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Immobilization of Bromocresol Purple in Inorganic-Organic Sol-Gel Thin Film with Presence of anionic and non-ionic surfactants

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Abstract

Sol-gel materials known as organically modified silicates (ORMOSILs) offer interesting features such as chemical and mechanical stability. In this paper VTES (vinyltriethoxysilane) and TEOS (tetraalkoxysilane) are mixed in 3:1 ratio. Sol-gel solution was prepared by hydrolysis process of precursors by using ethanol as solvent. After a while a pH-sensitive indicator bromocresol purple (BCP) and surfactant were incorporate into the sol-gel mixture. The percentage of sodium dodecyl sulfate (SDS) and polyethylene glycol (PEG) which act as surfactant were varied to observe the effect of improving host material's nanostructure as well as the interaction between BCP and sol-gel matrices. The absorption peak of the BCP dye changed significantly in the presence of surfactant compared to pure VTES: TEOS mixture (control) in the range of 400 to 450nm. The presence of BCP dye in the sol-gel mixture can be determined via FTIR spectrum with a =C–H stretch in aromatics observed at 3100-3000 cm^{-1} which represented the aromatic of the BCP structure. The addition of BCP and surfactant had influenced the FTIR spectra of VTES: TEOS sol-gel materials. Addition of an anionic surfactant to the sol-gel mixtures was found to increase the BCP dye and the sol-gel matrices interaction, thus reducing the dye's tendency to leach. This work shows that sol-gel derived matrices yield dyes with sufficient rigid environment and addition of the surfactant helps to improve the interaction of filler matrices. The anionic SDS shows better leaching resistant compared to non-ionic PEG surfactant. Results of this study offer an attractive possibility to optimize the doped sol gel matrices to be used as sensing material in aqueous condition.

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1. Introduction

Over the decades, the response and mechanism of numerous dyes in different matrices of polymers and sol-gels have been investigated[1]. Sol-gels have gained widespread interests for applications in optical sensing. However, a type of sol-gel materials known as Organically Modified Silicates (ORMOSILs) offer interesting features, such as chemical and mechanical stability[2]. The term "sol-gel" refers to a chemical process where metallic or semimetallic alkoxide precursors or their derivatives form composites at moderate temperatures through a chemical reaction. It is reported that the combination of organic vinyltriethoxysilane (VTES) and inorganic tetraethoxysilane (TEOS) can be used to make protective, hard and crack-free coating on substrates[3, 4]. Organic part of the hybrid materials can improve adhesion between coating and polymer substrate whilst the inorganic part can increase the hardness of the coating and remains unaltered during sol-gel process, acting as network modifiers that terminate the silica network. In ORMOSILs, the interconnection of organic and inorganic moieties in the matrices results in microstructure changes, improvement of density, flexibility and optical properties[5]. Typical processes for preparing ORMOSILs are cohydrolysis and co-condensation from a mixture of tetralkoxysilane (TEOS) and an organic group of the organotrialkoxysilane such as of vinyltriethoxysilane (VTES). The nonreactive organic groups do not undergo hydrolysis or condensation, but remain unaltered during the sol–gel process and act as a network modifier that terminates the silicate networks by react with the remaining active site after the hydrolysis or condensation process. In addition to chemical and mechanical properties of the ORMOSILs material, other important parameter is their optical properties for sensor application such as excellent sensitivity, short response time and low limit of detection when doped with a colorimetric or fluorimetric indicator[4].

Wide range of organic dyes are suitable due to several factors, namely high surface area of the host matrix, porosity of the material formed and low temperature of the sol-gel method. In recent years, great attention has been put in the encapsulation of sensitive dyes into porous sol-gel materials[6,7]. The ability of bromocresol purple to detect ammonia in aqueous solution makes it as one of the materials with high potential to be used as sensing material in ammonium detection and as for that reason Bromocresol Purple is being chosen for this study. However, BCP dye could potentially leach out from the host matrix which could undermine its stability[1]. Therefore, a surfactant was introduced to improve the dye-sol gel matrix interaction. Formation of mesostructures of silica matrix with high silica porosity is achievable by using surfactants and it was found that the resulting mesostructures could efficiently host sensing molecules. One notable example could be found in the work of Avnir and co-workers[8] who reported that chemical and spectral properties of co-doped pH indicators were affected by immobilization of several surfactants in sol–gel matrices.

The main objective of this study is to observe the effect of surfactant in reducing the rate of leaching of the dye as well as investigating its effect on physical properties of sol gel film. Bromocresol Purple (BCP), an organic dye, was incorporated into VTES and TEOS precursors with different surfactant ratios of SDS and PEG. The sol-gel precursor mixtures were then drop-casted on slide glasses to form thin films and subsequently undergone heat treatment. BCP doped sol-gel matrices absorption spectral and physical properties of the matrices were analyzed. Finally sol-gel film's leaching behavior was studied.

Nomenclature

VTES	Vinyltriethoxysilane
TEOS	Tetralkoxysilane
BCP	Bromocresol purple
PEG	Polyethylene glycol
SDS	Sodium dodecyl sulfate