

## THE INFLUENCE OF DIFFERENT WORKING GASES ON THE QUALITIES OF SiO<sub>2</sub> NANOSTRUCTURE

D. COADA <sup>a</sup>, M. NAGL <sup>b</sup>, Th. LECHLEITNER <sup>b</sup>, H. PULKER <sup>b</sup>

<sup>a</sup>Department of Physics, The Ovidius University of Constanța, Constanța, 8700, Romania  
dcoada@univ-ovidius.ro

<sup>b</sup>Thin Film Technology Group of the Institute of Ion Physics, University of Innsbruck,  
Austria

*Abstract* The aim of this investigation is to determine the influence of Ar, Xe and Kr, as working gases on deposition rate and optical SiO<sub>2</sub>-nanostructure properties. We observed a maximum deposition rate for Argon and a minimum deposition rate for Xenon. A variation of working gases shows no negative influence on the optical properties of SiO<sub>2</sub> films. Refractive index remains high for all different working gases.

*Keywords:* SiO<sub>2</sub> – films, RF – sputtering, thin film deposition.

### 1. INTRODUCTION

Sputtering is considered to be the best technique for conventional metal deposition. Good step coverage over fine lines and difficult geometries is possible with careful control of the sputtering conditions. Sputtering can also provide control of film thickness uniformity. The sputtering process is quantified in terms of the sputtering yield, defined as the number of target atoms ejected per incident particle. The yield depends on the target species and the nature, energy and angle of incidence of the bombarding species.

Sputter-ejected species have kinetic energies considerably greater than thermal. In addition, depending on the experimental configuration, the substrate and growing film may also be subjected to low-energy particle bombardment from accelerated host lattice species, dopants, inert-gas ions and energetic particles backscattered from the target [1].

Cathode considerations are important because particles generated during deposition are often a function of the material being deposited; aluminum films are the easiest to control and silica and titanium - tungsten the most difficult.

Mechanical design involves considerations such as providing shielding materials that is not likely to flake and matching the thermal coefficient of all exposed materials in the process chamber to the films that are difficult to deposit (i. e. SiO<sub>2</sub> and Ti - W) [2]. In addition, to obtain the necessary particle levels for today's processing needs, most vendors of sputtering systems have seriously reconsidered the traditional wafer motion techniques in vacuum.

Sputtering is a statistical process, which occurs as a result of a momentum - exchange collision cascade process initiated near the target surface by an incident energetic projectile. In an RF glow discharge, there are many inelastic collisions of ions in the sheath. For this reason, when the ions impact the substrate surface their energies vary from 0 to V<sub>s</sub>, when V<sub>s</sub> is the substrate potential with respect to the glow [3].

The sputtering rate, which is the rate at which material is removed from target, is given by

$$R = \frac{G \cdot S(V) \cdot P}{V(1 + z)} \quad (1)$$

where  $S(V)$  is the sputtering yield of the target material at a voltage  $V$ ,  $P$  is the total measured power,  $z$  is the secondary electron emission coefficient, and  $G$  is a geometric factor [4]. The sputtering yield  $S(V)$  increases with the target voltage and, at a constant total pressure, the sputtering rate is proportional to the power density.

Sputtering deposition rate is directly proportional to source power within the tested range from 1 to 2kW and thus easy to predict [3].

## 2. EXPERIMENTAL

Thin film deposition has been carried out with an Edwards AUTO 306 plant equipped with a RF-Magnetron-Sputter device. The substrates were not heated nor rotated over the target.

The main adjustable process parameters are input power, total gas pressure and target-substrate distance. A thin film quartz monitoring system controlled film thickness during deposition. Total gas pressure was  $5,0 \cdot 10^{-3}$  mbar at a target-substrate distance of 60 mm.

Optical characterization and determination of refractive index and film thickness of SiO<sub>2</sub> films on B270-Glass substrates has been performed with a spectral photometer Perkin Elmer Lambda 19 using transmission- and reflection-spectra and calculations based on the work of Swanepoel [5].

## 3. RESULTS AND DISCUSSION

It is necessary that, for different applications, the sputtering parameters for SiO<sub>2</sub> film deposition are carefully selected to achieve the desired film properties. It has been observed that the deposition rate is a function of the sputtering rate, total pressure and the target - to - substrate distance. The result of the variation of these parameters was examined in another work at our institute [6].

The sputtering rate is a function of target material mass, sputter yield, kind of working gas and ion current density [7].

The sputtering yield tends to be greatest when the mass of the bombarding particle is of the same order of magnitude or larger than that of the target atoms. The use of inert - gas ions avoids chemical reactions at the target and substrate. Argon is often used because of its mass compatibility with materials of engineering interest and its low cost.

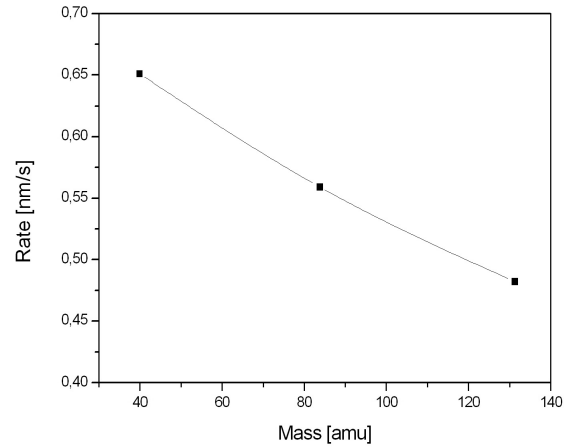


Fig. 1 - Variation of deposition rate as a function of working gas mass (Ar, Kr and Xe).

The characteristic of sputtered coatings is usually good adherence to the substrate with a density close to bulk material. The refractive index of the film is closely related to film density. Therefore refractive index is a representative characteristic for the quality of a thin film.

A variation of working gases shows no negative influence on the optical properties of  $\text{SiO}_2$  films. The obtained refractive indices are in the range of the well-documented films sputtered with Argon of increasing kinetic energy as working gas. An increase of mass of the working gas could have a positive influence on the refractive index of sputtered  $\text{SiO}_2$  films, due to a higher densification of the growing film by high energetic bombarding particles. But this needs to be proved by additional measurements.

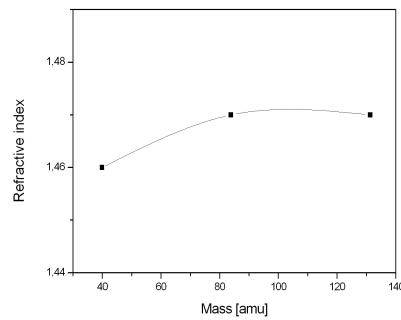


Fig. 2 - Refractive index of sputtered  $\text{SiO}_2$  films with different working gases (Ar, Kr, Xe).

#### 4. CONCLUSION

The quality of deposited thin films depends strongly on the sputtering conditions. It is therefore necessary to select the magnetron sputtering parameters carefully to achieve the desired film properties. The aim of this investigation was to determine the influence of different working gases on deposition rate, substrate temperature and optical film properties.

Molecular masses of the involved materials induce a maximum deposition rate for Argon and a minimum deposition rate for Xenon, confirmed by the experiment.

Refractive index remains high for all different working gases.

Argon is commonly used as working gas; it is reliable and not too expensive and shows the highest deposition rate for most materials.

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