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A Paper Sensor Printed with Multifunctional Bio/Nano Materials

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S. Jenifer
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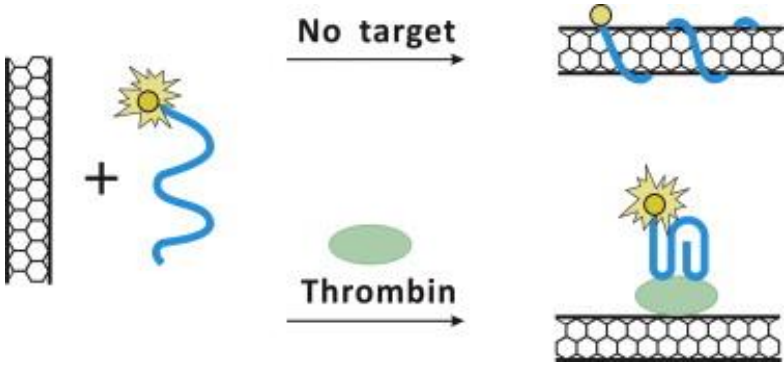
INTRODUCTION

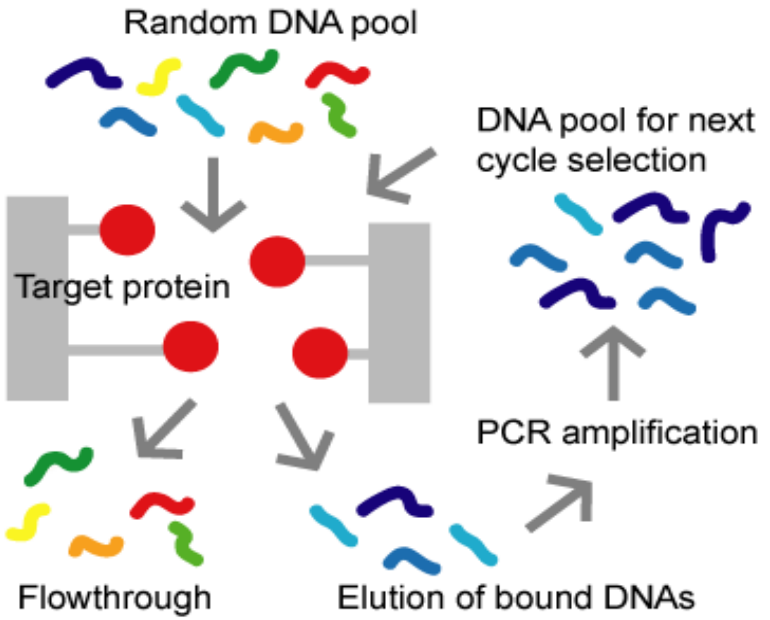
- **Aptamers:**
  Oligonucleotide or peptide molecules that bind to a specific target molecule. Aptamers are usually created by selecting them from a large random sequence pool.



https://doi.org/10.1016/j.aca.2014.04.055

- **DNAzymes:** DNAzymes are catalytically active DNA molecules.

- **SELEX:** (**S**ystematic **E**volution of **L**igands by **EX**ponential enrichment) technique in molecular biology for producing oligonucleotides of either single-stranded DNA or RNA that specifically bind to a target ligand or ligands.



altair.sci.hokudai.ac.jp

SIGNIFICANCE

- Detect trace amounts of many **different type** of analytes(Metals, biomarkers, DNA, RNA, toxins etc.)
- Long-term stability, high affinity and selectivity for target.
- Molecules as **small** as 60 daltons, ten times smaller than the smallest antibody targets.
- Development/production does not involve animals or living cells, it is possible to select for aptamers to toxic compounds, including zootoxins and pathogenic bacteria.
- Doesn't require an **immune response**, aptamer selection relies primarily on the "fit" of tertiary aptamer structures to target molecules.
- Production is easily scalable

FULL PAPER
Fluorescence Detection
ADVANCED FUNCTIONAL MATERIALS
www.afm-journal.de

