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GaAs MIS STRUCTURES - PROMISING OR HOPELESS?

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MOS configurations have been pivotal in the striking advances of Si technology, particularly in LSI, VLSI, and will continue to be in the projected ULSI. The compatibility of the chemical and physical properties of SiO_2 with Si is primarily responsible for the unique electronic characteristics of Si-SiO_2 interfaces. For many years extensive and intensive work has been devoted to the study and development of GaAs MOS (or MIS) structures whose electronic potential could extend the range of applications beyond that of Si MOS structures.

Major problems, however, have been encountered; the native Ga-As oxides have presented immense complexities regarding chemical kinetics and thermodynamics (numerous chemical interactions and phases are possible in the oxidation process). Furthermore, the electrical properties of these oxides and the electronic characterization of the GaAs-oxide interfaces have been elusive. Other GaAs MIS structures (e.g., involving Si_3N_4) have not revealed sound reasons for greater optimism.

In extensive studies on GaAs MIS structures in our laboratory the complexities reported by other investigators have been also encountered. However, it was shown that these complexities stem from the inherent nature of the GaAs surfaces and that they are not significantly affected by the nature or type of the insulator involved. Thus, employing spectral and transient responses of photostimulated currents in GaAs MOS or MIS (e.g., Si_3N_4 structures) two discrete deep traps 0.7 and 0.85 eV below the conduction band were found with concentrations on the order of $10^{12}cm^{-2}$. The energy positions of these traps are invariable regardless of the nature of the insulator (or method of its formation) and the conductivity type of GaAs. In fact, the energy positions of these traps are the same as those found on clean GaAs surfaces with oxygen and/or metal adatom submonolayer coverage. Since clean GaAs surfaces exhibit no surface states, it is apparent that these deep levels are induced by the interaction of the GaAs surfaces with essentially any ambient. In addition, and in contrast to surfaces with low oxygen coverage, the GaAs-thick insulator interfaces exhibit a high density of shallow donors and acceptors. Photoexcitation of these donor-acceptor pairs lead to a gigantic photoionization of the deep interface states with rates three orders of magnitude greater than those of direct transitions into the conduction and valence bands.

The properties of the deep interface states were found to account for all major electronic characteristics of the GaAs-MIS structures, whereas the properties of the insulator layer itself were found to play only a secondary role in the behavior of these structures.

The origin of the interface states has been attributed to point defects (e.g., vacancies) or point defect complexes induced by the interactions of the GaAs surfaces leading to the formation of the insulating layer. It is quite possible that these defects are similar in nature to those responsible for deep levels in bulk GaAs crystals. In recent years remarkable progress has been made towards understanding the nature of bulk deep levels and their interactions.

An attempt will be made in this communication to assess the feasibility of applying the knowledge on bulk deep level behavior to the control of GaAs-insulator interface deep levels. Accordingly, the question will be considered: can the present problems associated with MIS structures be overcome and thus, can the immense application potential of these structures be eventually realized?