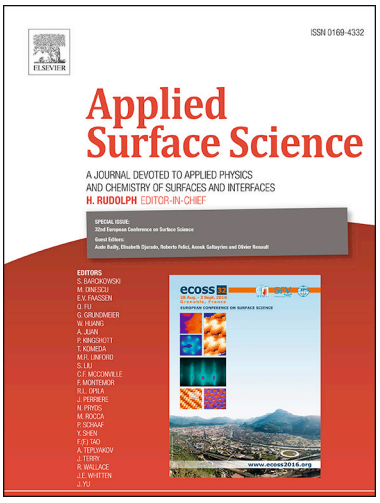

Full Length Article

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Detecting Fermi-level shifts by Auger electron spectroscopy in Si and GaAs

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Abstract

In this paper, changes in surface Fermi-level of Si and GaAs, caused by doping and cleaning, are investigated by Auger electron spectroscopy. Based on the Auger voltage contrast, we compared the Auger transition peak energy but with higher accuracy by using a more accurate analyzer and an improved peak position determination method.

For silicon, a peak shift as large as 0.46 eV was detected when comparing a cleaned p-type and n-type wafer, which corresponds rather well with the theoretical difference in Fermi-levels. If no cleaning was applied, the peak position did not differ significantly for both wafer types, indicating Fermi-level pinning in the band gap.

For GaAs, peak shifts were detected after cleaning with HF and $(NH_4)_2S$-solutions in an inert atmosphere (N_2-gas). Although the $(NH_4)_2S$-cleaning in N_2 is very efficient in removing the oxygen from the surface, the observed Ga- and As-peak shifts are smaller than those obtained after the HF-cleaning. It is shown that the magnitude of the shift is related to the surface composition. After Si-deposition on the $(NH_4)_2S$-cleaned surface, the Fermi-level shifts back to a similar position as observed for an as-received wafer, indicating that this combination is not successful in unpinning the Fermi-level of GaAs.

1. Introduction

Up to now, Auger electron spectroscopy (AES) is mostly used to investigate the elemental composition of the surface, sometimes combined with sputtering to obtain depth profiles. However, the technique also allows obtaining information on changes in the surface Fermi-level[1-4]. The determination of the Fermi-level position is of great interest in the electronics industry, as the movement of the Fermi-level is crucial for the correct functioning of several devices such as the metal oxide semiconductor field effect transistor (MOSFET). For this particular application, detailed investigation of the Fermi-level is necessary to better understand pinning of the Fermi-level in the bandgap, which is detrimental to the functionality of a MOSFET device. Especially in III-V semiconductors, which are considered as promising candidates to replace silicon in the MOSFET industry to obtain faster electronics[5], Fermi-level pinning is a major issue due to the presence of a native oxide layer[6, 7]. AES is especially suited to investigate the surface of these semiconductors after surface treatments as it is very surface specific (measuring depth of 4-50 Å[8]) and allows quantifying the treatment efficiency[9] and to determine the Fermi-level shift upon surface treatment. A major advantage of AES compared to X-ray photoelectron spectroscopy (XPS), which is often used for similar purposes, is the higher spatial resolution (3-30 nm for AES, while that of XPS is only 150 nm to 15 µm[10]).