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Ag nanoparticle-doped SiO_2/TiO_2 hybrid optical sensitive thin film for optical element applications

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ABSTRACT

The optical sensitive thin film by Ag nanoparticles doped SiO_2/TiO_2 hybrid was successfully deposited via sol-gel spin coating technique. Photo-induced polymerization of photosensitive Ag-doped SiO_2/TiO_2 hybrid initiated by irgacure 784 photoinitiator was illustrated under visible region by He—Cd laser 442 nm. Silane coupling was used as a starting precursor to providing cross-linking in the photochemical reaction process. The structural properties and existing elements of photosensitive films were characterized by XRD, TEM and EDX. Meanwhile, surface morphology of the photosensitive hybrid films was monitored by FE-SEM. Moreover, the optical absorption of the photosensitive hybrid films was analyzed by UV–Vis spectroscopy. These results indicated that the compatibility of photosensitive hybrid material was formed. The SiO_2/TiO_2 photosensitive hybrid films with uniformly distributed Ag ions and intensive coloration characteristic for surface plasmon resonance phenomena relating to the enhancement of optical absorption in visible region. As-prepared photosensitive hybrid films with enhanced optical properties can be proposed for optical elements.

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1. Introduction

Recently, organic-inorganic hybrid materials have been attracted considerable attention due to distinguished properties such as thermal stability, exceptional optical properties in an inorganic material and elasticity, low temperature in the formation process of an organic material [1]. Owing to unique chemical and physical properties by controlling the ratio between organic and inorganic materials, hybrid materials have been extensively utilized in a wide range of optical applications. Typically, photosensitive materials mainly contain functional polymer, solvent, photo-sensitizer and additive. The photochemical reaction process of photosensitive films is occurred by cross-linking function initiated by photo sensitized material on film surface [2]. Organic material based on silicate Methacryloxypropyltrimethoxysilane (MAPTMS) silane coupling agent was typically considered for practical usage. MAPTMS silane coupling is a polymer in bi-functional molecule structure which contains an organic functional group and methoxy functional group, these chemical reactions can be summarized as follows [3]:

$$R-Si(OCH_3)_3 + 3H_2O \rightarrow R-Si(OH)_3 + 3CH_3OH \quad (1)$$

$$2R-Si(OH)_3 \leftrightarrow R-Si(OH)_2-O-Si(OH)_2-R + H_2O \quad (2)$$

$$R-Si(OH)_2-O-Si(OH)_2-R + CH_3OH \leftrightarrow R-Si-(OH)_2-O-CH_3 + R-Si(OH)_2-OH \quad (3)$$

Titanium isopropoxide is an inorganic compound that coupling with MAPTMS to improve the optical properties in photosensitive hybrid materials. The possible chemical reactions of both materials can be summarized by following expressions;

$$R-Si(OH)_2-OH + OH-Ti \rightarrow R-Si(OH)_2-O-Ti + H_2O \quad (4)$$

$$R-Si(CH)_2-OCH_3 + OH-Ti \rightarrow R-Si(OCH_2)-O-Ti + CH_3OH \quad (5)$$

Essentially, the photosensitive hybrid films has been prepared via sol-gel process. The sol-gel technique is an attractive method because of its simplicity, safety, cost effectiveness, ease of doping, homogeneity, low process temperature, reproducibility and large production capability with uniformity in large area coatings [4]. In addition, the enhancement of optical absorption in well-suited operating wavelength of

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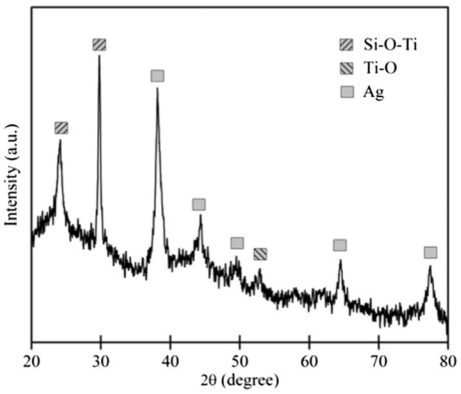

Fig. 1. XRD pattern of as-synthesized Ag-doped SiO_2/TiO_2 powder.

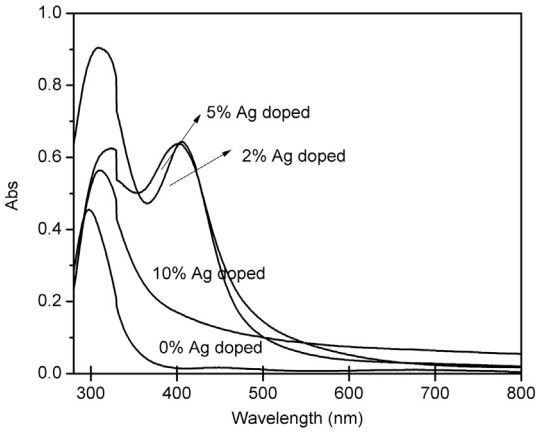

Fig. 2. Optical absorption of photosensitive Ag-doped SiO_2/TiO_2 hybrid films with various Ag content of 0%, 2% and 10%.

photosensitive material can be achieved by the incorporation of metal nanostructures. Au, Pt, Pd and Ag nanoparticles are among the most extensively used additives for adjusting the absorptivity of photosensitive hybrid materials for specific wavelength due to their strong optical absorptivity related to surface plasmon resonance phenomena (SPR) [5]. It is recognized that the optical absorption in the visible region of metal nanoparticles on the surface of photosensitive hybrid films strongly depends on its size and shape. The incident photon frequency is resonant with the collective oscillation of the conduction and free electrons on the surface metal particles embedded in the film corresponding to the increase of absorption intensity in the film due to SPR effect [6–7].

