Deposition and characterisation of ultra low k dielectric films for 45 nm node Cu interconnect systems of CMOS logic ICs

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1 Introduction

Methylsilsesquioxane (MSQ) is a promising candidate for ULK dielectric layers since it has a significantly lower density than silicon dioxide. Due to the methyl groups bonded to the Si-O-network of the MSQ it is much more hydrophobic and requires no additional hydrophobisation treatment like silica aerogel. At Center for Microtechnologies investigation of the MSQ-based and porogen containing spin on material LK2200™ provided by Rohm&Haas has been performed over the last year. The material is dedicated for dielectric layers in advanced 45nm Cu interconnect systems of CMOS logic ICs. The porogen consists in acrylic nanoparticles introduced in order to control the porosity of the layers. After porogen removal by annealing mesoporous films with k-value of about 2.2 were obtained. Integration, especially patterning and CMP can be also carried out on porogen containing films. This “post-integration-burnout” or “post-CMP-burnout” approach is known as “SOLID-FIRST-PROCESS”. In that case films have only intrinsic porosity of the MSQ skeleton and withstand much better chemical attack as well as mechanical load.

The deposition process for LK2200™ was adapted to Suss Microtech spin on track provided for deposition of low k materials. The obtained dielectric films were characterized in order to determine their starting properties before integration and to study their modification during integration.

2 Electrical properties

A simple stacked parallel plate capacitor approach was used to quantify dielectric film properties by capacitance measurements with a mercury probe. Dielectric constants were measured at a frequency of 100 kHz. Leakage current density was determined at an electrical field of 1 MV/cm. For determination of field break down voltage 17 points were generally tested. The cumulative frequency is shown in Fig. 1. Mean values are given in
Tab. ***1***.

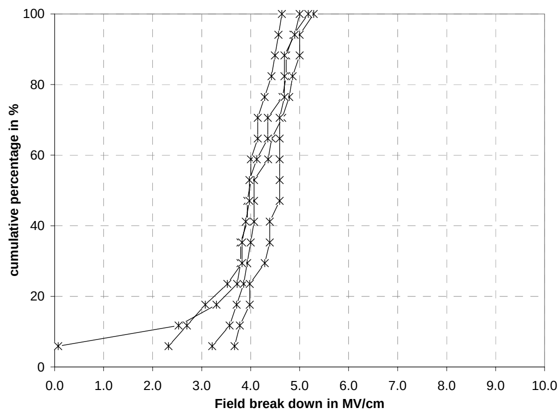

Fig. 1: Cumulative frequency for FBD of LK2200

Tab. 1: Electrical features of LK2200 ™

	mean k-value	**mean $I_{leakage}$ in A/cm²**	**mean FBD in MV/cm**
LK2200 (ver6)	2.28±0.05 (3σ=2.1%)	$1.8*10^{-10}$	4.2

3 Porosity and Mechanical properties

Youngs modulus is one of the most critical features of the material. All relevant mechanical properties like hardness, strength and crack resistance are related to the elastic constant. On the other hand Youngs modulus depends strongly on porosity. Pore size distribution and porosity was determined by ellipsometric porosimetry in co-operation with SOPRA France (see Fig. 2).

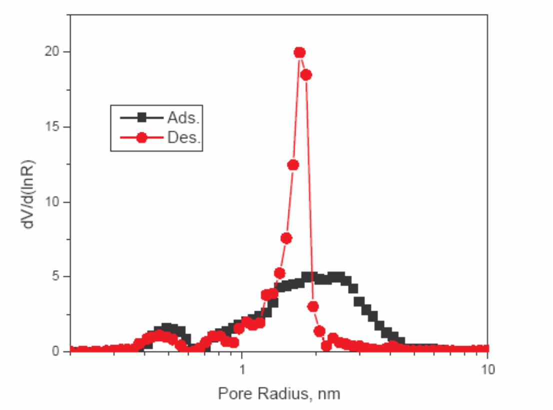

Fig. 2 Pore size distribution for LK2200 ™ obtained from ellipsometric porosimetry (SOPRA)

An estimation of the porosity π can deduced from effective refractive index of the dielectric film n_r using LORENTZ-LORENTZ-Effective Medium Approximation, if the refractive index of the skeleton n_s is known:

$$\pi = 1 - \left[\frac{n_r^2 - 1}{n_r^2 + 2}\right] / \left[\frac{n_s^2 - 1}{n_s^2 + 2}\right]$$

Both values for porosity, from ellipsometric porosimetry (EP) and from refractive index (SE), are compared in Tab. 2.

Tab. 2 Porosity and mean pore radius of LK2200 ™

	porosity (n_{msq}~1.45)		mean pore radius
	EP	SE	
LK2200	31 %	30 %	2.1 nm

Measurement of the elastic constant needs careful investigation of the limits of the selected method. Nanoindentation as an often applied method causes generally inelastic deformation of the material by indenter penetration. Additionally, substrate influence is significant for thin layers and for penetration depths of more than 10% of film thickness. At TU Chemnitz an advanced measurement procedure called “elastic measurement” was developed using a spherical indenter and very low indenter loads. It is assumed, that with this method a nearly elastic deformation state of the material is possible to realize without damage of the film. The obtained values correlate well with the elastic constants determined by laser-acoustic measurement. Dispersion of surface acoustic waves causes only very small deformation. Therefore the condition for pure elastic deformation state is achieved. The results for the Youngs moduli are summarized in Tab. 3.

Tab. 3: Youngs modulus of LK2200 ™

	Youngs Modulus	
	Nanoindentation	LSAW
LK2200	2.9 GPa ± 0.91 (spherical indenter) 4.0 GPa ± 0.43 (Berkovich indenter)	3.2 GPa ± 0.08

In order to evaluate internal stress and adhesion strength the dielectric film was deposited on several sublayers (SiO, SiN, SiC, SiCN) and were capped with several hardmask materials (HM2800, SiO, SiN, SiC, SiCN). All dielectric film stacks passed the adhesion tape test without failure. The internal stress of the dielectric film was found to be below 100MPa.

4 Outlooks

Since the LK2200™ films exhibit excellent electrical and mechanical properties these dielectric films has been dedicated for integration in Single DAMASCENE architecture for Cu/low k interconnect systems for the next research phase.

Acknowledgement

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