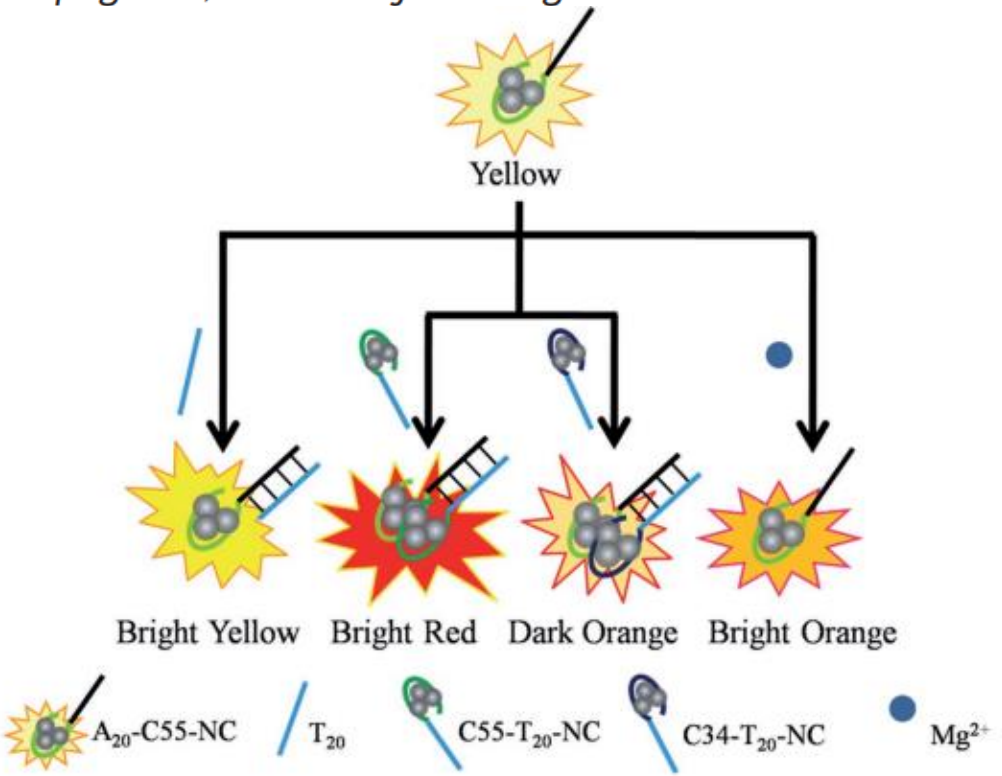
A Multicolor Chameleon DNA-templated Silver Nanocluster and Its Application for Ratiometric Fluorescence Target Detection with Exponential Signal Response

Adv. Funct. Mater. **2017**, *27*, 1704092

*Weijun Zhou, Jinbo Zhu, Daoqing Fan, Ye Teng, Xiaoqing Zhu, and Shaojun Dong**

•DNA-templated silver nanocluster (AgNC) is found whose fluorescence color can be switched among yellow, orange, and red by the regulation of complementary DNA, nonfluorescent assistant AgNC as well as Mg^{2+}.

•The ratiometric probes demonstrate an exponential growth of signal response with **nanomolar sensitivity.**



July 25, 2018

LANGMUIR

Article

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Lighting Up Fluorescent Silver Clusters via Target-Catalyzed Hairpin Assembly for Amplified Biosensing

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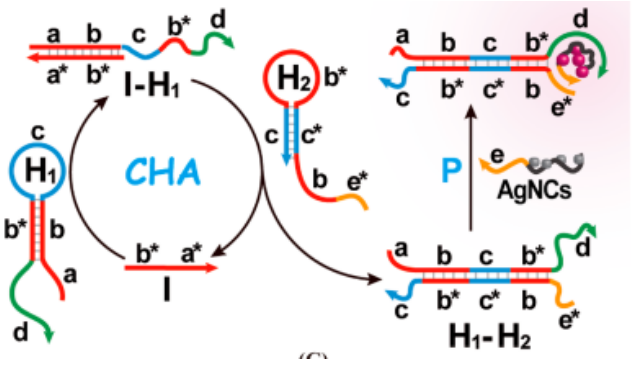
- Target catalyzes the assembly of two hairpins into dsDNA structures for amplified detection.
- The AgNCs enhancer (G-rich) sequence and the AgNCs accommodation sequence were respectively grafted onto two different hairpin structures.
- The analyte initiated the CHA reaction that autonomously and successively brought the fluorescence enhancer and AgNCs into close proximity, leading to the fluorescence enhancement that could be visualized easily by a simple apparatus.
- One mechanism is that the secondary structure of G-rich sequences (e.g., Gquadraplex) favors the formation of red-emitting DNA-AgNCs. The other mechanism is a possible electron transfer from guanine bases to DNA-AgNCs that trigger on their fluorescence



RELEVANCE

- Sensing of metal ions.
- Removal of metal ions from water.
- SERS based sensors.

