DIGIPREDICT

Protein detection based on Si Nanowire FET Sensor Arrays: Antibodies Fragments and Back-Gate amplification to overcome charge screening in ionic liquids

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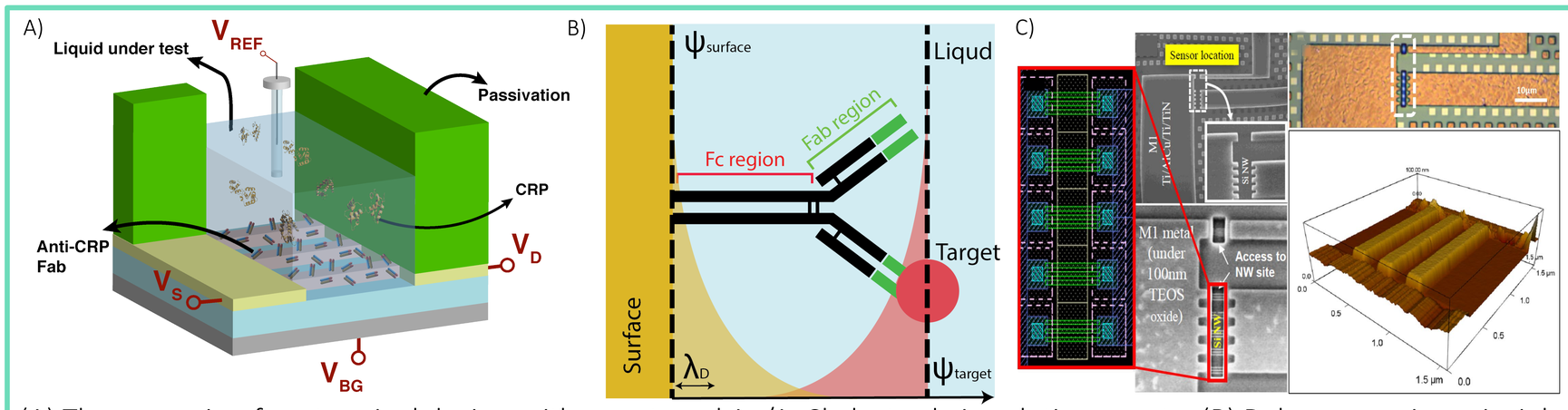
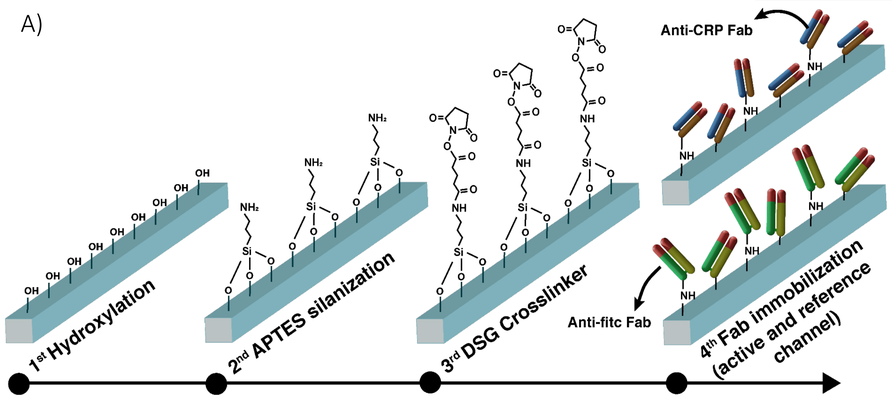


(A) The sensor is a four-terminal device, with an external Ag/AgCl electrode in solution as gate. (B) Debye screening principle in FET-based sensors. (C) SiNWs layout and details by SEM and AFM images. CEA-LETI designed and fabricated the chip.

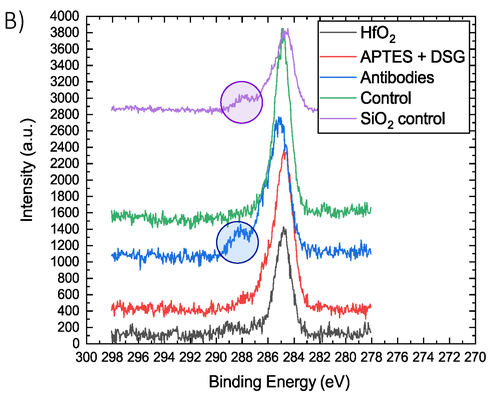
Introduction

We report a C-Reactive Protein biosensor based on SiNW arrays. To overcome the Debye screening limitations of charged analytes with FET-based technology we exploit antibody fragments and an internal amplification given by the double-gate structure of the system.
We demonstrated CRP detection in the human physiological concentration range.

Surface Functionalization



Antibody fragments (Fab) are immobilized on the nanowires' hafnium oxide surface through a silanization chemistry. We immobilize two different antibodies species on the active and reference sensor.



The immobilization protocol was assessed by XPS spectroscopy, by analyzing the evolution of the C1s peak after each step of the functionalization. After linking the antibodies to the surface, a secondary peak at 288.3eV appears, indicating the presence of the peptide bond.

