Incorporation of nio into sio$_2$, tio$_2$, al$_2$o$_3$, and na$_{4.2}$ca$_{2.8}$ (si$_6$o$_{18}$) matrices: Medium effect on the optical properties and catalytic degradation of methylene blue

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Abstract
The medium effect of the optical and catalytic degradation of methylene blue was studied in the NiO/SiO$_2$, NiO/TiO$_2$, NiO/Al$_2$O$_3$, and NiO/Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$) composites, which were prepared by a solid-state method. The new composites were characterized by XRD (X-ray diffraction of powder), SEM/EDS, TEM, and HR-TEM. The size of the NiO nanoparticles obtained from the PSP-4-PVP (polyvinylpyrrolidone) precursors inside the different matrices follow the order of SiO$_2$ > TiO$_2$ > Al$_2$O$_3$. However, NiO nanoparticles obtained from the chitosan precursor does not present an effect on the particle size. It was found that the medium effect of the matrices (SiO$_2$, TiO$_2$, Al$_2$O$_3$, and Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$)) on the photocatalytic methylene blue degradation, can be described as a specific interaction of the NiO material acting as a semiconductor with the M$_x$O$_y$ materials through a possible p-n junction. The highest catalytic activity was found for the TiO$_2$ and glass composites where a favorable p-n junction was formed. The isolating character of Al$_2$O$_3$ and SiO$_2$ and their non-semiconductor behavior preclude this interaction to form a p-n junction, and thus a lower catalytic activity. NiO/SiO$_2$ and NiO/Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$) showed a similar photocatalytic behavior. On the other hand, the effect of the matrix on the optical properties for the NiO/SiO$_2$, NiO/TiO$_2$, NiO/Al$_2$O$_3$, and NiO/Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$) composites can be described by the different dielectric constants of the SiO$_2$, TiO$_2$, Al$_2$O$_3$, Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$) matrices. The maxima absorption of the composites ($\lambda_{\text{max}}$) exhibit a direct relationship with the dielectric constants, while their semiconductor bandgap ($E_g$) present an inverse relationship with the dielectric constants. A direct relationship between $\lambda_{\text{max}}$ and $E_g$ was found from these correlations. The effect of the polymer precursor on the particle size can explain some deviations from this relationship, as the correlation between the particle size and absorption is well known. Finally, the NiO/Na$_{4.2}$Ca$_{2.8}$ (Si$_6$O$_{18}$) composite was reported in this work for the first time.

Author keywords
Chitosan
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