Organosilicate Glass Dielectrics for High Performance FPD Applications

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Abstract

Organosilicate Glass has quite a long history in the Semiconductor industry but has received very limited evaluation for Display industry applications. In this paper, we would like to introduce several kinds of Organosilicate Glasses for Display applications.

1. Introduction

Traditionally, organic-based materials have been used in most Display applications that require insulation, passivation or planarization. Organic-based materials provide several advantages such as ease in making photo-definable material with simple procedures and ease in reworking. But as the device performance becomes more critical, the properties of Organosilicate Glasses can contribute to improved display performance. These properties include high transmittance, low birefringence, high thermal stability, plasma resistance, electrical insulation, planarization, low out-gassing and ease of processing.

Three different Organosilicates are introduced in this paper. The first is Trimethylsilane, $(CH_3)_3SiH$ (Dow Corning (R) Z3MS CVD Precursor). Amorphous silicon oxycarbide (a-SiCO:H) film is deposited using standard PECVD reactors generally with Oxydant gas and Z3MS^{TM}. The second is Methylsilsesquioxane (MSQ, hereafter OSQ1). Figure 1 shows the general chemical structure of an Organosilsesquioxane. In case of OSQ1, the R-group is Methyl (CH_3-). The third is another Organosilsesquioxane that has multiple R-groups (hereafter OSQ2). Different R-groups provide different performance in adhesion, mechanical strength, heat and crack resistance etc. Therefore, by judicious selection of the R-groups, the resin can be designed for the application. As a-SiCO:H films are generated by CVD, they are conformal rather than planarizing, with step coverage better than CVD deposited SiO_2 or SiNx using SiH_4.

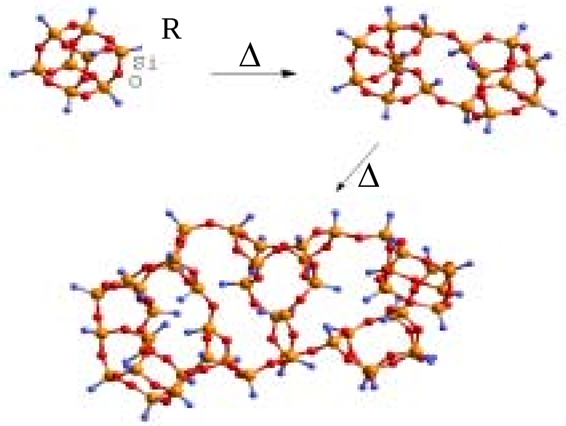


Figure 1. Chemical bonding structure of general Organosilsesquioxane during curing process

All three films provide better transmittance, lower outgassing and better heat and plasma resistance than comparable organic-based materials. The key summary of the Organosilicate films is listed in Table 1.

Table. 1 Key summary of the Organosilicate films

	a-SiCO:H	OSQ1	OSQ2
Deposition	PECVD	Spin / Spinless	Spin / Spinless
Chemistry Description	Amorphous Silicon oxycarbide	Methylsil-sesquioxane	Organosil-sesquioxane with multi R-groups

2.Insulation Applications

2.1 PECVD a-SiCO:H Film using Z3MS^{TM}

Because a-SiCO:H exhibits a low dielectric constant (~ 2.7) this film is suitable for the passivation layer of TFT-LCD and OLED backplane in order to increase the pixel aperture ratio. [1][2] In practice, existing CVD tools in the manufacturing facility can be utilized to deposit a-SiCO:H film. Demonstrated advantages include improved light output in TFT-LCD for high aperture application and reduced outgassing from a-SiCO:H to improve the lifetime of an OLED device. a-SiCO:H from Z3MS^{TM} had been compared with conventional SiNx Passivation in LCD panels, and we observed about 30% overall brightness enhancement(Table 2 [3]).

Recently, barrier technology has been developed using Trimethylsilane as a precursor to deposit a-SiC:H which provides excellent gas barrier performance.[4] Barrier applications for flexible substrate and OLED Thin Film Encapsulation have been targeted with this thin film technology.

