EMCMRE-1
Marrakech-Morocco
November 21-25 2011

First Euro-Mediterranean Conference on Materials and Renewable Energies (EMCMRE-1)
21-25 November 2011

Low temperature plasma processes for the deposition of silicon thin films and solar cells: from amorphous to crystalline

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Abstract:

Over the last decades, plasma enhanced chemical deposition has been developed as a versatile tool for silicon thin film deposition. Starting with a disordered semiconductor (hydrogenated amorphous silicon), the progress in understanding plasma processes and plasma/surface interactions has allowed producing a wide range of silicon thin films: plymorphous, nanocrystalline, microcrystalline and more recently epitaxial growth. While standard growth models based on SiH_3 radicals may apply for well controlled and low rate deposition conditions, increasing the deposition rate is synonymous of enhanced gas phase reactions leading to the formation of silicon clusters and nanocrystals in the plasma. Even though common sense would suggest that this is something to be avoided, we have been using plasma synthesized silicon nanocrystals to improve the electronic properties of polymorphous and microcrystalline silicon while increasing their deposition rate [1,2] as well as solar cell efficiency. We have extended this approach to the epitaxial growth of crystalline silicon thin films at low temperature (~ 200 ℃). This is a commonly observed and undesired effect when depositing a-Si:H on crystalline silicon for heterojunction solar cells. However, one can take benefit of this to produce crystalline silicon/germanium quantum wells as shown in Fig.1 or to produce thin crystalline silicon heterojunction solar cells as shown in Fig. 2. Besides the applied interest of these results, they also raise questions about the growth mechanism of such epitaxial films at low temperature. Our plasma and material studies point towards the crucial importance of plasma synthesized silicon nanocrystals in the achievement of epitaxial growth and open the way to new applications of standard plasma processes. They also allow us to foresee high efficiency triple junction solar cells based on low cost and low temperature processes.

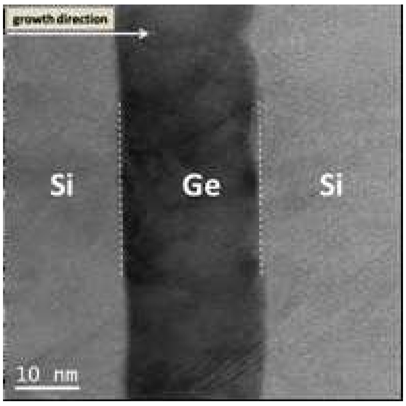

Fig. 1 – Crystalline Si/Ge multilayer produced by standard PECVD at 175℃.

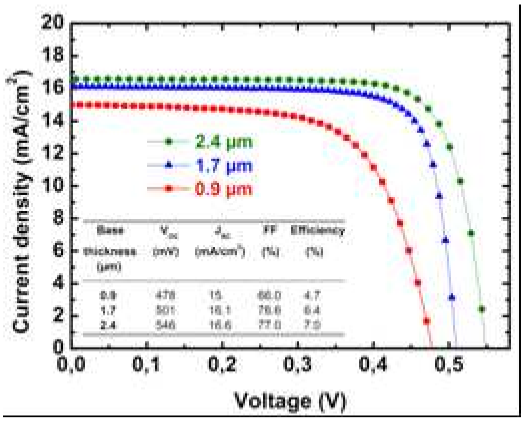

Fig 2 – J(V) characteristics of heterojunction solar cells in which the active c-Si layer was epitaxially grown at 175 ℃

1. P. Roca i Cabarrocas, Th Nguyen-Tran, Y. Djeridane, A. Abramov, E. Johnson and G. Patriarche. J. Phys. D: Appl. Phys. 40 (2007) pp. 2258-2266.
2. P. Roca i Cabarrocas, Y. Djeridane, Th. Nguyen Tran, E.V. Johnson, A. Abramov and Q. Zhang. Plasma Phys. Control. Fusion 50 (2008) 124037