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Investigation of biochemical sensing mechanism in organic electrochemical transistors: effect of electrochemical potential and capacitance

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Organic electrochemical transistors (OECTs) offer a unique set of advantages in the development of biosensor devices including high sensitivity, low cost, easy fabrication, flexibility and biocompatibility. These devices can operate as sensors in two different modes, a faradaic mode and a non-faradaic mode. The faradaic mode is used for the detection of redox active molecules and this kind of sensing is limited by the reactivity of the analyte and the electrochemical stability of the device components. On the other hand, the non-faradaic mode relies on binding events and does not involve an electrochemical reaction. This last strategy broadens the range of applications, since it can be used for the detection of nonredox active species or biological species such as proteins and biomarkers by using bioreceptors such as antibodies[1], nanobodies[2] and aptamers[3].

Despite their promise, the sensing mechanism of the non-faradaic sensing devices is poorly understood and hence, the further development of the technology is impeded. Here, we focus on the effect of two most critical aspects, namely, the electrochemical potentials and capacitance interplay on sensor operation. Using model electrodes as the gate contacts, we decoupled these phenomena to determine the contribution of each of them to the sensing signal and understand how and in which conditions these are favorable/unfavorable for the sensing performance. We have also developed a protocol that allows to operate the device in the safest regime and control in real time the state of the polymer to avoid (i) irreversible over-oxidation of the channel, (ii) side reactions caused by the electrolyte that can damage the channel or the biofunctionalization layer, and (iii) stress on the gate electrode. This protocol allows us to match the stability requirements of the organic semiconductor and the biofunctionalization layer and maximize the long-term stability of the device.

For this study we used two types of (semi)conducting polymers in the channel, allowing us to compare the sensor performance of OECTs operating in two distinct modes, i.e., accumulation and depletion modes. As an example of the results obtained with this study and to give a general guideline for the development of biosensors, nanobody functionalized OECTs were used to detect the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus.

References

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