4th International Symposium on
Energy Challenges & Mechanics
- working on small scales

11-13 August 2015
Aberdeen, Scotland, UK

Dynamics of surface photo-voltage in GaAs systems studied with time-resolved photoelectron spectroscopy

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Accepted for publication on the 8th of February 2015

Solar cells are indispensable devices to generate electric power from natural lights. The key idea originates from a photo-voltage effect of semiconductors. Further understandings of the mechanism are required to get more efficient, intelligent, and cheap solar cells. Moreover, deep understandings of Surface Photo-Voltage (SPV) are required in the field of high-energy accelerator to produce a high-brilliant and ultra-short beam using a photo-cathode. These application subjects need opposite technology with each other, but their essential point shares common basic understandings.

In this report, experimental data of SPV on clean and negative-electron affinity surface of GaAs, which were obtained with time-resolved photoelectron spectroscopy using synchrotron radiation and laser light, are presented. Moreover, SPV data obtained using ultra-fast laser lights are reported. The experiments were carried out at UVSOR BL5A in IMS and Saga University BL13 in Saga-LS. Samples of n- and p-type GaAs with different dopant concentrations were measured at room and low temperatures. To investigate the effects of surface barriers, negative-affinity surfaces of GaAs and its super-lattices were also measured. Cr/GaAs samples were investigated to study the effect due to the metallic over layer as well.

After introduction of the basic concepts of band bending and static SPV, which are based on the electromagnetic theory and a thermionic emission model, the experimental results are analyzed in details and the dynamics of SPV are discussed. The present results show clearly the creation and annihilation processes of SPV, which are related to excited-states of electronic states in semiconductor surface. The creation and annihilation processes of SPV involve slow and fast components. The fast component indicates the important role of hot carriers and non-thermionic process, i.e. non-equilibrium dynamics.

Keywords: Surface Photo-Voltage, Time-resolved photoelectron spectroscopy, GaAs, Dynamics, non-thermionic process