Development of glass surfaces with self-cleaning properties under visible light irradiation based on BiOI/TiO_2 heterojunction.

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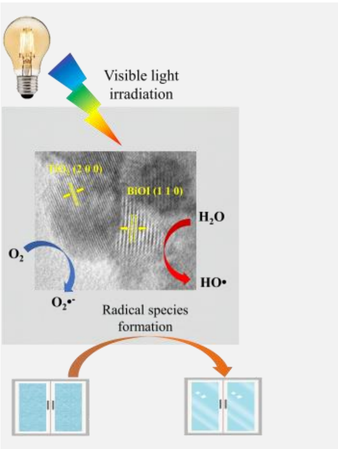

The screens of mobile devices, consisting mainly of glass, act as fomites, actively participating in the transmission of diseases caused by microorganisms. Therefore, the design of glass surfaces with self-cleaning properties could have an impact on the development of mobile device screens with self-cleaning properties, contributing to the reduction of infectious disease transmission. The present work focuses on the development of glass surfaces with self-cleaning properties based on photocatalytic activity of bismuth oxyiodide/titanium dioxide heterostructures under visible light. For this purpose, BiOI/TiO_2 heterostructures were synthesized, characterized (via XRD, UV-Vis DRS, BET surface area, SEM, HRTEM, and EIS) and immobilized on glass surfaces. Additionally, glass surfaces with immobilized BiOI/TiO_2 nanoparticles showed better photocatalytic performance than glass surfaces with pure TiO_2 and BiOI immobilized nanoparticles.

Introduction

Mobile devices are essential in modern life but can act as fomites serving as vehicles in transmission of harmful microorganisms [1]. Bhoonderowa et al. (2014) found bacterial contamination on 91.7% of 192 sampled cell phones [2]. Several semiconductor metal oxides like TiO_2 and BiOI, exhibit self-cleaning and antimicrobial properties due to their property to generate oxidizing species *in situ* when they are irradiated by electromagnetic radiation with energies equal to or higher than the forbidden energy band. While TiO_2 and BiOI have been separately used to confer self-cleaning abilities to surfaces like glass and ceramics, there are no reports that combine the properties of TiO_2 and BiOI in a single heterojunction material supported on a surface. This study introduces a novel approach: developing a glass surface with inmobilized BiOI/TiO_2 heterostructures with self-cleaning properties under visible light irradiation.

Material and Methods

<u>BiOI/TiO_2 synthesis</u>: BiOI/TiO_2 nanoparticles were prepared following the coprecipitation method reported by Li et al. (2018) with adaptations.

<u>Characterization of BiOI/TiO_2:</u> the synthesized nanoparticles of BiOI/TiO2 heterostructures were characterized by XRD, UV-Vis DRS, BET surface area, SEM, TEM, HRTEM and EIS techniques.

<u>Evaluation of photocatalytic activity in aqueous BiOI/TiO_2 medium:</u> photocatalytic degradation kinetics of methyl orange dye was performed was performed in a solar simulator equipped with a xenon lamp.[4]

<u>Immobilization of synthesized BiOI/TiO_2 nanoparticles on glass</u>: tetraethylorthosilicate solution adjusted to pH 1.5 was applied to flat square pieces of glass.[5] Then, the prepared photocatalyst nanoparticle suspension was applied to the surface of the glass pieces by brushing.

<u>Identification of radical species:</u> radical species formed on the surface of glass with immobilized photocatalyst nanoparticles under simulated solar radiation were identified by electron paramagnetic resonance using DMPO spin trap.

<u>Determination of self-cleaning properties of glass pieces with immobilized BiOI/TiO_2 nanoparticles:</u> the determination of self-cleaning properties was performed based on ISO 27448:2009 test. The contact angle of a water droplet of 5 μL volume was measured with respect to the irradiation time using an optical tensiometer.

