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Tailoring of optical and wetting properties of sputter deposited silica thin films by glancing angle deposition

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ABSTRACT

Synthesis of silica thin films by RF magnetron sputtering using glancing angle deposition (GLAD) has been reported here. Films deposited at four different oblique angles (45°, 60°, 75°, 85°) show transition from featureless to columnar structure. The silica films have been characterized for their optical and wetting properties and they exhibit potential for use in applications such as antireflection coatings, self-cleaning coatings, antifogging coatings, etc. The reflectance decreases to a minimum of 3.15% whereas transmittance increases to a maximum of 93.43% when the films have been deposited at an oblique angle of 85°. Water contact angle measurements were done to show the hydrophilic nature of the films. The hydrophilicity of the films gets enhanced and a minimum water contact angle of 20° is achieved with increase in the oblique angle of deposition owing to the increase in the values of roughness.

1. Introduction

One-dimensional nanostructured films like nanorods or nanocolumns have unique properties like anisotropy and large aspect ratio (length/diameter) making them nanoscale building blocks in nanoelectronics, photonics, etc. and have stimulated great research interest [1]. Oblique angle deposition (OAD) is a very useful technique which has enabled researchers to develop unique nanostructures with tailored morphology [2–7]. Recently it has been shown that, by combining oblique angle deposition (OAD) with active control of the substrate rotation relative to the vapor source, a technique referred to as glancing angle deposition (GLAD), one can produce nano-sized columnar films with controlled porosity and shapes [8–13].

Glancing angle deposition (GLAD) is an advanced physical vapor deposition technique which is based on impingement of the incident flux onto the substrate from extremely oblique flux incidence angles $\alpha > 80^\circ$ (measured relative to the substrate normal) as shown in Fig. 1(a). During the initial growth of the films, the impinging atoms form isolated columns which cast shadow for the arriving vapor flux following line of sight deposition (as shown in Fig. 1(b)). Hence the taller islands will receive more impinging atoms as compared to the smaller ones. This allows only the taller islands to grow and leads to the formation of a columnar structure. The competition between limited adatom surface mobility and shadowing effect plays a key role in the evolution of the columnar structure of the thin film. One dimensional nanostructures fabricated by OAD and GLAD find application as antireflection coating [14,15], omnidirectional reflectors [16], superhydrophobic coatings [17], solar cells [18], sensors [19], photonic band-gap crystals [20], etc.

Although, e-beam evaporation is more extensively used for this purpose due to its high directionality, sputtering is also being used for developing nanostructures by GLAD. Sputtering is a physical vapor deposition (PVD) method which is widely used for depositing thin films applicable for a wide range of applications [21–23]. Sputter deposited films are more uniform and homogenous in nature and exhibit better adhesion with the substrate as compared to the evaporated films. These advantages provide sputtering an edge over evaporation in the deposition of high quality films. The sputtering process also provides better step coverage as compared to evaporation. Silica thin films have been extensively grown by GLAD technique using evaporation but much work has not yet been done using sputtering. Till date, there is only one report of sputter deposition of silica using GLAD [24]. In this work, GLAD has been employed to grow silica thin films with varied morphology using sputtering. They have been grown in different GLAD conditions and have been characterized to study their optical and wetting properties.

2. Experimental

Silica films were deposited on Si(1 0 0) and glass substrates in a RF magnetron sputtering system (AJA International). 99.9% pure silicon disc (2 in. diameter, 3 mm thick) was used as the sputter target along with oxygen and argon as the reactive and sputtering gasses, respectively. Inclined stainless steel substrate holders were fabricated for holding the substrates at oblique angles. The films were deposited by GLAD mechanism at oblique angles (angle between the substrate normal and the incident flux) of 45°, 60°, 75° and 85° and a rotation of 30 rpm was applied to the substrates. The level of base pressure achieved before deposition was 8×10^{-4} Pa (6×10^{-6} Torr). Deposition was done at room temperature (no heating) at a RF power of 150 W and a working pressure of 0.27 Pa (2 mTorr). The O_2 and Ar flow rates used were 5 and 10 sccm, respectively. The substrates were kept at a distance of 15 cm from the target.

A field emission scanning electron microscope (FESEM) (Supra 55, Carl-Zeiss) was used for imaging of the morphology and cross section of the silica films. The reflectance and transmittance

