MOVPE Development for III/V Multijunction CPV at Spectrolab

Chris Fetzer[1], William Hong[2], Xing-Quan Liu[2], James Chang[2], Maggy Lau[2], Andreea Boca[2], Diane Larrabee[2], Richard King[2], Peter Hebert[2], James Ermer[2], and Rudy Parekh[3]

[1]Corresponding author: Dr. Chris Fetzer, Boeing-Spectrolab, 12500 Gladstone Ave, Sylmar, CA, USA, christopher.m.fetzer@boeing.com, 818-898-2893

[2]Boeing-Spectrolab, Sylmar, CA, USA

[3]Veeco MOCVD Systems, Somerset, NJ, USA

1. Introduction

Demonstrating the 41.6% efficiency world record [1] in concentrator photovoltaics (CPV) requires many areas of expertise. One key element is the metal-organic vapor phase epitaxial (MOVPE) growth of the crystalline device structure for III/V multijunction photovoltaics. This work gives an overview of the present status and future work of Spectrolab in MOVPE development for production III/V multijunction CPV cells.

2. Current Epitaxial Products

C1MJ and C2MJ solar cells with target efficiencies of 36.5% and 37.5%, respectively, at maximum power (50.0 W/cm^2, AM1.5D, ASTM G173-03 spectrum, 25ºC) were developed and produced using Spectrolab's Turbodisk E400 epitaxial tools. These tools produce 12 x 4" dia. wafers per epitaxial run. The novel Veeco Turbodisk K475 epitaxial tool has been under development over the past few years. A new CPV product offering, C3MJ with a target efficiency of 38.5% under the same conditions as quoted above was concurrently developed and qualified on both tools. The K475 platform provides several challenges and advantages for production of the epiwafers which feed C3MJ bare cells. The key challenge is that the K-series platform is relatively undeveloped for the As/P epitaxy needed for multijunction CPV, despite its GaN device heritage. The ability to simultaneously load and run as well as a 15 x 4" dia. configuration raises the throughput ceiling by ~40% over the E400 tools. Multiple in-situ tools such as real-time emissivity corrected pyrometry and wafer curvature add new capability to monitor the process which has improved key process capabilities (Cp) by up to 2x over the E400, with expected further improvement in Cp attainable in certain areas. These advantages result in early, small builds of C3MJ cells produced from epiwafers from the K475 with an additional 1.5% relative improvement in efficiency over cells from the E400 tool, as shown in Figure 1.

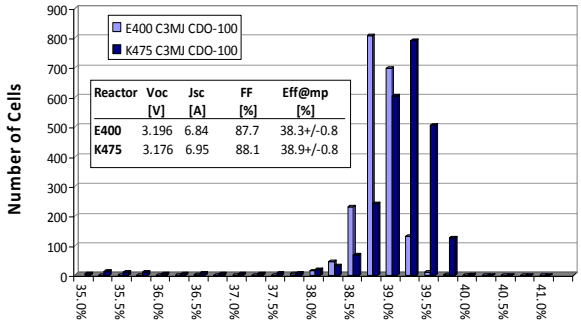

Figure 1. Eff@mp (AM1.5D, 50W/cm2, 25°C, ASTM G173-03) for CDO-100 cells

3. Future Epitaxial Products

Among the various projects under development are the 6" (150 mm) dia. C3MJ epiwafer and the targeted 40.0% efficient C4MJ product. C3MJ cells based on a 7 x 6" configuration show efficiencies equal to those of C3MJ cells produced on 4" dia. wafers over most of the wafer. Thickness uniformity and composition uniformity are also equally attainable on 4" and 6" dia. wafers. Prototype 40% cells for C4MJ take advantage of the in-situ wafer curvature capability of the K475 reactor to repeatedly produce upright metamorphic GaInP/5%-InGaAs/Ge cells with 100% crystal lattice relaxation by 5-point maps of High Resolution X-ray Diffraction in run-to-run stability testing. These same epitaxial experiments have provided early builds averaging 39.6% efficiency at max power spanning multiple experimental runs.

References

[1] R. R. King, *et al.* (2009). 24th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg.