Low temperature deposition and effect of plasma power on tin oxide thin films prepared by modified plasma enhanced chemical vapor deposition

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This work presents low temperature (200 and 300 °C) thin film deposition of tin oxide (SnO2) using modified plasma enhanced chemical vapor deposition as a function of radio frequency power (100 – 500 W). Stannic chloride (SnCl4) was used as precursor and oxygen (O2, 300 SCCM) as reactant gas. Fine granular morphology was observed with tetragonal rutile structure grown along the [110] direction, at all the deposition conditions. Higher plasma power resulted in smoother morphology, improved crystallinity, and enhanced conductivity. Electrical resistivity value of as low as ~0.01 Ω cm was obtained at the deposition temperature of 500 °C and 250 W of plasma power.


I. INTRODUCTION

Tin oxide is a suitable candidate that finds wide application in the field of sensors, opacifiers, solar cells, etc. Its low cost, chemical stability, and useful electrical properties made it a favorable industrial compound. It belongs to a class of materials that combines high electrical conductivity with optical transparency and thus constitutes an important component for the optoelectronic applications.

Thin films of SnO2 have been prepared by variety of techniques such as reactive sputtering, spray pyrolysis, evaporation, sol-gel, pulsed laser deposition, plasma-assisted/enhanced chemical vapor deposition, and thermal chemical vapor deposition (CVD). Among all these, CVD has meaningful advantages such as large area growth, precise control over thickness, and superior conformal coverage. The results reported in the literature clearly demonstrated that the physical properties of the film are strongly dependent on the method and the conditions of the film preparation. For example, use of labile organometallic molecules allows deposition of thin films at low temperatures that most inorganic substrates can tolerate.

In most of the cases, a heat treatment at or above 400 °C is required for the formation or crystallization of metal oxide films. This requirement hinders the fabrication of metal oxide thin films on (i) Si devices (due to reaction with Si), (ii) low temperature substrates such as polyethylene (PET) substrates, (iii) flexible plastic films, (iv) inorganic substrates, etc. Therefore, to fabricate/deposit metal oxide thin films on such substrates, it is necessary to decrease the deposition temperature. Among the above mentioned and reported methods, the sol-gel and metal-organic chemical vapor deposition (MOCVD) have become promising methods to prepare metal oxide thin films because of their simplicity, accuracy in compositional control, and low facility investment.

Here we present a systematic study on the low temperature deposition of thin films of SnO2 and the effect of rf plasma on the growth and crystallinity of the deposited film. For this study the conventional plasma enhanced CVD system was modified for precursor heating. Hydrated stannic chloride was used as a precursor and O2 was used as a reactant gas. The rf-plasma power was varied from 100 to 500 W, whereas the substrate was kept at 200 and 300 °C.

II. EXPERIMENT

Silicon wafers with (100) orientation were used as a substrate, which were cleaned using conventional cleaning process. The deposition system was modified to differ from the conventional MOCVD/plasma enhanced CVD (PECVD), as shown in Fig. 1. Instead of bubbler, a small alumina boat was used for precursor heating which was kept at one end (gas inlet side) of 1 m long quartz tube. Substrates were loaded at other end, plasma downstream/exhaust side. Precursor and substrates were heated individually and rf coil was placed in between the two. Distance between precursor and plasma coil was optimized in advance to avoid the direct exposure of precursor to plasma. Inductively coupled rf-power supply (13.56 MHz) was used for plasma generation.

Hydrated SnCl4 · xH2O (Junsei Chemicals, Japan) was used as a precursor that was heated to 90 °C. Oxygen (99.99% pure) was used as a reactant gas with a flow rate of 300 SCCM (SCCM denotes cubic centimeter per minute at STP). Since the vapors were carried through the plasma, the vapor condensation was avoided, unlike the conventional MOCVD technique where vapor condensation is a problem. The precursor and substrates were heated to the required temperature in vacuum (10−3 Torr) and the deposition was

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