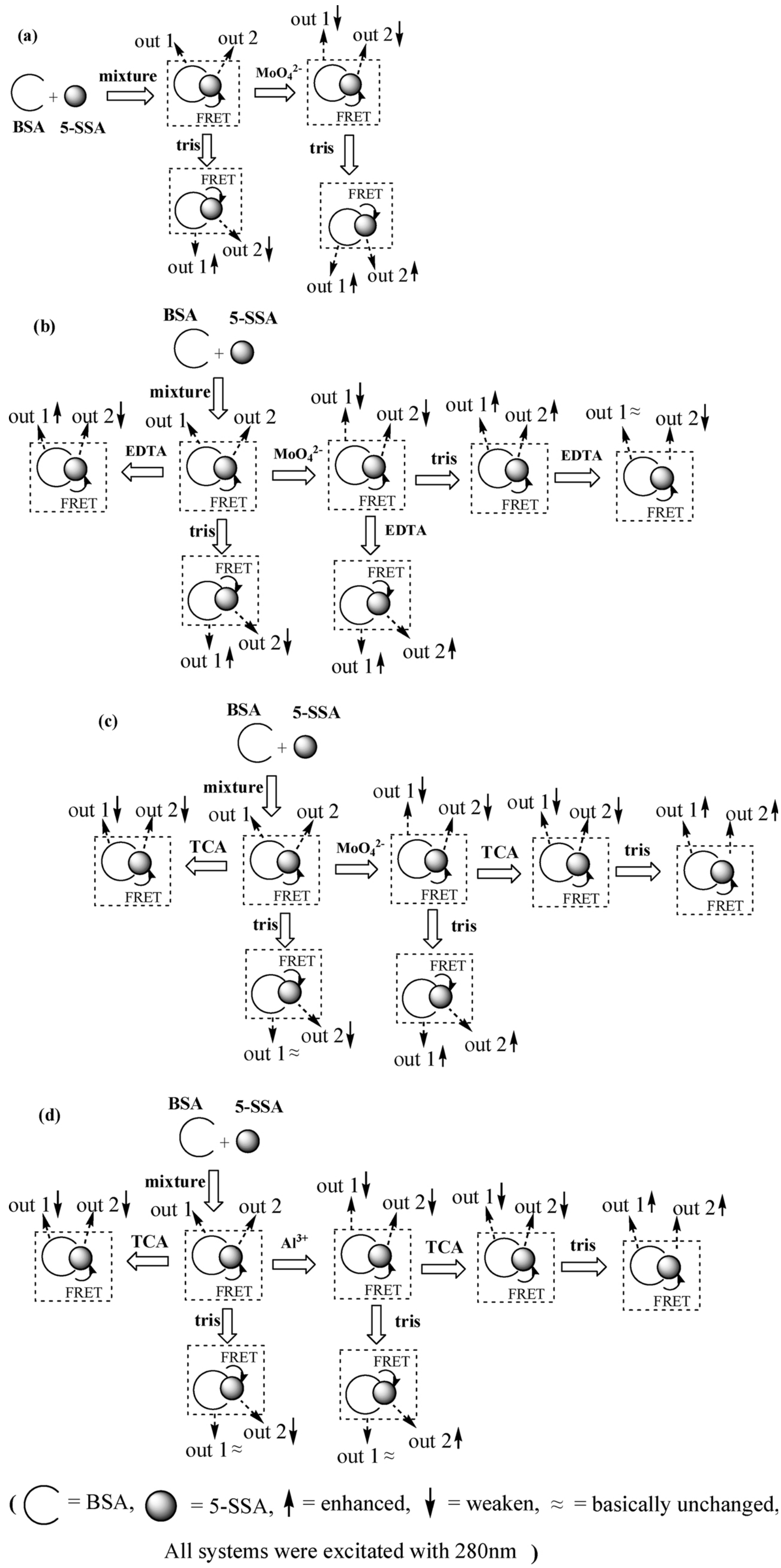

Fig. 1. Logic device schematic consisting of BSA and 5-SSA (a: half-subtractor, b: digital logic circuit 1, c: digital logic circuit 2, d: digital logic circuit 3).