Introduction
Transparent conductive oxide (TCO) films have been widely employed as the transparent conductive electrode for optoelectronic devices, such as liquid panel displays, solar cells, and organic light emitting devices because of their low resistivity and high transmittance in the visible region. However, the electrical properties of TCO films should still be further improved for use as transparent electrodes for high-performance optoelectronics applications. Recently, we investigated nano-scale surface modifications of borosilicate glass plates by applying a thermal nanoimprint technique, in which atomic-step induced nanopattern molds of oxides (NiO, α-Al₂O₃) were used. There is a possibility that crystal growth of thin films on the glass plates can be controlled by employing the nanopatterned substrate. Use of these nanoimprinted glass substrates for TCO thin film fabrication is expected to result in a highly-oriented film due to the homogenization of crystal nucleation and growth on the nanostructure of the nanoimprinted glass surface. The high crystal orientation of the films might decrease carrier scattering, that is, increase a carrier mobility.

Experimental
The stepped sapphire molds for glass nanoimprint were prepared by annealing a mirror-polished commercial sapphire (0001) substrate at 1000–1400°C for 3 h in air. We used a thermal nanoimprinter (X-200: SCIVAX. Co.) for the glass nanoimprint experiment. We pressed the mold onto the glass plate at 3 MPa in a vacuum (5Pa) and then heated it at 600°C for 5 min.

ITO film deposition on the nanoimprinted glass and the non-patterned commercial glass substrates was carried out by the PLD method. A pulsed KrF excimer laser was focused onto the sintered target of 5 wt.%-Sn doped In₂O₃ (ITO). The film deposition was conducted at room temperature (RT) or 200 °C under a 1×10⁻² Torr O₂ atmosphere. The films as-deposited at RT were then annealed for further crystallization in a vacuum at temperatures from 100 to 300°C for 3 h. After deposition, samples were characterized by reflection high-energy electron diffraction (RHEED), x-ray diffraction (XRD), atomic force microscopy (AFM) and four probe method.

Result & Discussion
Figure 1(a) shows the surface morphology of the ITO film (300 nm thick) annealed at 200°C after being deposited at RT on the nanoimprinted glass (step height: ~ 2nm, step separation: ~1μm). The ITO film has the nanostructured surface, reflecting the step and terrace morphology of the nanoimprinted glass surface. The high crystal orientation of the films might decrease carrier scattering, that is, increase a carrier mobility.

Figure 2 (b) shows XRD pattern of the ITO film deposited at RT on the nanoimprinted glass. The XRD pattern Fig. 1. AFM image of the ITO thin film.
Fig. 2. (a) RHEED image and (b) XRD profile of the ITO thin film.

The resistivity of the ITO thin films deposited on the nanoimprinted glass was by about 10% lower than that on the non-patterned commercial glass. This is probably due to the higher crystal orientation of the films grown on the nanoimprinted glass surface.

Future work
I plan to use other patterning glass substrates, such as nanochannel pattern, for deposition of ITO thin films and use buffer layer. In addition, intend to examine the carrier concentration and Hall mobility by van der Pauw measurement. Then apply these nanoimprinted glasses to substrate for the other TCO films.

Publications
Philosophical papers

Presentation at International meetings
3. Yasuyuki Akita et al. “Fabrication of nanostructured ITO thin films on nanoimprinted glasses by pulsed laser deposition” SPIE Photonic West, LASE2009, San Jose, USA.