Environ. Sci. Technol. 2009 43, 9335–9340

Arsenic Removal from Vietnamese Groundwater Using the Arsenic-Binding DNA Aptamer

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Received April 6, 2009. Revised manuscript received October 27, 2009. Accepted October 28, 2009.

LUMINESCENCE
The Journal of Biological and Chemical Luminescence

RESEARCH ARTICLE | Full Access

A simple gold nanoplasmonic SERS method for trace Hg^{2+} based on aptamer-regulating graphene oxide catalysis

Chongning Li, Xiaoliang Wang, Aihui Liang, Yanghe Luo, Guiqing Wen, Zhiliang Jiang

First published: 17 July 2018 | https://doi.org/10.1002/bio.3517

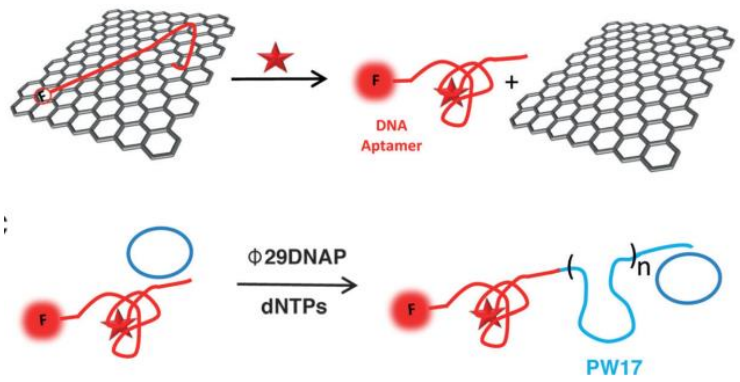
•DNA aptamers were first **desorbed** from reduced graphene oxide (GO) upon target-induced structure switching, with the released aptamer then acting as a primer for RCA.

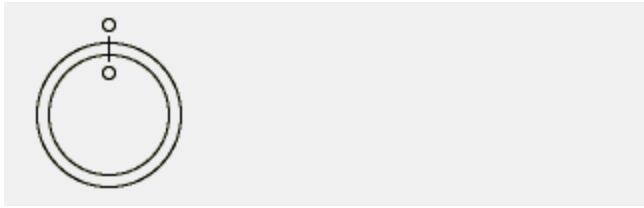
•The RCA reaction generated repetitive sequence units that could easily be detected using colorimetric or fluorimetric readouts.

• RNA aptamer on a paper device (for detection of ATP, a general bacterial marker) and the use of a DNA aptamer for glutamate dehydrogenase (GDH, a marker for *Clostridium difficile*).

•RCA products (RP) contain repetitive units of a peroxidase-mimicking DNAzyme, PW17, which generate a colorimetric signal in the presence of H2O2 and compounds such as 3,3',5,5'-tetramethylbenzidine (TMB) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS).

•Attempts to perform the RCA directly on Zone 1 were unsuccessful as the desorbed aptamer readsorbed on the GO surface over time





Rolling circle amplification

Biochimie 145 (2018) 151–157

Contents lists available at ScienceDirect

Biochimie

journal homepage: www.elsevier.com/locate/biochi

Research paper

Selection and characterization of DNA aptamers for detection of glutamate dehydrogenase from *Clostridium difficile*

