Study of GaN growth by PECVD: towards a reduction in solar cell industrialisation costs

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Solar cells based on III-V materials have reached the highest efficiency of any technology available today, i.e. up to 47% under concentration[1]. Nevertheless, their cost is a hundred times higher than that of c-Si solar cells[2]. Most of this cost difference comes from i) the III-V or Ge substrate required to grow a single crystal layer and ii) the growth process. In a recent project we have shown how the use of a virtual substrate can tackle the first part of the challenge[3]. In this work, we address the second one.

To this end, we have developed a new strategy for the epitaxial growth of III-V materials by using Plasma-Enhanced Chemical Vapor Deposition (PECVD) technique, with the aim of drastically reducing their cost in comparison with usual semiconductor deposition processes such as Molecular Beam Epitaxy (MBE) or Metal Organic Chemical Vapor Deposition (MOCVD). Indeed, plasma assistance allows us to work at lower temperatures thus reducing thermal stresses and hopefully defects, especially the risks of dislocations. Moreover, this process enables low pressure operation, which reduces drastically the precursor consumption. Some works showing the feasibility of such an approach were published in the 1980s[4] and the subject is again attracting interest[5] due to the strong growth of the photovoltaic market. Recently, we have shown that it is possible to grow gallium nitride (GaN) films by PECVD at low temperature. Here we present the results of this GaN growth as a "friendly" process before addressing the challenge of gallium arsenide (GaAs) which requires the use of highly toxic gases. By tuning the deposition conditions, thanks to a large number of parameters such as precursor flow rates, plasma power, chamber pressure, substrate and trimethylgallium bubbler temperatures, we were able to grow GaN layers directly on silicon and sapphire substrates. The obtained films show columnar grains (Figure 1) and uniform Ga and N depth profiles with Ga/N ratio close to 1:1 (Figure 2). The crystalline quality is promising with a preferred growth orientation along the c-axis of the wurtzite structure (Figure 3). In addition, a Raman analysis revealed the active phonon mode E_2(high) and A_1(low) of GaN (Figure 4). These results were obtained using a process temperature of only 550°C, compared to about 1000°C for current industrial MOCVD.

Therefore, they raise the prospects of a more affordable method for the growth of III-V materials, with the potential to obtain large-scale epitaxial films, thus addressing the important issue of costs for III-V device industry.

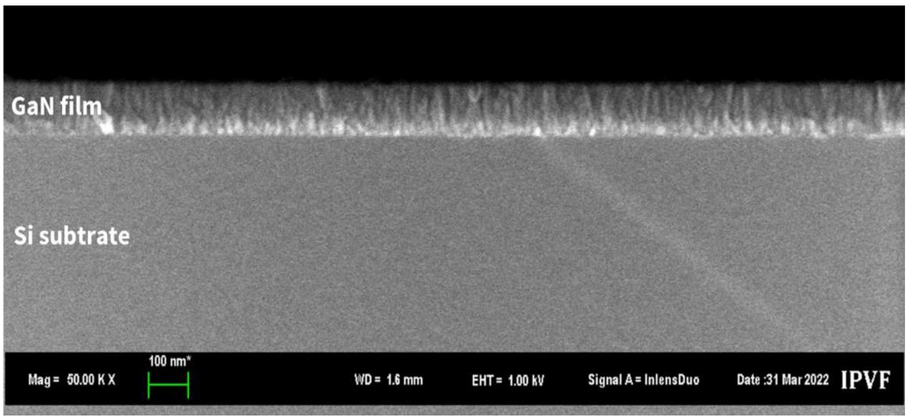

Figure 1 SEM cross section of a GaN-on-Si sample grown by PECVD

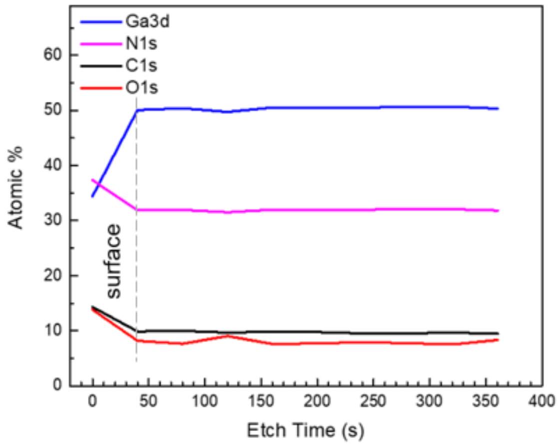

Figure 2 XPS in-depth profile of GaN-on-Si

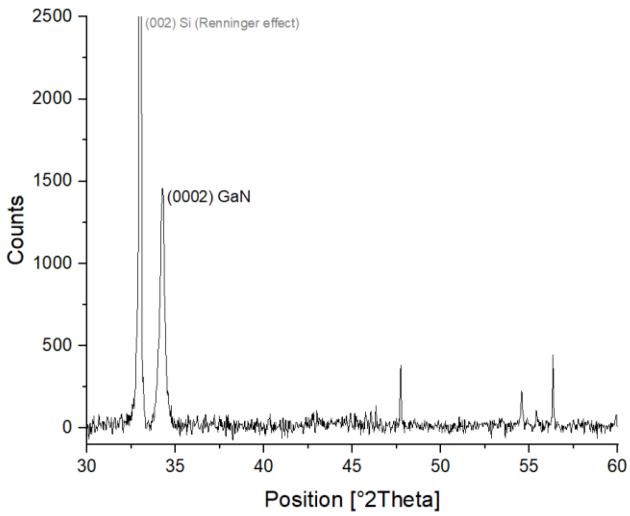

Figure 3 XRD pattern of GaN-on-Si

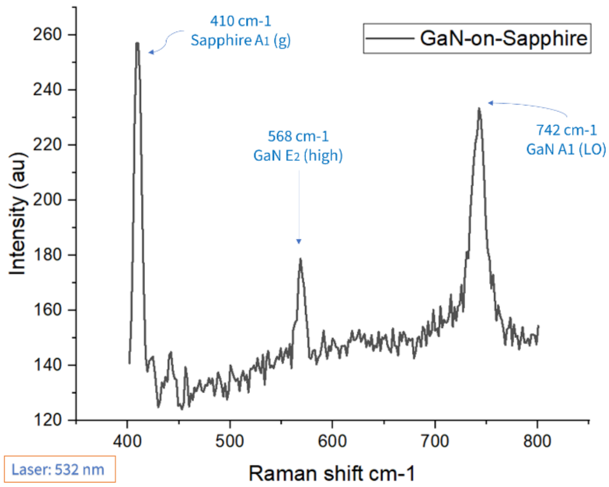

Figure 4 Raman spectrum of GaN-on-sapphire

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