Effect of Ar Ion Bombardment on XPS Analysis of Chemical State

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Abstract

Material characteristics are very crucial to the performance of an electronic device. During the development of advanced process technology, process monitor and even the failure analysis, analysis tools are utilized to understand the characteristics of material and failure mechanism of the device. By doing the analysis, the quality of the device and process issues can be resolved. The physical morphology and dimension of the device can be observed by Optical microscope (OM), Scanning Electron Microscope (SEM), and Transmission Electron Microscope (TEM). However, for obtaining chemical composition and chemical state, surface analysis tools such as energy dispersive X-ray spectrometer (EDX), Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectrometer (SIMS) are utilized. In this study, the effect of ion bombardment on the XPS analysis of chemical state is discussed.

XPS has been widely used in the analysis of chemical state in a material. The escape depth of the X-ray generated photoelectron from an element is only a few nanometers. To clean the contaminated surface layer or for depth profiling, Ar ion beam bombardment is frequently conducted. The change of the chemical state during the Ar ion beam bombardment in some metallic oxide materials has been reported in the literatures.\(^1\), \(^2\) These metal oxide materials have been used in the electronic component. The original chemical state of the element is important to understand the root cause of the failure. During the Ar ion bombardment, the reduction reaction changes the chemical states of the metal and result in the artifact of the data.

MnO\(_2\) has been used as electrodes of a Ta capacitor, which has high charge storage density. The MnO\(_2\) could be reduced to MnO and Mn\(_2\)O\(_3\) in the capacitor working environment. The change of the chemical state and affected depth can be obtained by XPS with Ar ion beam. During the XPS analysis, after removing 10nm of the surface layer by Ar ion beam, the ratio of the MnO\(_2\) is reduced \(\sim 15\%\). Mn\(^{4+}\) could be reduced to Mn\(^{2+}\) and Mn\(^{3+}\) due to the ion bombardment. To interpret the XPS analysis result, care must be taken to check the ion bombardment effect. In order to avoid this effect, lower down the ion sputtering energy, using molecular ions, changing the ion beam incident angle or mechanical angle lapping of the sample are necessary.

Although XPS is good at analyzing the chemical state of the element, the X-ray beam size limits the analysis in the actual device structure. X-ray with sub-micron beam size will help to overcome this barrier.

Keywords – Chemical State, XPS, Ion Bombardment, Reduction, Metallic Oxide

References