第 21 卷第 1 期　　半 导 体 学 报　　Vol. 21, No. 1
2000 年 1 月　　CHINESE JOURNAL OF SEMICONDUCTORS　　Jan., 2000

Surface Oxidative Characterization of LPE HgCdTe Epilayer Studied by X-ray Photoelectron Spectroscopy*

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Abstract The surface oxidative characterization of Liquid Phase Epitaxy (LPE) HgCdTe epilayer has been studied by X-ray Photoelectron Spectroscopy (XPS) and Scanning Electron Microscopy (SEM). HgCdTe surface is exposed by various processing steps. After measurement and analysis, we draw a conclusion that the native oxide film can be reduced and removed by the solution of lactic acid in ethylene glycol after being etched by bromine in absolute ethyl alcohol. The result shows the main optical and electrical parameters have not been changed after the treatment and the processing method given here can successfully remove the native oxides of LPE HgCdTe epilayer to obtain a clean surface. It indicates that the pre-treatment before HgCdTe surface passivation can affect the passivant/ HgCdTe interface properties.

Key Words: Characterization, HgCdTe, LPE, XPS
PACC: 7280E, 8160, 7960
Article ID: 0253-4177(2000)01-0008-04

1 Introduction

The characteristics of semiconductors surface and interface play a decisive role in many device technologies. The technology of infrared detectors based on HgCdTe requires to control the surface condition of this narrow gap semiconductor material strictly. The most desirable surface condition would be characterized by a homogeneous stoichiometric composition, without crystalline defects and a minimum amount of oxides as well as the surface contaminants. LPE HgCdTe epilayers from Te-rich solution at 470℃ had been studied[1] and revealed to be of an Hg-enriched surface region with a depth of 0.5 to 1.0μm. This is due to Hg diffusing into the layer during the process of cooling down to the

* Supported by Chinese National High Technology (863) Plan.
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Received 3 June 1999, revised manuscript received 1 September 1999

room temperature. Annealing of as-grown epilayer material can cause an out-diffusion of Hg to accumulate on the surface[2]. On the other hand, the LPE HgCdTe epilayer surface exposed by various steps during the ex-situ passivation will lead to oxide formation, impurity contamination and scratches, which affect the passivant/ HgCdTe interface properties and device performance greatly[3]. In order to reduce and eliminate the oxides and contaminants, the appropriate surface pre-treatment is necessary prior to the deposition of the passivation film. However, it is difficult to obtain an ideal surface which is only etched by bromine in methanol or ethylene glycol[4~6].

This paper presents a surface pre-treatment method of LPE HgCdTe epilayer to reduce the oxides and contaminants. The result shows the main optical and electrical parameters have not been changed after processing, and the native oxides of LPE HgCdTe epilayer can be removed successfully and a clean surface be obtained.

2 Experimental Procedure

The P-type HgCdTe epitaxial layers with the typical thickness ~ 20μm, were grown on (111) B CdZnTe substrates by liquid phase epitaxy (LPE) at the temperature of 470℃ in Te-rich solution with vertical dipping technique. The surface has been investigated by Scanning Electron Microscopy (SEM) and X-ray Photoelectron Spectroscopy (XPS) before and after the treatment respectively. XPS spectra were carried out by PHI 5500 ESCA system, with Mg-K$_\alpha$ ($h\gamma$= 1253.6eV) X-ray source operating at 300W. The incident angle between X-ray radiation and the epilayer surface was 45°. The spectrometer was calibrated from C1s level at 284.6eV binding energy. Background pressure in the analysis chamber was about 5×10^{-8}Pa. The LPE epilayer was loaded into the analysis chamber to have XPS and SEM measurements, as well as to measure the optical and electrical parameters. Then the samples were treated as follows: first, they were cleaned carefully with acetone and absolute ethyl alcohol in sequence. Next, the samples were etched by 0.5% bromine in absolute ethyl alcohol solution for 10 seconds and rinsed by absolute ethyl alcohol. Finally the HgCdTe surface was immersed in the solution of lactic acid in ethylene glycol for 20 seconds and rinsed in overflowing DI water. The treated samples were dried by flowing nitrogen and immediately transferred into the analysis chamber to perform the relative measurements.

3 Result and Discussion

Figure 1(a) and Figure 1(b) show the selected-area channeling patterns (SACPs) before and after the treatment, respectively. It shows that the SACPs of the treated surface are better than those of the untreated one through comparing electron channeling pattern contrast and high-order lines. Obviously, the brightness and smoothness of the treated surface can meet the requirement of infrared device technology. The surface quality is improved after the treatment, and the amount of oxides and the surface contaminants has

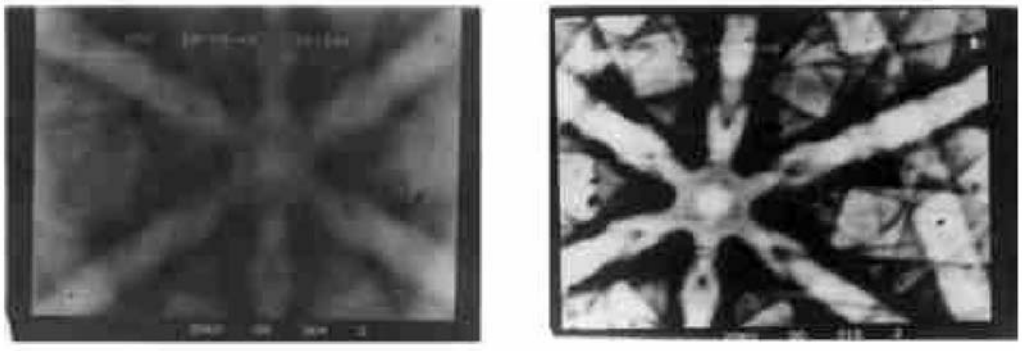
been reduced greatly.

