Antibody-gated indicator releasing mesoporous materials: a potential biosensor platform for rapid diagnostic tests

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The urgent necessity to carry out reliable and relevant analytical measurements directly at a point-of-need is one of the current drivers for the development of miniaturised analytical systems, quick tests and wearables. Despite their simplicity, this type of tests must guarantee analytical relevance and reliability like laboratory-based analysis, e.g., in terms of sensitivity, selectivity, immunity against false positives and false negatives as well as robustness and repeatability. Keeping in mind the high sensitivity offered by gated indicator-releasing micro- and nanoparticles due to their inherent features of signal amplification, we performed several optimisations to develop a potential biosensor platform for use in rapid tests. Conceptually, these gated materials are closely related to drug delivery systems, consisting of high porous materials usually closed with macromolecular "caps" and loaded with indicator molecules that are released in presence of a target analyte. However, the key difference between the two types of functional materials is that many drug delivery systems should deliver their cargo over a longer period, often many hours, whereas the gated materials prepared for sensing should show fast release kinetics, on the order of <5 min.

With the aim to optimise and adapt gated materials for sensing purposes, we prepared in this work several antibody-gated materials for small-molecule sensing. The materials consisted of porous silica particles containing indicator molecules in the pores and certain hapten molecules grafted to the particle surface close to the pore openings. The pores were then capped with antibodies binding to these haptens, thus inhibiting the escape of the indicators from inside of the pores. In presence of the corresponding analyte, the antibody is displaced from the surface of the material, allowing the escape of the indicators. This allows the detection of the analyte indirectly through an inherent signal amplification. In this work, the insecticide permethrin, a type-I pyrethroid, was selected as target model, because type-I pyrethroids play an important role in airplane disinfection. A first in-depth study of the various chemical tuning options of such antibody gated systems was performed. Different mesoporous silica supports, different functionalisation routes and different loading sequences were assessed. The materials' performances were evaluated by studying their temporal response behaviour and detection sensitivity, including the tightness of pore closure (through the amount of blank release in absence of analyte) and the release kinetics. Our results indicate that the better the paratope-accommodating Fab region of the antibody "cap" fits into the host material's pore openings, the better the closing/opening mechanism can be controlled. Because such materials can be used in various different formats from suspension assays[1] via microfluidic chips[2] to test strip-based lateral flow assays,[3] such materials present a powerful analytical particle platform for the sensitive analytics and diagnostics outside of a laboratory, realising sensitivities down to the µg kg^{-1} range in less analysis times of less than 5 min as we have recently demonstrated.[4]

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