Enhanced Saccharide Sensing Based on Simple Phenylboronic Acid Receptor Coupled with Suzuki Homocoupling Reaction

*Su-Ying Xu, Yi-Bi Ruan, Xing-Xing Luo, Yu-Feng Gao, Jin-Song Zhao, Jiang-Shan Shen and Yun-Bao Jiang**

Department of Chemistry, College of Chemistry and Chemical Engineering, and the MOE Key Laboratory of Analytical Sciences, Xiamen University, Xiamen 361005, China

Tel./Fax: (+86)592 218 8372; E-mail: ybjiang@xmu.edu.cn

Electronic Supplementary Information (ESI)

(1) Experimental

Commercially available chemicals from Sigma-Aldrich were used as received. Fluorescence spectra were taken on a Hitachi F-4500 fluorescence spectrometer using a 1-cm quartz cell, with excitation and emission slits of 5 nm. Temperature effect on the Suzuki homocoupling reaction was examined by monitoring biphenyl fluorescence intensity profiles on Shimadzu RF-5301PC fluorescence spectrophotometer. pH values of the buffer solutions were measured on Mettler Toledo 320 pH meter. Buffer solutions of pH 9.0 to 10.6 were 0.10 mol L^{-1} $NaHCO_3$-Na_2CO_3 and of pH 7.58 to 8.52 were mixtures of 0.10 mol L^{-1} HEPES solution and 0.10 mol L^{-1} NaOH. Pd-catalyst was used after incubation in buffer solutions for 1 hr since the catalyst originally in the form of H_2PdCl_4 may undergo ligand exchange upon mixing with the buffer.

(2) Appendix

$$\begin{array}{ccccc} 2A & + & 2B & \Leftrightarrow & 2C \\ \downarrow & & & & \downarrow \\ D & & & & D \end{array}$$

In this scheme, A represents phenylboronic acid, B is the saccharide and C is the saccharide boronate, while D is the Suzuki homocoupling reaction product. Assume binding constant of the saccharide with boronic acid is K, then

$$K = [C] / [A][B] \quad (1)$$

For Suzuki homocoupling reactions of boropnic acid A and boronate C,

$$\partial[D]_A / \partial t = k_1 [A]^2 \quad (2)$$

$$\partial[D]_C / \partial t = k_2 [C]^2 \quad (3)$$

Therefore,

$$[D]_A = \int k_1 [A]_t^2 \, \partial t \quad (4)$$

$$[D]_C = \int k_2 [C]_t^2 \, \partial t \quad (5)$$

In which k_1 and k_2 are rate constants including contribution of the Pd-catalyst and $k_1 > k_2$, $[D]_A$ and $[D]_C$ are the product concentrations of the reactions from A and C, respectively, while $[X]_t$ represents the concentration of species X at time t.

Concentration of each species is related to the fluorescence intensity (I) by following equations,

$$[A] = I_A / k \Phi_A \varepsilon_A \quad (6)$$

$$[C] = I_C / k \Phi_C \varepsilon_C \quad (7)$$

$$[D] = I_D / k \Phi_D \varepsilon_D \quad (8)$$

In which k, Φ_X and ε_X are ratio constant, fluorescence quantum yield and molar absorption coefficient of species X, respectively.

In classic saccharide sensing based on its interaction with boronic acid, the ratio of I_A/I_C reflects the sensitivity of fluorescent sensing ($I_A > I_C$). Taking into account the binding constant (1), we have,

$$I_A / I_C = K [B] \Phi_A \varepsilon_A / \Phi_C \varepsilon_C \quad (9)$$

For the new strategy proposed here, I_D^A/I_D^C now reflects the sensitivity. I_D^A and I_D^C are the fluorescence intensities of D of Suzuki coupling reactions from A and C, respectively, $I_D^A > I_D^C$.

$$\begin{aligned} I_D^A/I_D^C &= [D]_A / [D]_C \\ &= \int k_1 [A]_t^2 \, \partial t / \int k_2 [C]_t^2 \, \partial t \\ &= \int k_1 [A]^2 \, \partial t / \int k_2 K^2 [A]_t^2 [B]_t^2 \, \partial t \end{aligned} \quad (10)$$

