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Effect of the ion-beam bombardment and annealing temperature on sol-gel derived yttrium aluminum oxide film as liquid crystal alignment layer

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We demonstrated a homogeneous liquid-crystal (LC) alignment state on yttrium aluminum oxide (YAlO) films, where the alignment was induced by ion-beam (IB) irradiation. Topographical analysis was performed by atomic force microscopy as a function of annealing temperature. Higher annealing temperatures yielded a smoother surface, accompanied by reduced light scattering. Transparency in the visible region increased on the surface fabricated at higher annealing temperatures. LC alignment mechanism was determined by X-ray diffraction (XRD) analysis. Moreover, IB-irradiated YAlO films annealed at temperatures greater than 200 °C exhibited good thermal stability and low capacitance–voltage hysteresis. The IB-irradiated YAlO films are suitable as alternative alignment layers in advanced LC display applications.

1. Introduction

Liquid-crystal (LC) alignment technology is the most important core technique used in LC applications. The rubbing method is conventionally used as an LC alignment technique because of its cost effectiveness and ease of processing [1,2]. However, the rubbing method has some problems, such as contact with the alignment layer, which causes accumulation of residual charge and generates local defects and debris, thereby limiting the fabrication of advanced LC devices [3,4]. The ion-beam (IB) method is a strong candidate for an alternative alignment technology because it is a representative non-contact method; thus, it has the potential to overcome the rubbing-induced limitation. In addition, the IB method is characterized by high reliability and controllability [4–6].

Alignment layer of the LC devices is characterized by the insulator with a dielectric constant. High-k dielectric thin films have been researched as an alternative alignment layer for advanced LC display because it could accumulate volume charge on their surface under low driving voltage compared to organic thin films thereby leading a low power consumption [7,8]. However, Lee et al. reported that representative high-k dielectrics HfO_2 fabricated by atomic layer deposition causes large capacitance-voltage (C–V) hysteresis, thereby giving a bad performance on the LC devices [2].

Because LC molecules are switched by the voltage applying to the LC devices, leakage current on the alignment layer could have negative effect on LC switching such as image sticking which is one of the most important issues on a good quality display. The nano-crystalline thin films can cause current leakage path on their surface due to their grain boundary. Amorphous thin film is preferred for a good insulator rather than nano-crystalline thin film [9].

In this study, we investigated uniform homogeneous LC alignment on the IB-irradiated YAlO layer with excellent residual DC property. YAlO is one of the high-k dielectric materials (dielectric constant~11) [10], and a promising candidate material for applications involving high operating temperatures due to high creep

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resistance and good chemical endurance [11,12]. Amorphous YAlO thin films were fabricated via sol-gel process. The LC alignment state and the thermal stability were investigated by polarized optical microscopy (POM). The capacitance–voltage (*C*–*V*) measurements were performed to evaluate the residual DC voltage property. Cost effective sol-gel process combined with good thermal stability and low capacitance hysteresis emphasizes that the YAlO layer is appropriate for alternative alignment layer on advanced LC display.

2. Experimental

Yttrium(III) nitarate hexahydrate (0.5 mol) and aluminum nitrate nonahydrate (0.5 mol) were dissolved in 2-methoxyethanol, and monoethanolamine and acetic acid were added using a dropper to stabilize the solution. The solution was then stirred for 4 h at 65 °C, followed by aging for at least 1 day in order to obtain the sol state of the solution. The aged solution was passed through a filter paper (Advantech; MFS filter paper; 200 nm pore size). Indium-tin-oxide-coated glass substrates were cleaned via the conventional cleaning process. The obtained YAlO solution was then spin-coated onto the ITO glass at 3000 rpm for 30 s at room temperature. The resulting thin films were annealed for 1 h in a furnace at 100, 200, 300, or 400 °C. The YAlO films were irradiated via an Ar-ion beam with an intensity of 2200 eV and an incident angle of 45° for 2 m using an advanced DuoPIGatron-type IB system.