Electrical Characterization

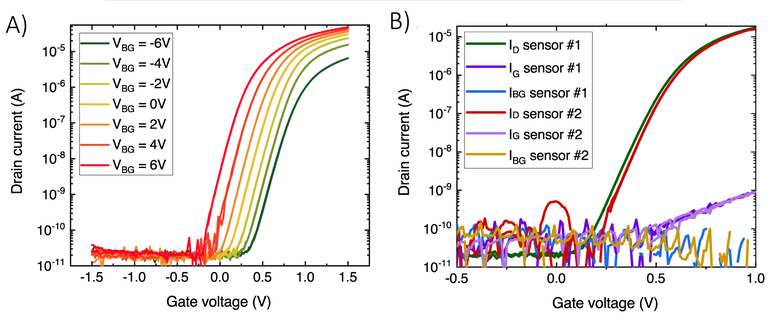
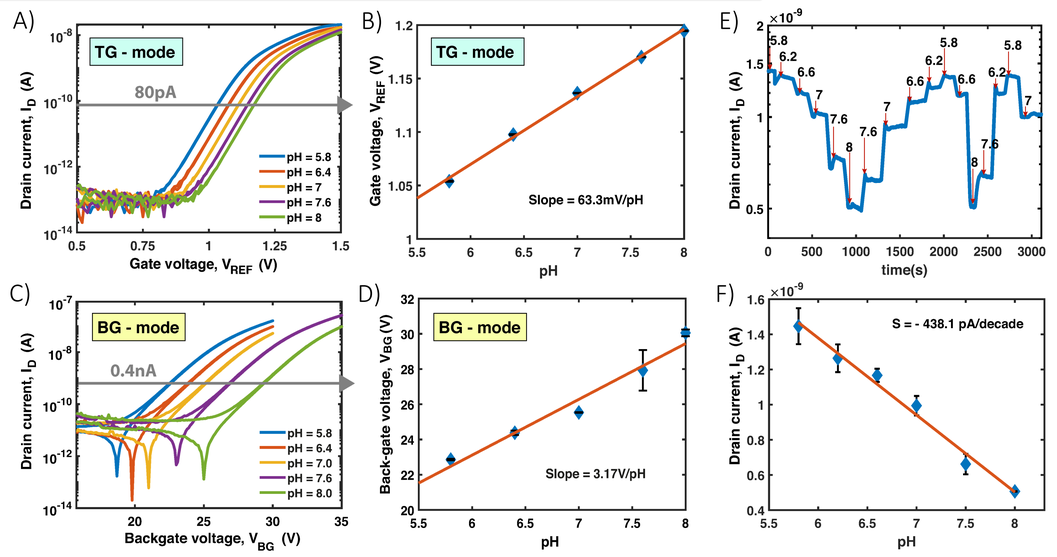


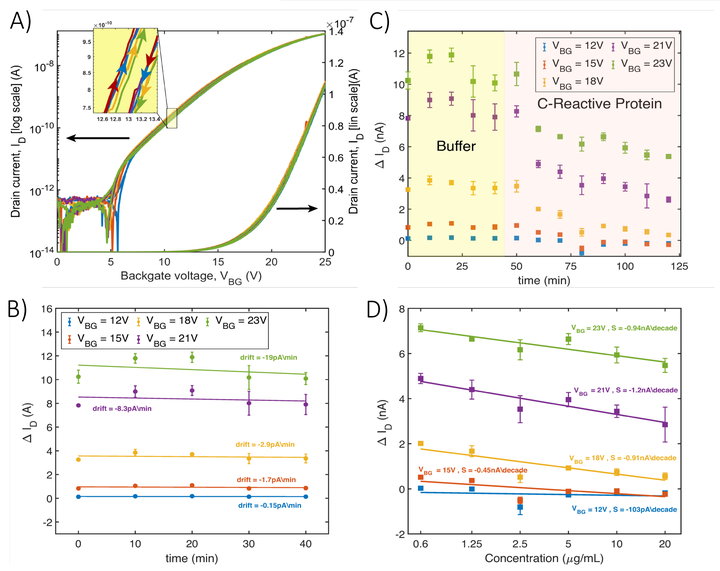
Fig. A shows the transfer characteristic of one SiNW array biased with different back-gate voltages, V_S = 0V and V_D = 0.3V. The sensor shows to be easily and reliably tunable, in order to position the bias point in the desired working region. Fig. B shows the gate and back-gate leakage currents.

pH sensing and Back-Gate amplification

Thanks to the double-gate structure, the sensor can be used either in top gate (TG) or bottom gate configuration. With the unfunctionalized SiNWs arrays we can monitor pH variation both in static (A-D) and dynamic conditions (E-F).
We report an internal signal amplification while using the sensor in back-gate configuration.



C-Reactive Protein Sensing



CRP detection is carried out in back-gate configuration. Fig. A shows the I_D-V_{BG} response of the active sensor, for four injections of the same buffer. The sensor stability is assessed by multiple buffer injections over time (Fig. B). We demonstrate CRP detection by extracting the differential response ($I_{Dactive}$ – $I_{dreference}$) towards different protein concentrations. Fig. C shows the response evolution over time, while Fig. D is a zoom on the concentration range for which the sensor shows a linear response.

Conclusions

- We report a sensor based on SiNW arrays able to detect CRP in the human physiological range
- We exploit the internal back-gate amplification to enhance the sensor response
- We immobilize antibody Fab fragments to reduce the distance between the sensor surface and the antigen binding sites
- The sensor shows great stability in buffer and low hysteresis
- We demonstrated real-time monitoring of pH variations

REFERENCE: Capua Luca and Sprunger Yann, et al. "Label-Free C-Reactive Protein Si Nanowire FET Sensor Arrays With Super-Nernstian Back-Gate Operation." IEEE Transactions on Electron Devices (2022).

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