Table 2. Comparison of display characteristics of a high aperture panel and of a standard 15" UXGA panel. [3]

	Low-K a-SiCO:H	Standard pixel (SiNx)
Brightness (9-point Avg)	210 cd/cm^2	160 cd/cm^2
Contrast Ratio	210 : 1	230 : 1
Panel Transmittance	8.47%	6.57%
Crosstalk(max.)	3.86%	3.98%
Passivation Layer	2.0µm	0.2µm

2.2 Organosilsesquioxane (OSQ)

OSQ1 and OSQ2 can be cured thermally at around 250°C~350°C or by UV irradiation if low-temperature or room temperature cure is required. TGA data of OSQ2 shows stable heat resistance up to about 400°C (Figure 2). High optical transparency is retained after the film is cured at 250°C ~ 410°C under nitrogen or air (Figure 3). This transparency and thermal stability are typical of silicon-based resins and generally more challenging for organic-based materials. Organosilsesquioxane resin passivation layers have been shown to provide more reliable TFT characteristics than an organic-based passivation layer. [5] An important consideration for passivation materials in the display backplane is the effect of the passivation material on the TFT—as a result of chemical damage or ionic impurities. These effects could provide unwanted current paths in the back channel region.

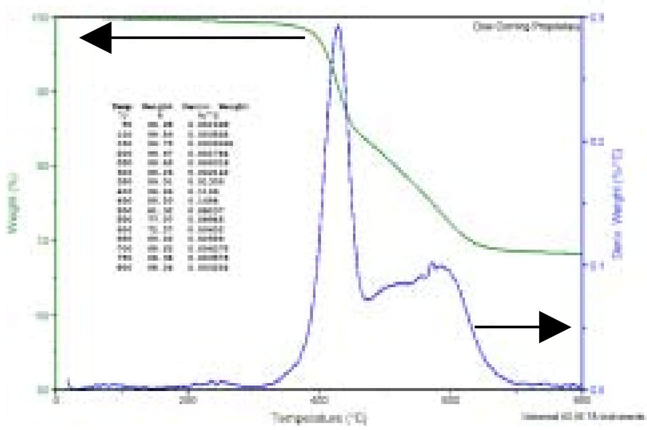


Figure 2. TGA data of OSQ2 in Inert Ambient

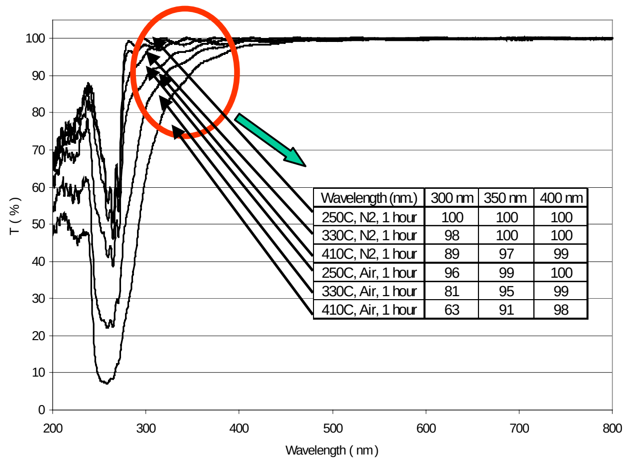
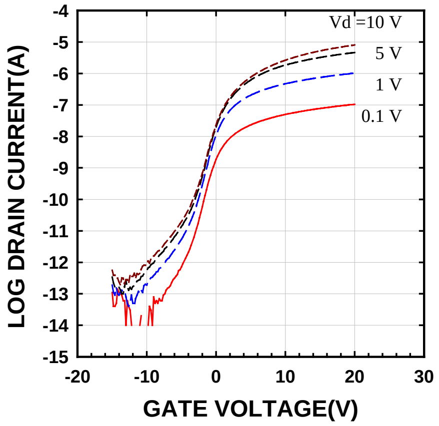


Figure 3. Optical transmittance of OSQ2 following a range of cure conditions

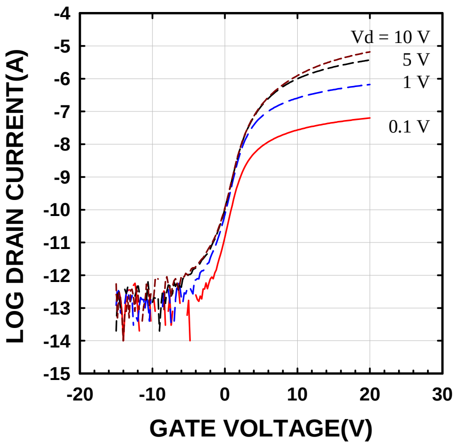
Figure 4(a) shows the transfer characteristics of an a-Si TFT passivated with commercially available acrylic resin material. Leakage current is evident in the off (negative gate voltage) region. By comparison, Figure 4 (b) shows the transfer characteristics of an a-Si:H TFT passivated with

OSQ1. Stable performance is measured in the off (negative gate voltage) region.

