The Fluorescence Properties of Graphene Oxide

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Graphene oxide (GO) is an intermediate on the route to chemically derived graphene, and it is easily synthesized. Its chemical structure is heterogeneous and consists of both, large areas of conjugated sp^2-systems and various electronically isolated oxygen containing functionalities [1]. Contradictory optical properties have been found. A band gap which enables photoluminescence is introduced into GO with increasing oxidation level [2, 3]. Due to the remaining large □-electron system, it can also act as a quencher of fluorescence [4]. GO is well dispersible in water and therefore of interest in many (bio)analytical applications. By tuning its size, oxidation level, number of layers and additional chemical functionalization it is possible to create tailored materials with specific optical properties.

We have systematically studied the multiple fluorescence of GO and its dependence on excitation wavelength, emission wavelength and pH value in the near-UV and visible (Fig. 1). The changes in fluorescence observed with alterations in pH do not depend on the excitation/emission wavelength. This may be useful for designing a probe compatible with many kinds of optical equipment (light sources, filters, etc.).

GO turned out to be a good quencher of the fluorescence of organic dyes, that are widely used in biological applications. Quenching was investigated in the presence of different concentrations of GO (Fig. 2a, b). The results were compared to models for dynamic or static quenching, but none of them matches the observations. However, the ’Sphere of action’ model turned out to adequately describe the quenching mechanism (Fig. 2c).

The understanding of the mechanism in fluorescence quenching of GO allowed to take advantage of these findings in several optical applications: The material was applied to an improved visualization of graphene under the microscope and resulted in a better contrast. This can help to identify the number of graphene layers and to obtain information on the uniformity of graphene films. GO also was used as a surface substrate in Raman spectroscopy, enabling the acquisition of Raman data of even strongly fluorescent samples due to the suppression of the fluorescence. This provides an additional way for the characterization of fluorophores.

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References

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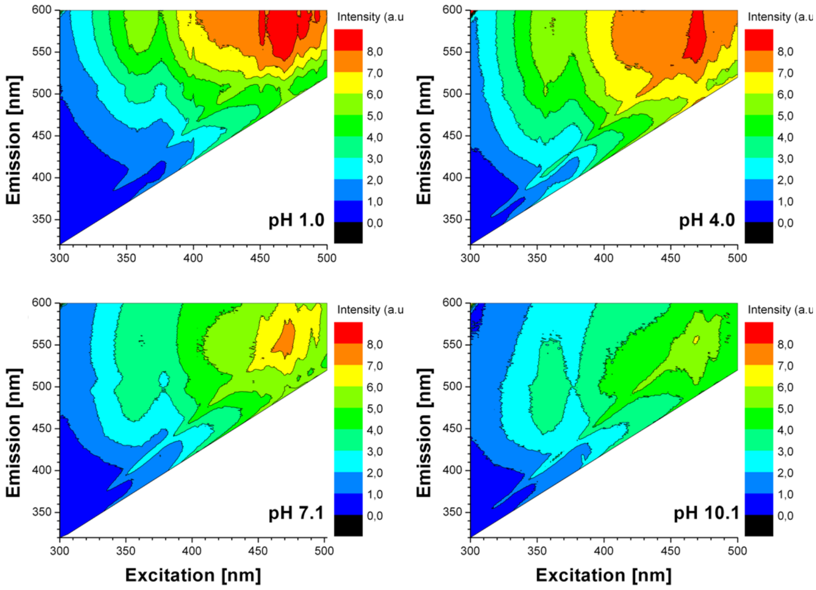
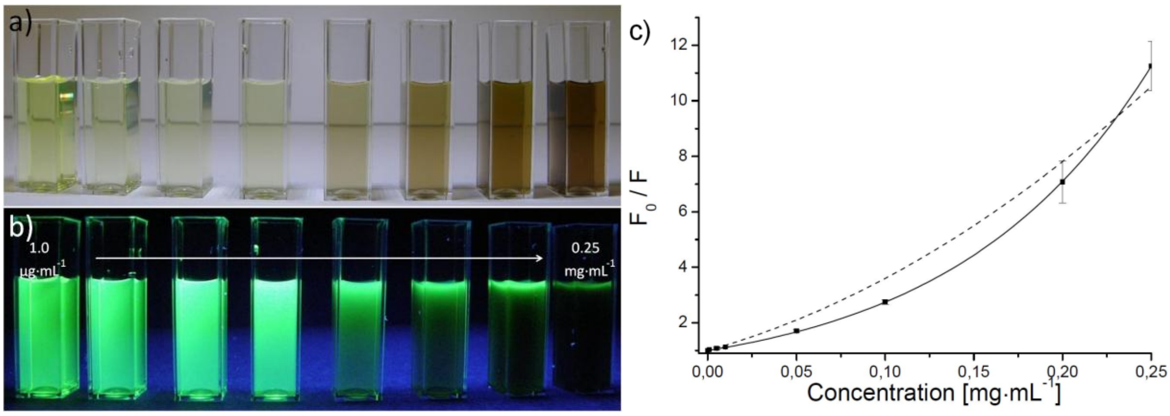
Figures

Figure 1:



Excitation-emission matrices of graphene oxide at pH values 1.0, 4.0, 7.1 and 10.1.

Figure 2:



5(6)-Carboxyfluorescein (10 µM) at pH7 with increasing concentrations of GO, examined under visible light (a) and UV light (b). The Stern-Volmer plot (c) shows the experimental data and theoretical fitting according to the two models of combined quenching (dashed line) and sphere of action (solid line).