The sensitivity enhancement factor can therefore be probed by the ratio of $(I_D^A/I_D^C)/(I_C/I_A)$,

$$(I_D^A/I_D^C)/(I_A/I_C) = (\int k_1 [A]_t^2 \, \partial t / \int k_2 K^2 [A]_t^2 [B]_t^2 \, \partial t) / (K [B] \Phi_A \varepsilon_A / \Phi_C \varepsilon_C)$$

$$= (k_1/k_2)\,(\Phi_C\,\varepsilon_C/\Phi_A\,\varepsilon_A)\,(1/K^3)\,(1/[B])\,(\int[A]_t^2\,\partial t \,/\, \int[A]_t^2\,[B]_t^2\,\partial t) \qquad (11)$$

in which $(k_1/k_2) > 1$ whereas $(\Phi_C\,\varepsilon_C\,/\,\Phi_A\,\varepsilon_A) < 1$ (for example, *ca*. 0.4 in the case of fructose, see Fig. 1). However, the starting concentrations of A and B are normally at mmol L^{-1} level or lower, while $[A]_t$, [B] and $[B]_t$, in particular [B] and $[B]_t$, are much lower, the rough term $1/(K^3[X]^3)$ in eq. (11) would therefore be much higher than 1, *i.e.* $1/(K^3[X]^3) >> 1$, the ratio defined by eq. (11) is therefore larger than 1.

An enhancement in the sensitivity of the proposed new strategy is hence expected.

(3) Figure S1

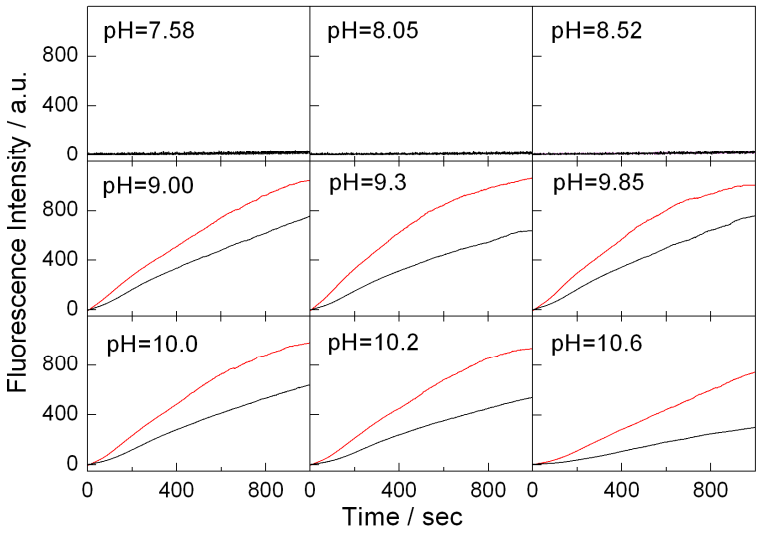

Fig. S1 Reaction kinetic profiles of the Suzuki homocoupling reactions in the absence (red) and presence (black) of D-fructose in solutions of different pH. Buffer solutions for pH 7.58, 8.05 and 8.52 were made from 0.1 mol L^{-1} HEPES and 1.0 mol L^{-1} NaOH and for pH 9.00, 9.3, 9.85, 10.0, 10.2 and 10.6 were mixtures of 0.02 mol L^{-1} Na_2CO_3 and 0.08 mol L^{-1} $NaHCO_3$.

(4) Figure S2

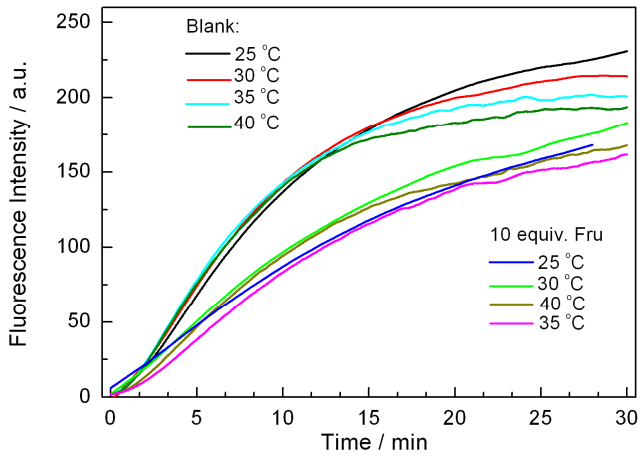

Fig. S2 Temperature effect on the kinetic profiles of Suzuki reaction in the absence and presence of 1.0×10^{-4} mol L^{-1} of D-fructose. [PBA] = 1.0×10^{-5} mol L^{-1}, [Pd] = 1.0×10^{-5} mol L^{-1}.