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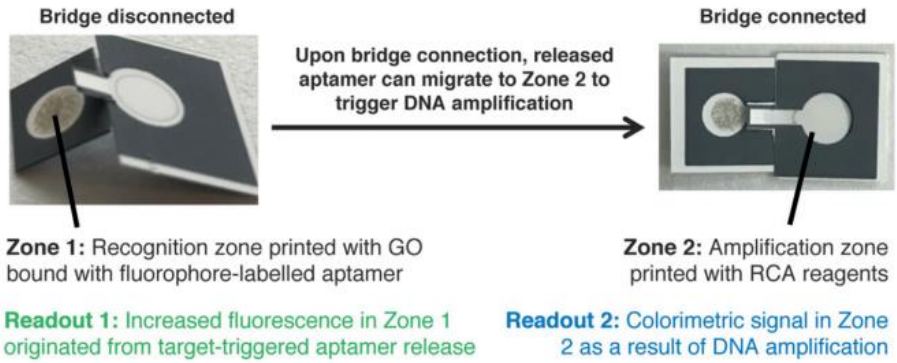
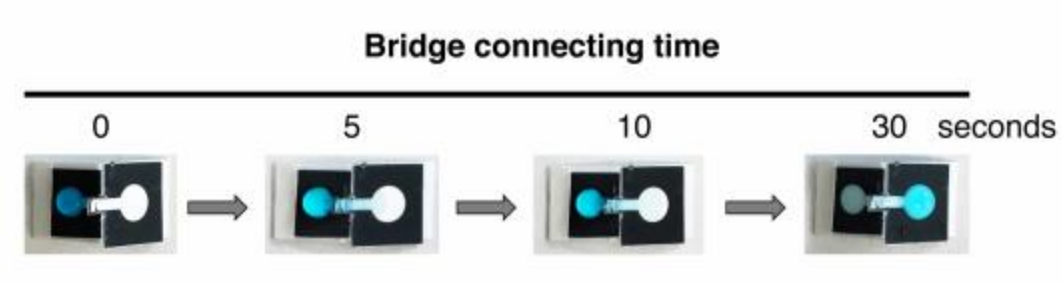
- π-rich conjugation domains allow graphene to directly interface with DNA through noncovalent π - π stacking interaction
- Graphene produces highly efficient fluorescence quenching based on energy transfer or electron transfer mechanisms.
- The presence of target triggers the release of a quencher-labeled complementary DNA strand from the fluorophore-labeled aptamer, accompanied by an increase of fluorescence intensity because of fluorescence dequenching.

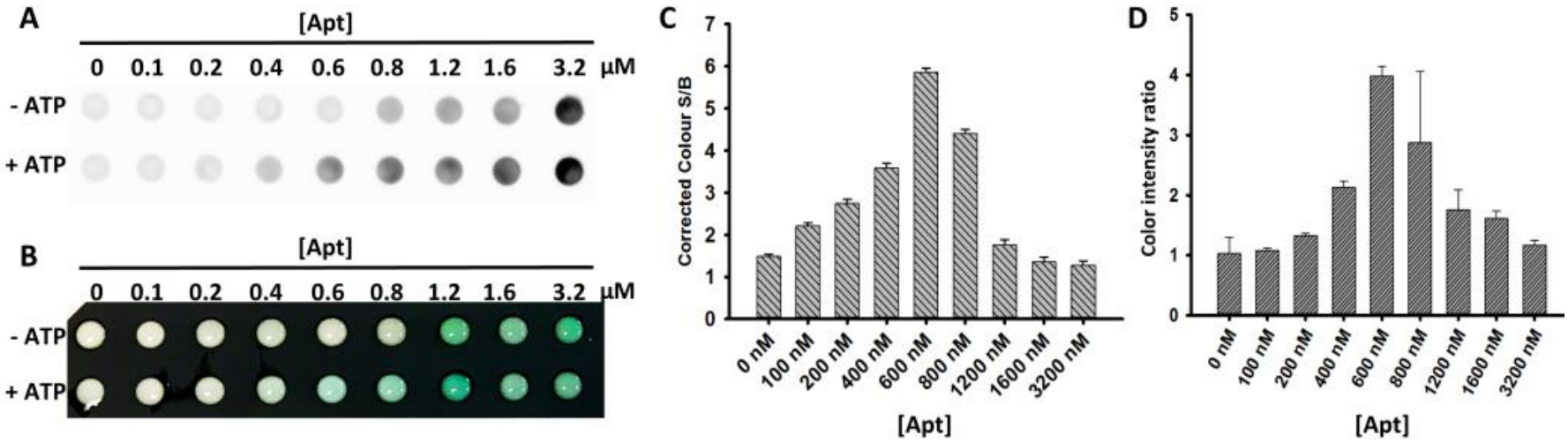
Design of the dual output paper-based aptasensor.

