Transparent Sol-Gel Hybrid Dielectric Material Coatings for Low k Passivation Layer

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Keywords: hybrid dielectric material, low k passivation, TFT, AMLCD

Abstract

Transparent sol-gel hybrid dielectric material (hybrimer) coating films were fabricated by spin coating and photo or thermal curing of sol-gel derived oligosiloxane resins. Hybrimer coating films are suitable as the passivation layer of TFT in AMLCD due to low dielectric constant, small loss tangent, low leakage current density, high transmittance and thermal stability.

1. Introduction

Silicon nitride (SiN_x) is generally used as the passivation layers of thin films transistors (TFT) in active matrix liquid crystal displays (AMLCD) due to their excellent electrical properties and uniform thickness over the topology of TFT. However, capacitive coupling caused by their high dielectric constant (k~7) can degrade TFT performance. Also, it is difficult to fabricate AMLCD with high resolution and brightness because of their low transmittance (<90%) at the visible region. Plasma enhanced chemical vapor deposition (PECVD) method for the deposition of SiN_x film has disadvantages of high costs and difficulties for surface planarization of large substrate. Therefore, soluble organic dielectric coating material with high insulation and transparency is required to replace the SiN_x passivation layer by PECVD. Recently, soluble siloxane-based low k dielectric coating materials with good insulating property and high transmittance (>90%) as the passivation layer of TFT has been reported. [1-3] In this study, we synthesized photo or thermally curable oligosiloxane resins by a sol-gel reaction of organo-silanes. Sol-gel hybrid dielectric material (hybrimer) coating films were fabricated by spin coating of photo or thermally curable oligosiloxane resins. We found that the fabricated coating films can be utilized as the passivation layer of TFT due to their electrical properties such as their low dielectric constant, small loss tangent, low leakage current density, high transmittance, thermal stability and good quality of coating film.

2. Experimental

Synthesis of photo or thermally curable oligosiloxane resins

Photo or thermally curable oligosiloxane resins for the fabrication of sol-gel hybrid dielectric materials (hybrimers) with low dielectric constant were synthesized by sol-gel reaction with conventional organo-alkoxysilanes. High condensation degree of photo or thermally curable oligosiloxane resins was achieved by the control of their compositions and reaction conditions. [4] The synthesized oligosiloxanes had methacrylate or epoxy groups as the functional groups for polymerization by UV or heat and perfluorochains to lower dielectric constant of hybrimers. The synthesized oligosiloxanes in the resin were well-dispersed due to steric effect by these functional groups.

Fabrication of sol-gel hybrid dielectric materials (hybrimers) with low dielectric constant

Hybrimer thin films for low k passivation layer in TFT were fabricated by spin coating with photo or thermally curable oligosiloxane resins. The photo curable oligosiloxane resin was photo-cured by UV lamp (Hg lamp) under N_2 condition. The thermally curable oligosiloxane resin was thermally cured at 200℃ for 12 hours. Thickness of the hybrimer thin film was controllable by the addition of solvent and around 1.5μm. The synthesis schemes of photo or thermally curable oligosiloxane resins and fabrication schemes of hybrimer thin films show in Figure 1.

