PearL and t-PearL – comprehensive photoluminescence characterization of compound semiconductor thin films

The transfer of Cu(In,Ga)Se_2 (CIGS) thin film photovoltaics from R&D to the gigawatt production scale leads to a growing demand for fully automated process control methods. To support this development, LayTec is proud to announce the extension of its portfolio of photoluminescence (PL) products for thin film semiconductor characterization. The spectral PL (sPL) product PearL has been successfully applied for several years for in-line production control of Cu(In,Ga)Se_2 (CIGS) thin film photovoltaic modules. Here, sPL allows for the spectral analysis of the effective CIGS band gap energy which is directly correlated to the [Ga]/([Ga]+[In]) atomic ratio (GGI). Furthermore, the PL signal also reveals information about the electronic quality of the CIGS thin films. Now t-PearL is specially designed for complimentary characterization of semiconductor thin films by means of time-resolved photoluminescence (TRPL). In contrast to sPL, TRPL investigates the time-resolved decay of the photoluminescence intensity at a fixed wavelength range. Thereby, it directly delivers key figures on the charge carrier lifetime of the semiconductor. Particularly, for thin film photovoltaic materials such as CIGS, CdTe and perovskites, this method has been well established in recent years in the research community but until today no commercial setup for integrated measurements in deposition chambers or production lines has been available. With t-PearL, this powerful metrology method can now be integrated directly in the deposition environment for measurement of carrier lifetimes as low as 5 nanoseconds. By vacuum integration it is also possible to investigate pristine thin films which have not yet been exposed to ambient conditions. For a most complete sample characterization PearL and t-PearL can be combined into one single system. Additionally, both methods are available as metrology components in LayTec's integrated combined in-line metrology stations ILMetro as well as in the stand-alone mapping stations EpiX. Modified versions for longer lifetime materials such as silicon are available on request.

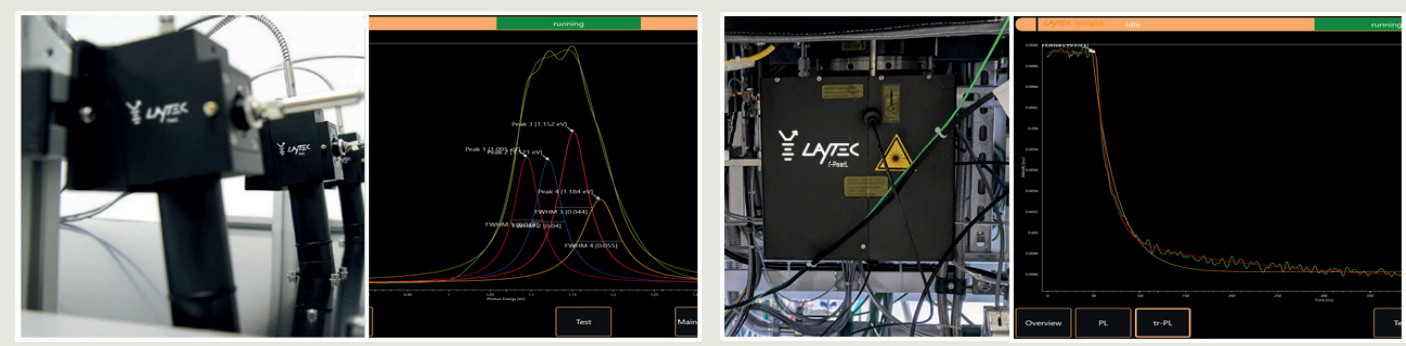

Fig. 1 Left: Production-integrated in-line PearL metrology system for spectral photoluminescence measurements and exemplary data for Cu(In,Ga)Se_2 (CIGS) measurements. Right: Vacuum-integrated combined PearL / t-PearL setup for in-vacuo CIGS analysis at ZSW in Stuttgart, Germany. Additionally, exemplary transients for CIGS time-resolved photoluminescence measurements are shown.

Commissioning of fully integrated combined in-situ and in-line metrology system at ZSW Stuttgart

In February 2021, the first combined PearL / t-PearL system was successfully installed and commissioned at the Zentrum für Sonnenenergie- und Wasserstoffforschung Baden-Württemberg (ZSW) in Stuttgart, Germany. The materials research team at ZSW will use this fully integrated metrology system in combination with various in-situ and in-line metrology methods to monitor and control the process development of the CIGS solar cells. The target is to further develop and improve the efficiency of CIGS thin film solar cells to values above 25% – i.e. beyond the current world record value of 23.4% – and to understand the mechanisms governing the performance of these devices. Therefore, a new vacuum cluster system combining two RIBER MBE 412 Molecular Beam Epitaxy (MBE) chambers and a VON ARDENNE Physical Vapor Deposition (PVD) chamber has been designed. Riber`s vacuum cluster system is a fully automated system which includes a RIBER central UHV cluster robot for transferring samples between all chambers. It is worth emphasizing that all LayTec systems have been fully interfaced into RIBER's Crystal XE control software for acquisition control and data recording. That enables for a quick and easy access to the relevant analytic parameters of each processed samples in Crystal XE software during or after thin film depositions for real-time monitoring or for later analysis. With reference to metrology methods, this cluster system employs LayTec`s InspiRe system for in-situ reflectance measurements in the MBE chamber during CIGS co-evaporation. Moreover, two EpiTT systems are integrated for monitoring the CIGS co-evaporation and the post-deposition treatment in-situ. Additionally, a combined PearL / t-PearL has been integrated in the transfer chamber between the RIBER MBE chamber and the VON ARDENNE PVD chamber. As a result, samples can be analyzed by both PL methods directly after CIGS deposition or post-deposition treatments as well as before and after TCO deposition. The resulting in-depth understanding of the CIGS material will enable further improvement of CIGS solar cells aiming at even more efficient CIGS record devices.