- Zone 1 is printed with aptamer (Apt):GO complex and Zone 2 is printed with pullulan solution with RCA reagents.
- Upon addition of a test sample to Zone 1 and incubation for **30 min**, the fluorescence intensity is read.
- The bridge is then connected and the solution mixture migrates to Zone 2. After 1 min, the bridge is disconnected.
- The RCA reaction is then conducted for 60 min, followed by addition of the colorimetric assay reagents.
- Colour appears in Zone 2 in about 5 min; a photo is then taken using a smartphone.



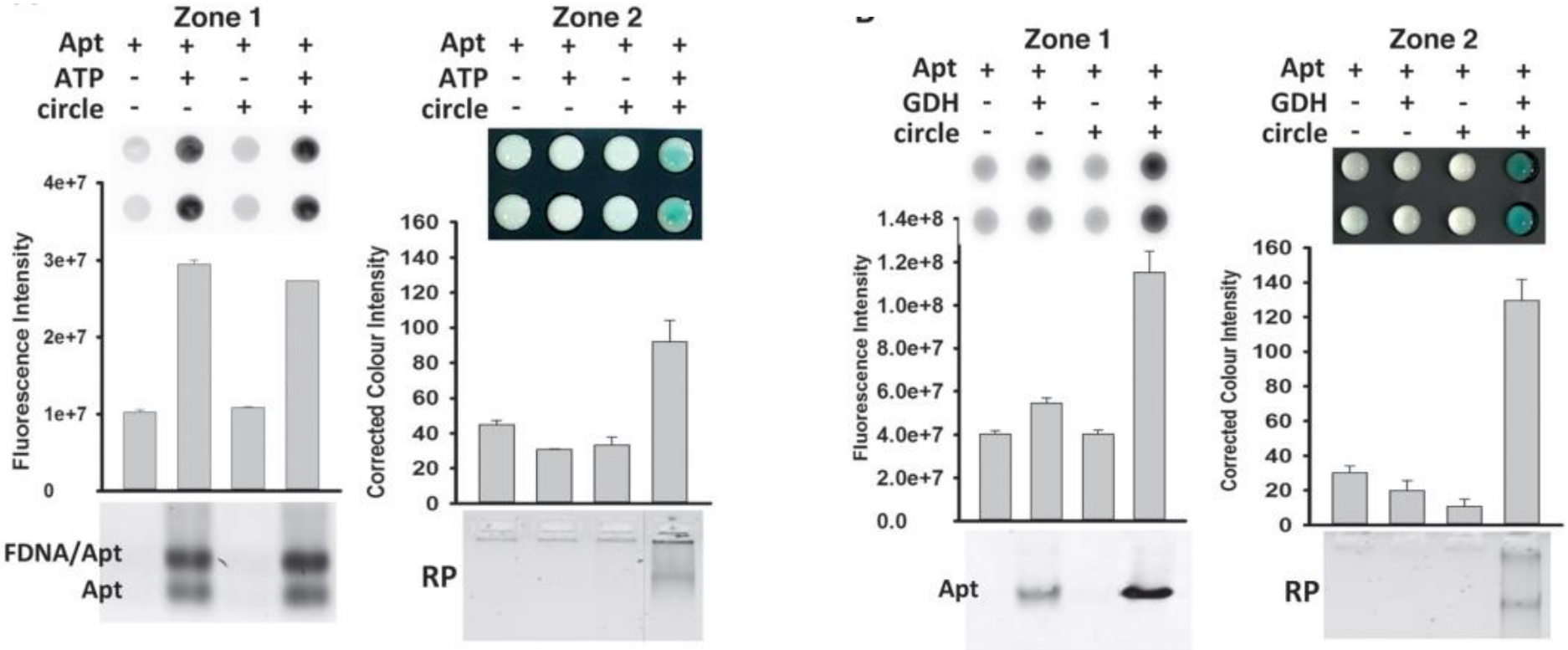


Connecting the bridge between Zone 1 (left zone) and Zone 2 (right zone) to allow for migration of solution from Zone 1 to Zone 2.