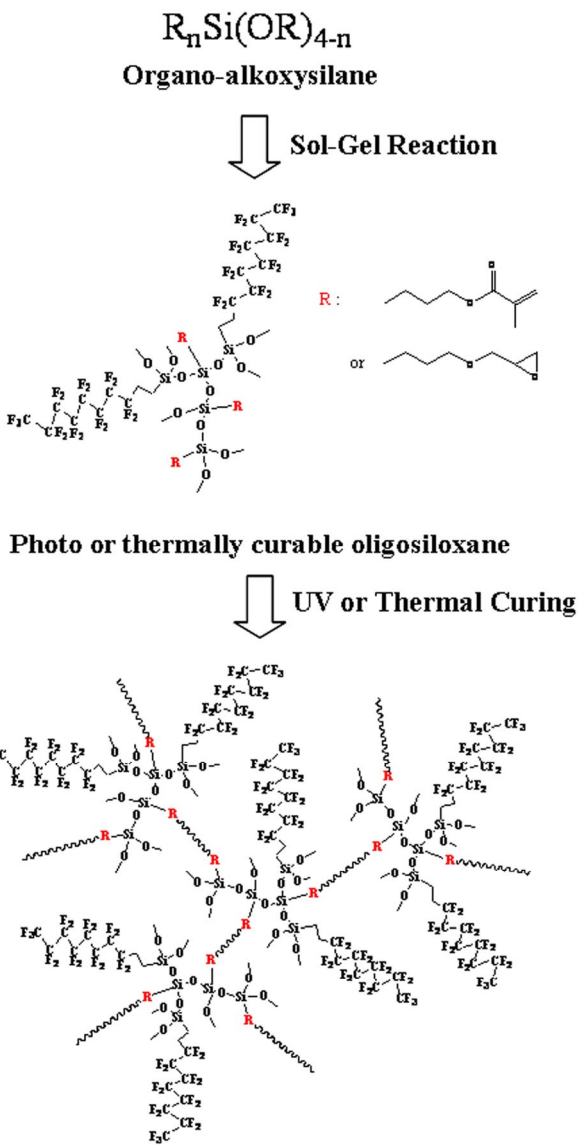

Fig. 1. Fabrication of hybrimers using sol-gel derived photo or thermally curable oligosiloxane.

3. Results and discussion

Photo or thermally curable oligosiloxane resins were spin-coated on ITO glass substrate, and then UV or thermally cured to fabricate the hybrimer thin films. Figure 2 shows cross-sectional SEM image of the hybrimer coating film. The hybrimer coating films are dense, crack-free and have uniform thickness with good adhesion with the ITO electrode.

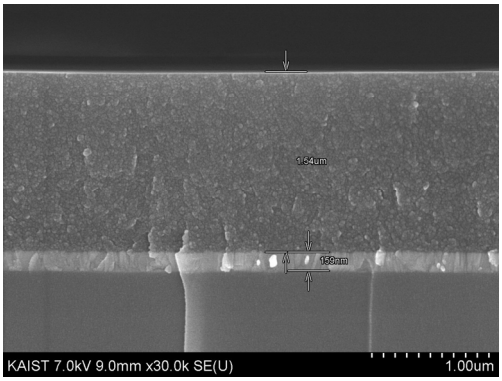

Fig. 2. SEM image of hybrimer thin film fabricated with photo or thermally curable oligosiloxane resins.

It is important to lower dielectric constant of passivation layer to decrease capacitive coupling by the passivation layer and improve TFT performance. Figure 3 represents the dielectric constant of the hybrimer coating films fabricated by photo or thermally curable oligosiloxane resins. The dielectric constants of the hybrimer coating films are 2.63 and 2.45 at 1MHz, respectively, which are lower than that of SiO_2 film (3.9). The low dielectric constant of these hybrimer coating films can reduce signal delay by capacitive coupling of the passivation layer.

Loss tangent of the hybrimer coating films is shown in Figure 3. The loss tangent of the hybrimer coating films fabricated by photo and thermal curing have small value of around 0.02 at 1MHz. Since the loss tangent is the ratio between displacement current and leakage current, small loss tangent means low leakage current density.

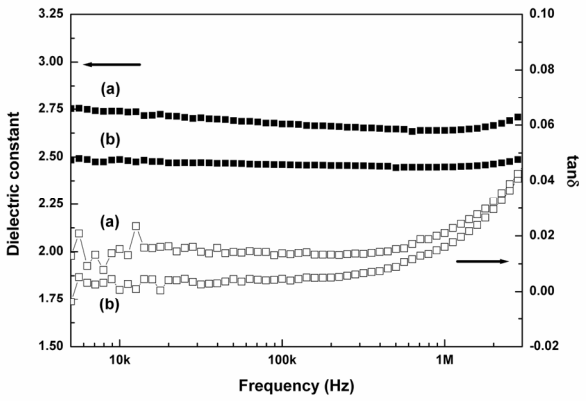

Fig. 3. Dielectric constant and loss tangent of hybrimer thin film fabricated with (a) photo or (b) thermally curable oligosiloxane resins.