Photoelectron spectra were measured by a Mg-K_α source and a concentric hemispheric analyzer. Each sample was taken survey scans normally in order to assure that no additional atomic species (such as Br, N, and S) were left on the surface after the treatment. For each sample, energy scans were taken for the Hg4f, Hg4d, Cd3d, Te3d, O1s and C1s photoelectrons. Due to the significant chemical shift, two components of tellurium Te_{ox} (oxidized tellurium) and Te_{red} (lattic bound tellurium or elemental Te) could be clearly distinguished[7,8], as can be used to evaluate the state of the native oxide on HgCdTe surface. Figure 2(a) and 2(b) are respective the Te3d and O1s photoelectron spectra of HgCdTe epilayers before and after the treatment. Before the treatment, the Te3d core level peak has a small shoulder, as is corresponding to the tellurium in the oxidative state. However, after the treatment, this small peak completely disappears and the core levels of Hg4f, Cd3d, and Te3d are in accordance with the composition of HgCdTe epilayer. It indicates that the oxidized tellurium has been removed during the treatment processes. The etching residue, elemental Te could not be found on the treated LPE HgCdTe epilayers. The O1s photoelectron intensity was fit in with Gaussian-Lorenzian curve. On the opposition to the Fig. 2(a), which is corresponding to the untreated surface, there is only a peak for the O1s photoelectron spectra in Fig. 2(b). It is obvious that the experimental curve is in good agreement with the Gaussian fitting curve for the treated surface. The residual oxygen has been completely attributed to the physical absorption oxygen on the treated surface (for instance, being hydroxide groups or carbon oxides). It is also beneficial to enlarge the capability and effectiveness of removing the native oxide film during the treatment processes.

The mobility and carrier concentration were measured by Van De Pauw method, the data measured at 77K are given as follows:

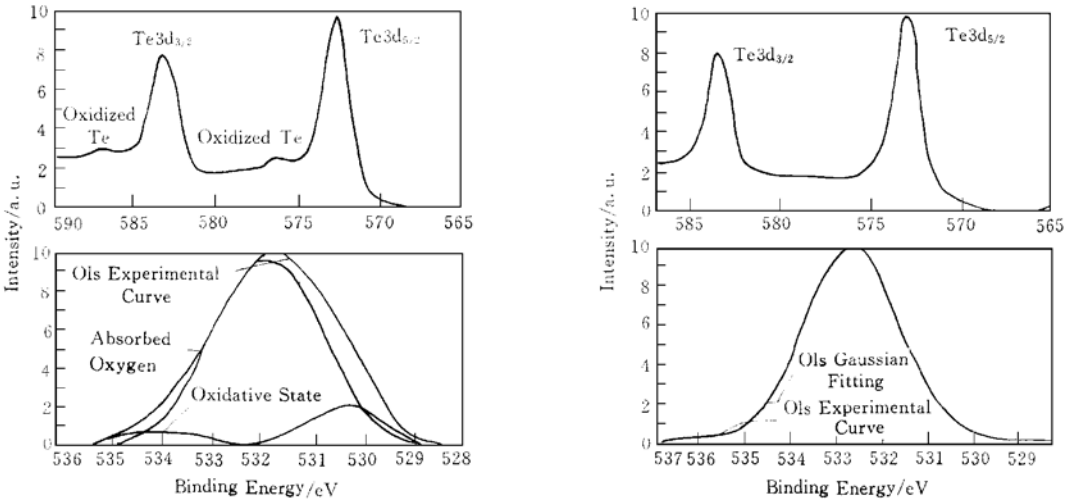
$P = 3.04\times10^{16}\text{cm}^{-3}$ $\mu = 4.88\times10^{2}\text{cm}^{2}/(\text{V}\cdot\text{s})$ (before the treatment)

$P = 3.09\times10^{16}\text{cm}^{-3}$ $\mu = 4.91\times10^{2}\text{cm}^{2}/(\text{V}\cdot\text{s})$ (after the treatment)



(a) untreated (b) treated

FIG. 1 SACPs of LPE HgCdTe Epilayer Surface



(a) untreated　　(b) treated

FIG. 2　Te3d and O1s XPS Spectra of LPE HgCdTe Epilayer

By comparing the optical and electrical parameters of LPE HgCdTe epilayer before and after the treatment, it is apparent that the main optical and electrical parameters of LPE HgCdTe epilayer have not been changed.

4　Conclusion

In conclusion, the surface treatment of LPE HgCdTe epilayer for passivation technology of infrared photodiode array has been introduced and investigated by SEM and XPS. We find that the treatment can reduce and remove the oxide film and contaminants. The optical and electrical parameters of LPE HgCdTe epilayer before and after the treatment have not been changed. The experimental results indicate that the appropriate surface pretreatment is necessary to the deposition of the passivation film, and is an important part of the photodiode array technology.

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