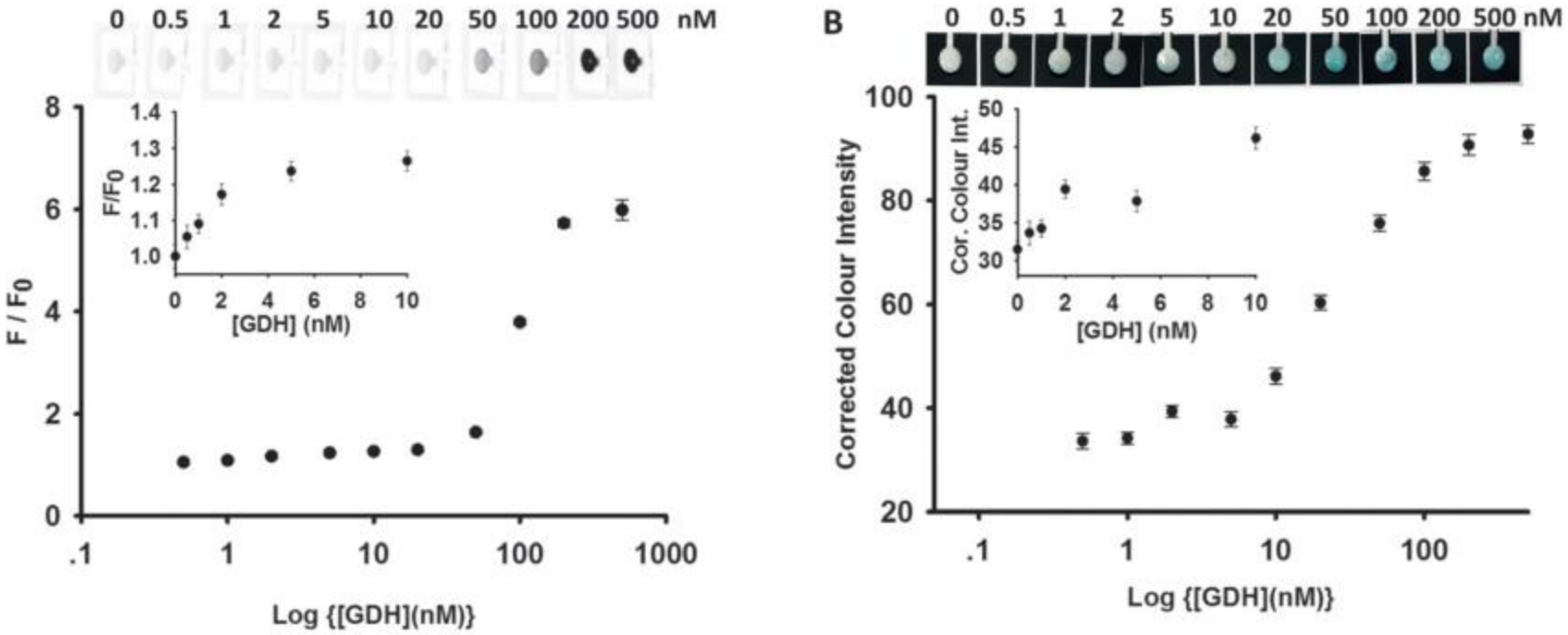
Optimization of the ATP sensor. **(A)** Fluorescence images of GO/aptamer complex upon incubation with reaction buffer ± 2 mM ATP for 30 minutes. The concentration of the GO suspension was 0.1 mg/ml. **(B)** Colorimetric assay following RCA using mixtures taken from panel A. (C) Fluorescence ratio of +ATP/-ATP samples vs. aptamer concentration. (C) Color intensity ratio of +ATP/-ATP samples vs. aptamer concentration.

Examination of functionality of aptamer/GO paper sensors.