We also measured leakage current density of the hybrimer coating films to support the result of the loss tangent. The leakage current density of the hybrimer coating films is shown in Figure 4. The leakage current densities of the hybrimer coating films by photo and thermally curable oligosolxane resins are around 15nAcm^{-2} and 7nAcm^{-2} at 1MVcm^{-1}, respectively. The leakage current densities of the hybrimer coating films show the same tendency with the loss tangents of the hybrimer coating films.

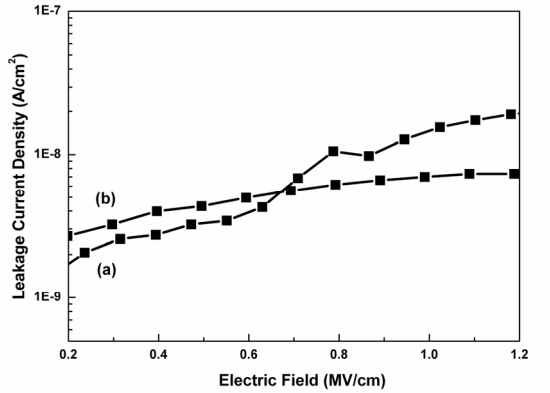

Fig. 4. Leakage current density of hybrimer thin film fabricated with (a) photo or (b) thermally curable oligosiloxane resins.

The passivation layer should be transparent for the fabrication of AMLCDs with high resolution and brightness. The transmittance of the hybrimer coating films at the visible range is represented in Figure 5. These hybrimer coating films exhibit excellent transmittance (>90%) and are colorless.

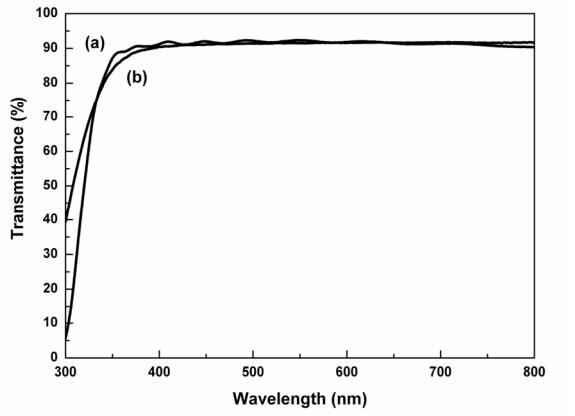

Fig. 5. Transmittance spectra of hybrimer thin film fabricated with (a) photo or (b) thermally curable oligosiloxane resins.

Because heat budget by the following process can occur outgassing of the fabricated passivation layer, thermal stability of the passivation layer is important factor to maintain their performance. As the previously reported, the hybrimer coating films had high thermal stability. [5,6] The 5% loss temperature of the hybrimer coating films by photo or thermally curable oligosiloxane resins were over 300℃. (Table 1)

Table 1. Thermal stablilty of hybrimer thin film fabricated with photo or thermally curable oligosiloxane resins

	Photo cured hybrimer	Thermally cured hybrimer
5% loss temperture	> 300℃	> 330℃

4. Summary

Hybrimer coating films were successfully fabricated by spin coating and photo or thermal curing of sol-gel derived oligosiloxane resins for low k passivation layer in TFT. Thickness of the hybrimer coating films was around 1.5 μm. They were dense, uniform, and crack-free with good adhesion with the ITO electrode. Because these hybrimer coating films have low dielectric constant (<2.7 at 1MHz), small loss tangent (~0.02 at 1MHz), low leakage current density (<20nAcm^{-2} at 1MVcm^{-1}), and excellent optical and thermal properties, they can be utilized as the low k passivation layer in TFT.

Acknowledgement

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MEST) (No. R11-2007-045-03002-0 and No. R01-2007-000-20815-0).

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