Graphene-TiO_2 hybrids for photocatalytic aided removal of VOCs and nitrogen oxides from outdoor environment

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Outdoor air is a valuable resource for current and future generations. While many policies and regulations on air quality have been promulgated worldwide over the past decades, airborne pollution still negatively affects health, therefore the life-style of human beings. Nitrogen oxides (NOx) and volatile organic compounds (VOCs) are common anthropogenic air pollutants. The exposure to those gases has been reported to be as the 5th ranking human health risk factor worldwide. Photocatalysis is one of the most investigated solar (photo)reactions to reduce this global threat. Titanium dioxide (TiO2), an Earth-abundant material, is amid the most promising photocatalysts. However, the relatively high recombination rate of the photogenerated exciton, dissipating the energy as light or heat, strongly reduces the resulting photocatalytic activity. To tackle this drawback, we have synthesised, via a green, clean, and simple sol–gel method, titania/graphene (0.5 and 1.0 wt% graphene nanoplatelets) hybrid nanomaterials. Photocatalytic activity was tested against three major pollutants found outdoor: nitrogen oxides (i.e. NOx = NO + NO2), and two different VOCs – benzene and isopropanol. Upon UV-A irradiation, distinct radicals were formed in presence of isopropanol and benzene, thus leading to different yet complex reaction pathways.

Results showed that the addition of 1.0 wt% of graphene to TiO2 enabled a two-fold increase in the photocatalytic removal of those gaseous pollutants, being fully recyclable over repeated tests. Indeed, the addition of graphene nanoplatelets to that semiconducting material acted as a highway for the electron mobility, enhancing the separation of the photogenerated exciton, thus decreasing their recombination rate. This makes our material an ideal candidate for multi-purpose environmental applications.

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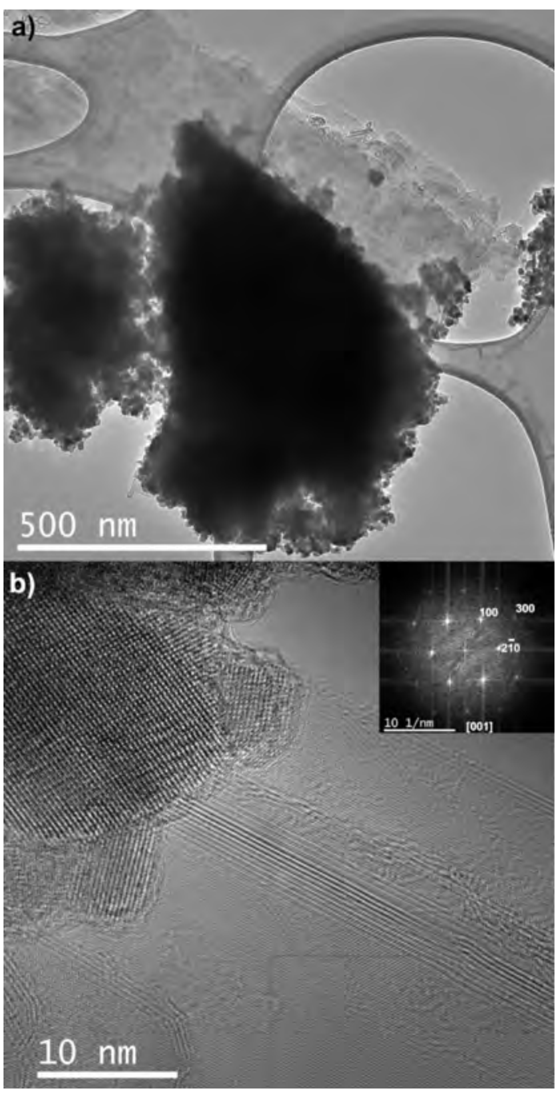

FIGURE 1
a) TEM image acquired on TiO2 modified with 1 wt% graphene nanoplatelets, thermally treated at 450 °C. b) HR-TEM image acquired on the same sample. The inset shows the FFT calculated on the area highlighted by the red square.

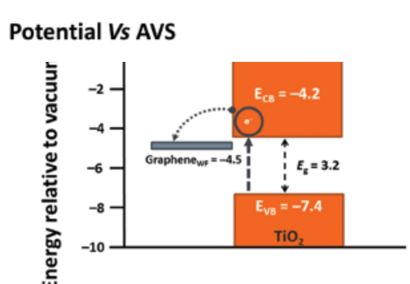

FIGURE 2
Proposed mechanism for improved spatial charge carrier separation in a graphene-TiO_2 hybrid material (following to UV-Vis excitation). In the band diagram, relative to the absolute vacuum scale, the dashed yellow arrow shows the electron transferring in titania (from the valence band to the conduction band) due to photocatalysis; the dotted yellow arrow depicts the successive electron transferring from the conduction band of TiO2 to graphene.