The photo patterning of photosensitive hybrid materials can be fabricated by several processes, for example, interference lithography [8], electron beam lithography [9] and photo lithography [10]. Among these processes, the photo mask lithography is an attractive process for practical usage because of low-cost mask usage, reduction of process complication and simply direct transfer patterns [11]. However, few research works have been emphasized on the utilization of Ag-doped SiO_2/TiO_2 hybrid optical sensitive thin films for the fabrication of optical elements.

In this work, the synthesis of photosensitive Ag-doped SiO_2/TiO_2 hybrid films was deposited by photo mask lithography technique assisted with sol-gel process. The structural and mechanical properties of photosensitive hybrid film with Ag loading were investigated by XRD, SEM and TEM. The optical properties of the photosensitive hybrid film were enhanced in the visible region by the incorporation of Ag nanoparticles in the hybrid films.

2. Materials and methods

2.1. Sample preparation

Methacryloxyproprytrimethoxysilane or (MAPTMS) silane coupling agent and titanium isopropoxide (TiP) were selected as starting precursors for organic and inorganic materials. Silver nitrate ($AgNO_3$) was

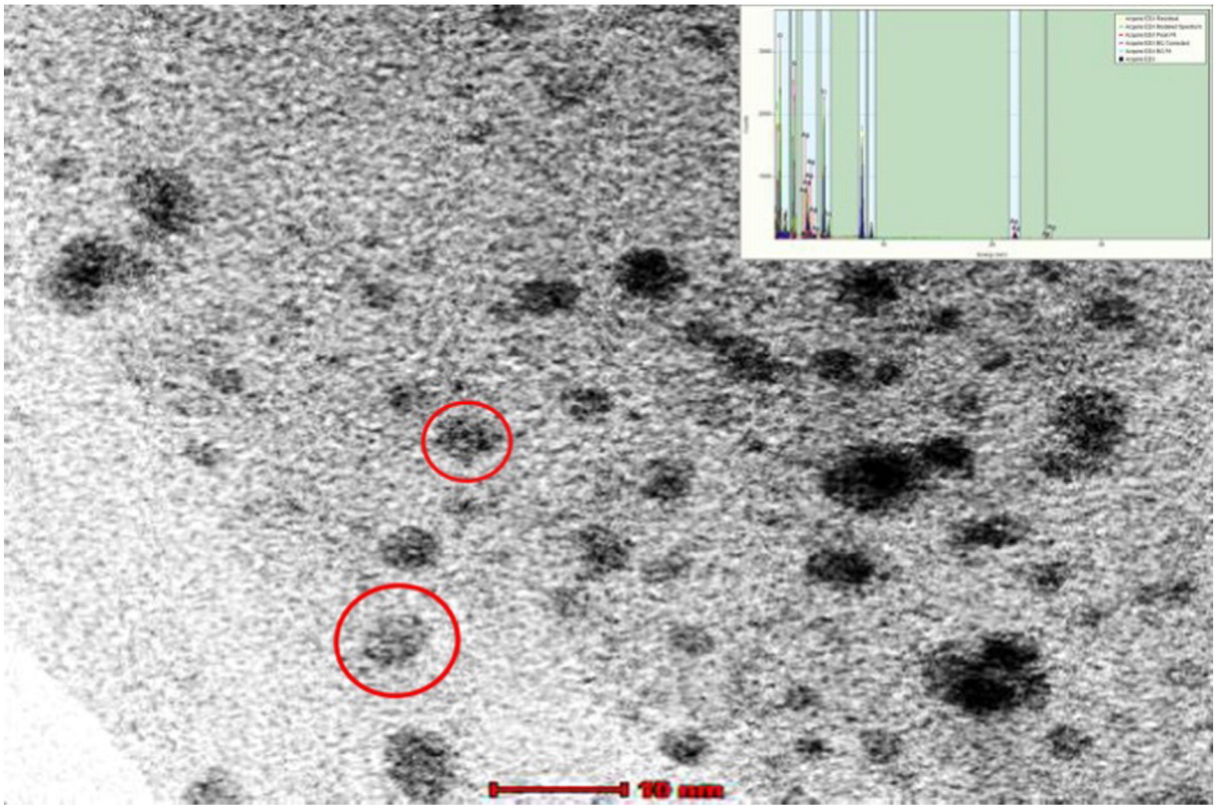

Fig. 3. TEM image of photosensitive Ag-doped SiO_2/TiO_2 hybrid film and EDX analysis (inset).

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