The LC cells were fabricated using the YAlO-coated substrates in an antiparallel configuration with cell gaps of 60 μm to confirm the alignment of the LCs. A nematic LC solution (Merck and Co., Inc.; $\Delta n = 0.0946$ and $\Delta\varepsilon = 10.7$) was injected into the cells. The LC alignment states and thermal stability tests were observed via POM (Olympus BXP51). The pretilt angle of the LC cells was measured using the crystal rotation method (TBA 107 tilt-bias angle evaluation device; Autronic). The characteristics of the YAlO films were investigated by atomic force microscopy (AFM) (Park Systems), and X-ray diffraction (XRD) (DMAX-IIIA, Rigaku). The optical transmittance was measured using accumulation mode with 3 times in the range 250–900 nm at room temperature using an ultraviolet–visible (UV–vis) spectrophotometer (V-650, JASCO Corporation). We measured optical transmittance 3 times using

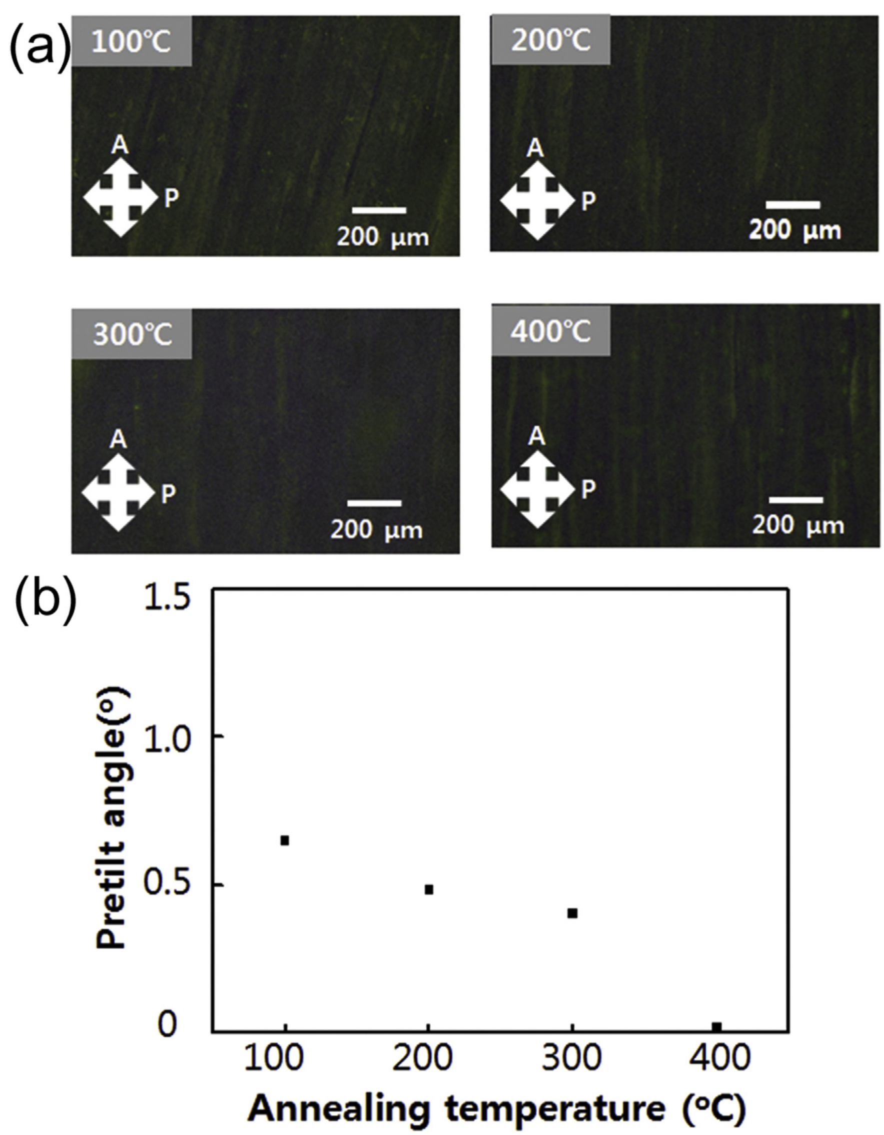

Fig. 1. Alignment state of the liquid crystals on YAlO films annealed at (a) 100, 200, 300, and 400 °C (P: polarizer; A: analyzer). (b) The calculated pretilt angle as a function of annealing temperature.