Results and Discussion

The synthesized materials consist of anatase phase of TiO_2 and tetragonal phase of BiOI. The structural and electronic properties are presented in Table 1. The photocatalyst that exhibited the best performance in MO degradation under simulated sunlight irradiation was $BiOI/TiO_2$ 1:9 with a rate constant of 0.0397 min^{-1}. SEM images reveal that the materials consist of TiO_2 nanoparticle clusters surrounded by BiOI nanosheets. High resolution transmission electron microscopy analysis on sample $BiOI_{(0.1)}/TiO_{2(0.9)}$ revealed the presence of heterojunctions between the (1 1 0) planes of BiOI and the (2 0 0) planes of TiO_2. The Nyquist electrochemical impedance spectroscopy (EIS) plot shows that the semicircular arc radii of sample $BiOI_{(0.1)}/TiO_{2(0.9)}$ are smaller than those of pure BiOI and TiO_2 materials. This suggests that the $BiOI/TiO_2$ heterojunction has the minimum resistance to charge transfer at the interface and surface, which facilitates faster charge transfer. EPR experiments shows that glass surfaces with immobilized nanoparticles of TiO_2, BiOI, and $BiOI_{(0.1)}/TiO2_{(0.9)}$ heterostructures can generate •OH radicals.

Fig. 1. Glass slides with immobilized photocatalysts. (A) TiO_2, (B) $BiOI_{(0.1)}/TiO_{2(0.9)}$ and (C) BiOI.

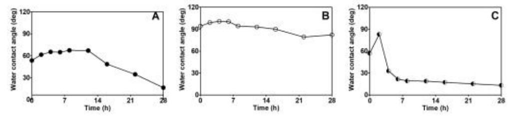

Figure 2. Self-cleaning properties of glass with immobilized photocatalysts determined by the variation of water contact angle as a function of irradiation time with simulated solar light. (A) TiO_2, (B) BiOI and (C) $BiOI_{(0.1)}/TiO_{2(0.9)}$.

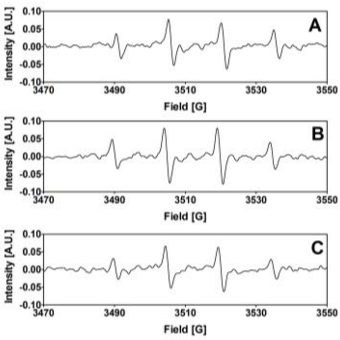

Figure 3. EPR spectra obtained after 15 min of simulated sunlight irradiation on glass slides with immobilized photocatalysts. (A) TiO_2, (B) BiOI and (C) $BiOI_{(0.1)}/TiO_{2(0.9)}$.

Table 1. Structural and electronic properties of the synthesized semiconductor photocatalysts.

Ptotocatalyst	BET surface area (m^2 g^{-1})	Pore size (nm)	Pore volume (cm^3 g^{-1})	Bandgap[a] (eV)
$BiOI_{(0.1)}/TiO_{2(0.9)}$	69	8.1	0.14	2.01
$BiOI_{(0.2)}/TiO_{2(0.8)}$	63	7.9	0.12	1.97
$BiOI_{(0.3)}/TiO_{2(0.7)}$	47	7.2	0.08	1.97
$BiOI_{(0.4)}/TiO_{2(0.6)}$	32	8.0	0.07	1.93
$BiOI_{(0.5)}/TiO_{2(0.5)}$	20	8.5	0.04	1.91
$BiOI_{(0.6)}/TiO_{2(0.4)}$	22	7.6	0.04	1.94
$BiOI_{(0.7)}/TiO_{2(0.3)}$	17	7.4	0.03	1.94
$BiOI_{(0.8)}/TiO_{2(0.2)}$	15	7.4	0.03	1.98
$BiOI_{(0.9)}/TiO_{2(0.1)}$	10	5.5	0.01	1.92

[a] Calculated from diffuse reflectance UV–Vis spectra using the Kubelka–Munk function.

Conclusions

Immobilization of $BiOI/TiO_2$ heterostructure on a glass surface was achieved. The glass surface with immobilized $BiOI_{(0.1)}/TiO_{2(0.9)}$ heterojunction nanoparticles showed better self-cleaning properties than the glass surface with BiOI or TiO_2 nanoparticles under simulated solar irradiation. This represents important progress in the development of self-cleaning surfaces with potential applications.

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