(5) Figure S3

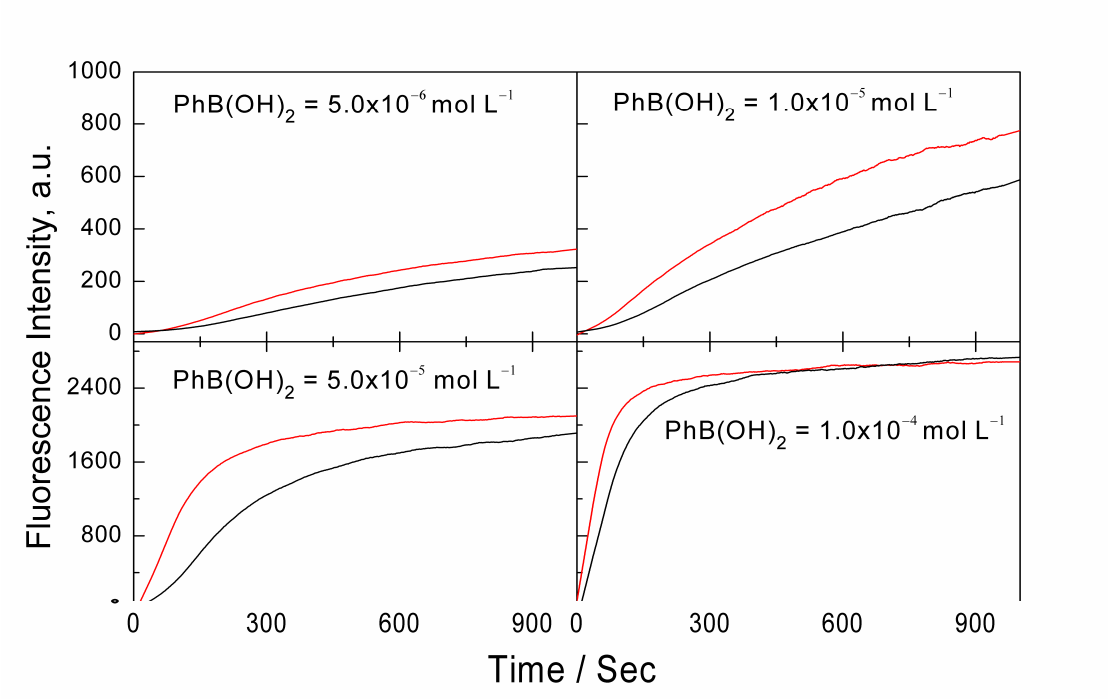

Fig. S3 Influence of phenylboronic acid concentration on the coupling reaction kinetic profiles. [D-fructose] = 1.0×10^{-4} mol L^{-1}, [Pd] = 1.0×10^{-5} mol L^{-1}.

(6) Figure S4

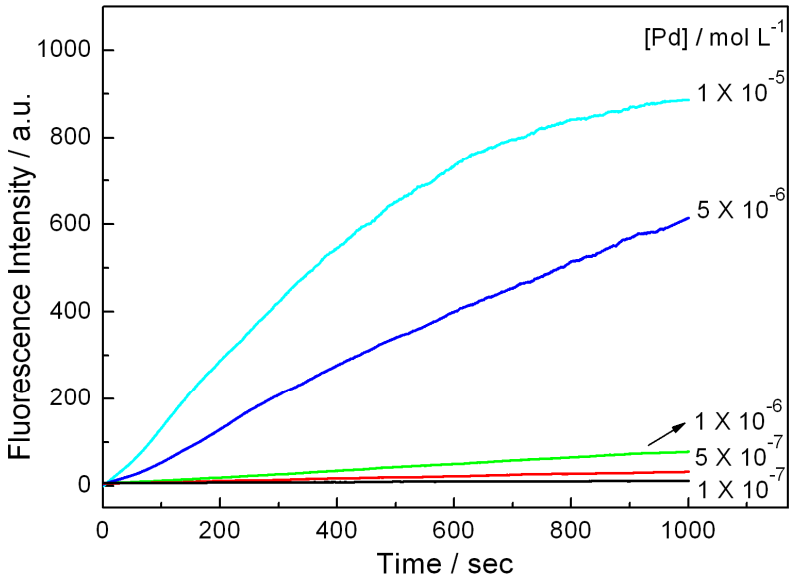

Fig. S4 Kinetic profiles of the coupling reaction at varying Pd-catalyst concentration. [PBA] = 1.0×10^{-5} mol L^{-1}.