A photo-definable and solvent developable organosilsesquioxane resin has been developed; this is a negative tone material.



(a) Transfer characteristics of a-Si:H TFT passivated with commercial Acryl product



(b) Transfer characteristics of a-Si:H TFT passivated with OSQ1

Figure 4. Transfer Characteristics of a-Si:H TFT

An optical micrograph of a patterned and developed photo defined organosilsesquioxane is shown in Figure 5. The numbers in the figure denote the line widths; a three micron resolution is apparent.

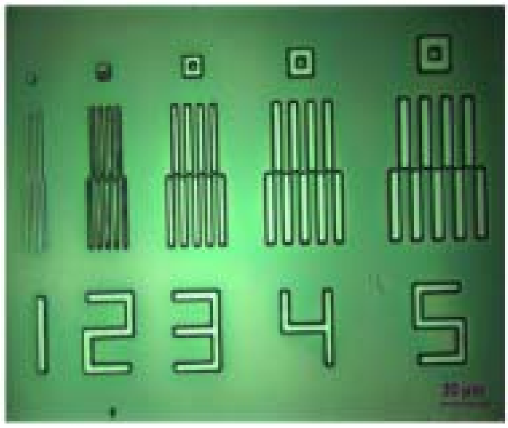


Figure 5. Top view optical micrograph of negative tone Photo defined OSQ

3. Applications which require Global Planarization

Organosilsesquioxane resins provide excellent global planarization capability. Figure 6 shows the cross-section SEM photographs of an organosilsesquioxane resin which was spin coated and cured over a CVD SiO_2 pattern using spin coating method. The silsesquioxane resin can be seen in the pattern gaps; a protective resin was used to overcoat the silsesquioxane to aid sectioning. Excellent global and local planarization are evident.

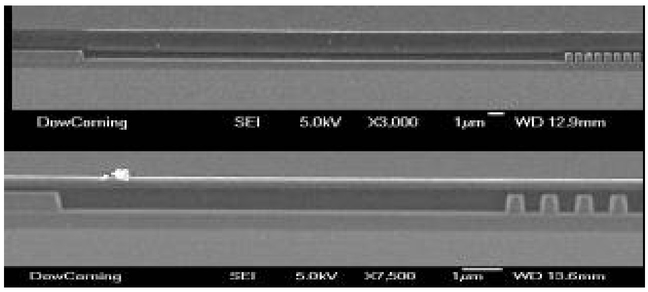


Figure 6. Optical cross-section SEM photographs of cured organosilsesquioxane

This excellent planarization performance has potential for display applications such as color filter overcoat, planarization of glass panel or flexible substrate and TFT passivation. Additionally, UV-curable organosilsesquioxane lends itself to low temperature or room temperature applications including processing on flexible or thermally sensitive substrates.

4. Light management Applications

Organosilsesquioxane resins exhibit similar or lower Refractive Index (R.I.) than glass panels. The R.I. can be tuned through selection of the appropriate “R” groups to suit the needs of light management applications. For example, the R.I. of OSQ2 is 1.54-1.55; the R.I. of Corning Eagle 2000™ display glass is 1.505-1.517 . Alternatively, the R.I. of OSQ1 is 1.40.

5. Summary

Several forms of organosilicate materials have been briefly reviewed in this paper with an eye towards high performance Display applications. PECVD delivered a-SiCO:H is offered as an alternative to SiNx for a-Si TFT passivation for high aperture. Organosilsesquioxane resins have been described and data presented which demonstrate high transparency, thermal stability, improved TFT performance, planarization and photo patterning. These materials are being examined as alternatives to conventional thin film materials in a range of Display applications where improved processing, performance or stability is required .

6. References

[1] Nakabu, S. et al., SID 99 DIEST, p.732 (1999)

[2] Shinjou, M. et al., AMLCD’96/IDW’96, p.201 (1996)

[3] Hong, W. S. et al., SID 03 DIGEST, p.1508 (2003)

[4] Weidner, W.K. et al., 48th SVC, To be published (2005)

[5] Choi, D. K. et al., IDW03, p.617 (2003)