Physical vapor deposition (sputtering) of epitaxial III-V materials (GaN) for photovoltaics

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Detailed balance modeling indicates that in order to achieve practical terrestrial photovoltaic efficiencies of greater than 50 %, materials with band gaps greater than 2.4 eV are required [1]. Apart from this feature, III-V nitrides such as GaN also demonstrate favorable photovoltaic properties such as low effective mass of carriers, high mobilities, high peak and saturation velocities and radiation tolerance [2]. GaN alloys also tend to exhibit very strong absorption of approximately 10^5 cm^{-1} at the band edge which allows a large fraction of the incident light to be absorbed in a few hundred nanometers of material. This is in contrast to the tens or hundreds of microns of material as is necessary in crystalline Si solar cells [3]. Yet, due to the technological and financial challenges in the high quality epitaxy, III-V nitride photovoltaics still remain a promising but a largely unexplored application.

Conventional methods such as MOCVD and MBE are used to grow high quality epitaxial GaN but these processing techniques require high temperatures ($> 800°$C) where the substrates are prone to thermal effects such as cracking and bowing. Sputtering is a promising approach to grow GaN at low temperatures. Our objective is grow and optimize the epitaxial grade GaN at low temperatures by plasma enhanced physical vapor deposition (sputtering). For this purpose, we have designed and built a plasma reactor which employs reactive magnetron sputtering and liquid Gallium is used as the sputtering target. Nitrogen (N_2) and Argon (Ar) are used as the process gases.

Sputtering of III-Vs is a challenging and a seldom explored research area due to its complexity in controlling the process parameters and the bombardment of energetic ions onto the substrate. As a step forward against these issues, this work will focus majorly on in-situ spectroscopic diagnostics.

PVD has several advantages over other conventional methods such as the use of eco-friendly gases, potential for high scalability, growth at lower temperatures and decreasing the production costs drastically. We believe that a high quality epitaxial grade GaN by sputtering would be a game changer not only for the photovoltaics community but also throughout the electronics industry.

References

[1] Alexis De Vos. Endoreversible thermodynamics of solar energy conversion oxford u. p, 1992.

[2] Yasushi Nanishi, Yoshiki Saito, and Tomohiro Yamaguchi. Rf-molecular beam epitaxy growth and properties of inn and related alloys. *Japanese journal of applied physics*, 42(5R):2549, 2003.

[3] Carl J Neufeld, Nikholas G Toledo, Samantha C Cruz, Michael Iza, Steven P DenBaars, and Umesh K Mishra. High quantum efficiency ingan/gan solar cells with 2.95 ev band gap. *Applied Physics Letters*, 93(14):143502, 2008.