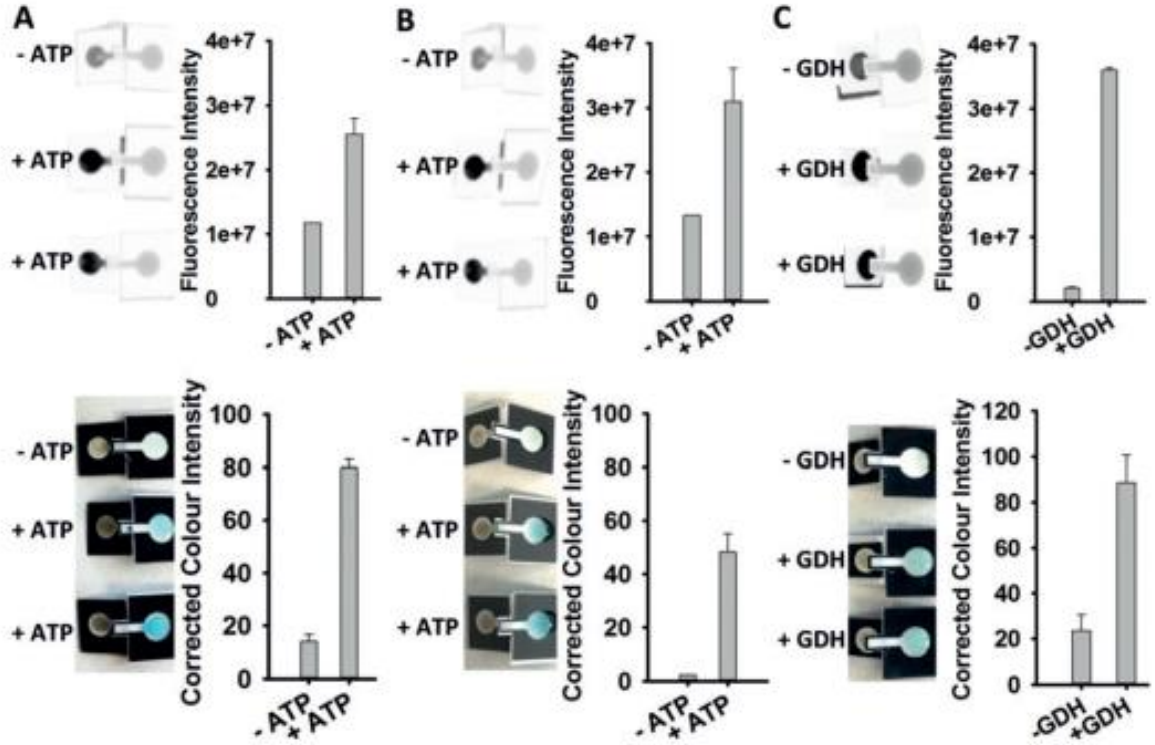
A) ATP sensor. B) GDH sensor. Left panel: Fluorescence image (top), fluorescence intensity (middle) and agarose analysis (bottom) of (A) ATP and (B) GDH system upon addition of: lane 1, buffer; lane 2, target only; lane 3, circular DNA template only; lane 4, target and circular DNA template. Right panel: Colorimetric image (top), color intensity (middle) and agarose gel analysis (bottom) of RCA reaction mixtures produced with the same samples taken from the left panel. After 60 min, H2O2, TMB and ABTS were added to initiate the colorimetric reaction. The image was captured by an iPhone at 5 min after all components were added.

Detection of GDH using the printed GDH sensor. Concentration–response curves



A) fluorescence readout and B) colorimetric readout. Different concentrations of GDH were introduced to Zone 1, then incubated for 30 min followed by fluorescence imaging. The solution was then migrated to Zone 2 by closing the bridge; RCA was performed for 1 min, after which H2O2, TMB and ABTS were added to initiate the colorimetric reaction. The image was captured by an iPhone 5 min after all components were added and analyzed by ImageJ to produce a color intensity value.

Robustness of dual-response paper sensors



Robustness of dual-response paper sensors. A) The ATP sensor with 1:1 ratio of human blood serum spiked with 2 mm ATP. B) The ATP sensor with 1:1 ratio of stool sample spiked with 2 mm ATP. C) The GDH sensor with 1:1 ratio of stool sample spiked with 500 nm GDH. Top panels show fluorescence responses of samples relative to unspiked controls, bottom panels show colorimetric responses of samples relative to unspiked controls.

SUMMARY

- The sensor provided a detection limit (LOD) of 10 µM for both the fluorescence readout and colorimetric readout in the case of the ATP sensor, and LOD values of 3 nm for both the fluorescence and colorimetric readouts for the GDH sensor.
- Both of the LOD values (ATP and GDH) were similar to or better than the values obtained in solution-based fluorescence assays
- The sensor also exhibited excellent selectivity. No fluorescence or color based signal was generated when GTP, UTP or CTP were added to the ATP sensor, or when Toxin A or Toxin B from C. difficile, or BSA were added to the GDH sensor
- Even direct addition of RNase to the RNA aptamer/GO complex or DNAse I to the GDH aptamer/GO complex on paper produced minimal degradation of the aptamer, showing that the GO effectively protects aptamers from degradation.

Thank you