

Ultrathin Ge epilayers on Si by low-temperature PECVD acting as virtual substrates for III-V / c-Si tandem solar cells

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Ultrathin (20 nm) epitaxial films of germanium are deposited on crystalline silicon wafers, to act as virtual substrates for the growth of III-V materials, opening a low-cost approach to tandem solar cells. Such ultrathin layers allow for cost reduction, along with the possibility of using the silicon wafer as the bottom cell in multijunction devices. Theoretical modelling has predicted efficiencies approaching 34% with 3JSC on Ge|Si substrates when the Ge thickness is kept below ~60 nm [1]. A simple plasma-enhanced chemical vapor deposition (PECVD) process at 175°C has been optimized to deposit these heteroepitaxial germanium films, which grow directly on the silicon wafers. An *in-situ* plasma cleaning step prior to Ge epitaxy makes the films more sustainable to high-temperature annealing in vacuum (up to 800°C) without any delamination. The suitability of the germanium heteroepitaxial films as virtual substrates is analysed by depositing III-V layers on them by conventional growth methods like chemical beam epitaxy (CBE) and metalorganic chemical vapor deposition (MOCVD). The properties of the GaAs films deposited on the virtual substrates are comparable in terms of roughness, microstructure, and crystallinity to these of the III-V layers co-deposited on c-Ge wafers, pointing at the effectiveness of the Ge epitaxial layers to act as virtual substrates for III-V epitaxial growth [2]. Moreover, the growing of c-Ge layers on c-Si substrates with 5° miscut avoids the formation of antiphase domains. These substrates are used to demonstrate functional tandem solar cells, proving the suitability of our low temperature and ultrathin virtual substrate approach.

[1] I. Garcia, M. Ghosh, V. Orejuela, P. Roca i Cabarrocas, I. Rey-Stolle: “III-V multijunction solar cells on ultrathin Ge/si virtual substrates grown at low temperature by RF PECVD”. Proc. 38th EUPVSEC, 6-10 September 2021

[2] M. Ghosh, P. Bulkin, F. Silva, E. Johnson, I. Florea, A. Tanguy, C. Renard, N. Vaissiere, J. Decobert, I. García, I. Rey-Stolle, P. Roca i Cabarrocas, “Ultrathin Ge epilayers on Si produced by low-temperature PECVD acting as virtual substrates for III-V / c-Si tandem solar cells”, Under review in Solar Energy materials and Solar cell, September 2021.