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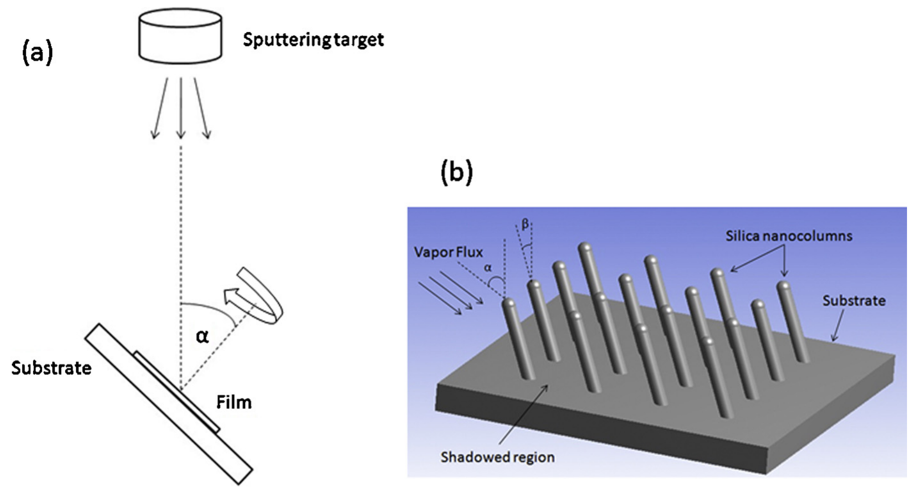

Fig. 1. (a) Schematic of GLAD setup and (b) mechanism of GLAD.

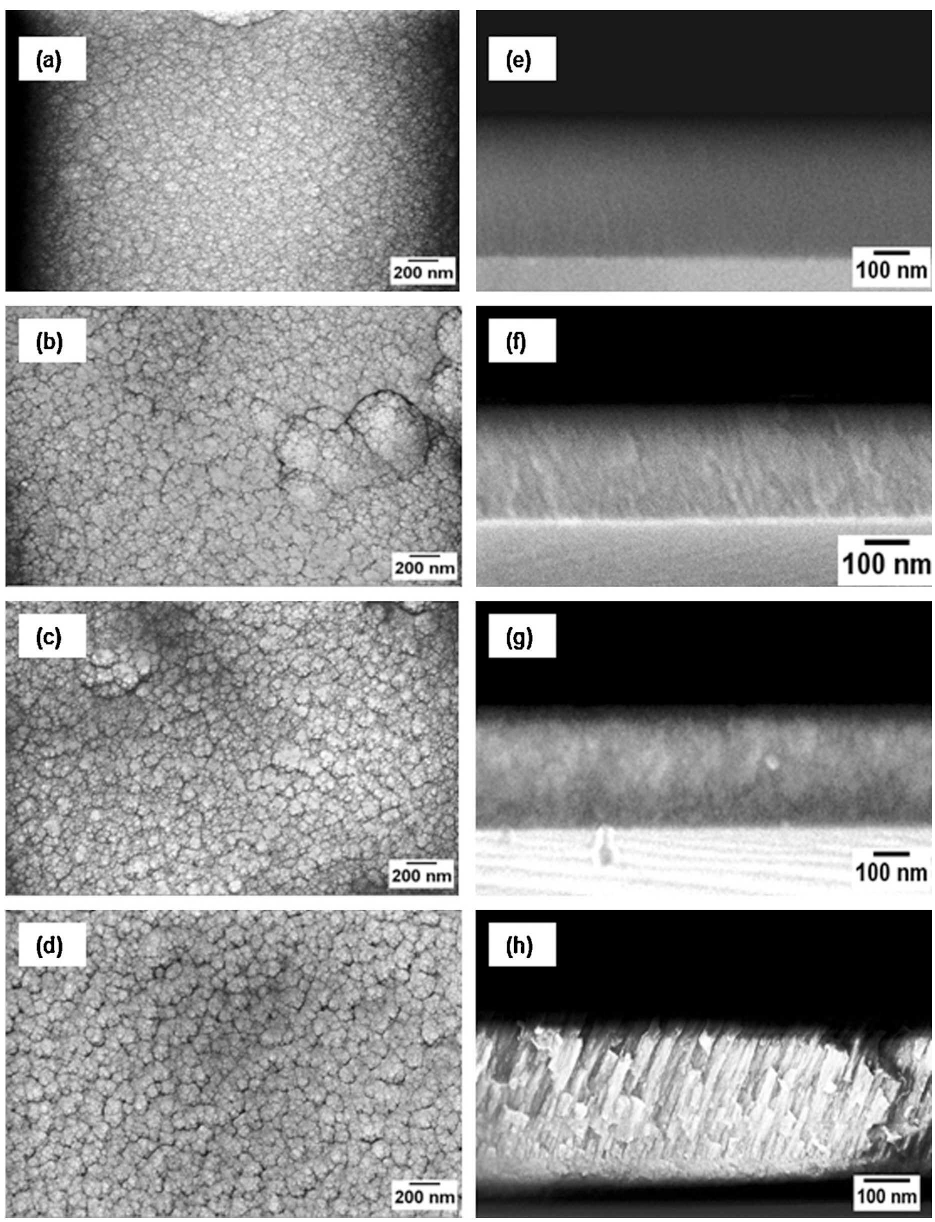

Fig. 2. Morphology of the films deposited at angles of (a) 45°, (b) 60°, (c) 75° and (d) 85°, and cross-section of the films deposited at angles of (e) 45°, (f) 60°, (g) 75° and (h) 85°.