Advanced measurement of Visible & Near-Infrared photoluminescence in energy materials

Application Note

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Introduction

Energy materials are a broad and diverse area of study. Among them, Indium Phosphide (InP) and Gallium Arsenide (GaAs) show characteristic photoluminescence peaks in the near-infrared light range [1]. At the same time, many other prominent energy materials such as Ta_3N_5 and diamond exhibit properties that can be observed in the visible part of the spectrum. Generally, capturing both of these ranges simultaneously with high resolution is challenging. However, with Andor's new technological advancements, we are now able to study a wide range of materials with high accuracy in a single setup, as we show here for the example of various semiconductor materials.

Setup

For our experiments, we used the Andor Kymera-193i-B1-SIL spectrograph that is specifically designed to study both the near-infrared and visible emissions. To ensure low noise and efficient detection, the spectrograph is paired with Andor's iDus DU416A-LDC-DD CCD detector.

Results

Upon excitation with 532 nm laser illumination, InP and GaAs show photoluminescence activity in the near-infrared range. This observation suggests a high value of both materials for future technological applications, especially for optoelectronics and photovoltaics, and motivates a detailed and comprehensive investigation of the materials' characteristic emission spectrum [2, 3, 4].

In contrast, most of the other energy materials we study in our group have a band gap in the visible region of the spectrum (Figure 2). The combination of Andor's sophisticated CCD detector and the Kymera spectrograph now allows us to realize high-quality measurements in both spectral regions in one setup. This not only makes individual measurements comparable and easier to implement, but we also benefit from a significantly improved signal to noise ratio (SNR), especially in the infrared regime. We illustrate this with the photoluminescence spectra of two InP and GaAs samples under 532 nm illumination (Figure 1), which we recorded with both the new Kymera spectrograph (New Setup) and the older spectrometer used previously (Old Setup).

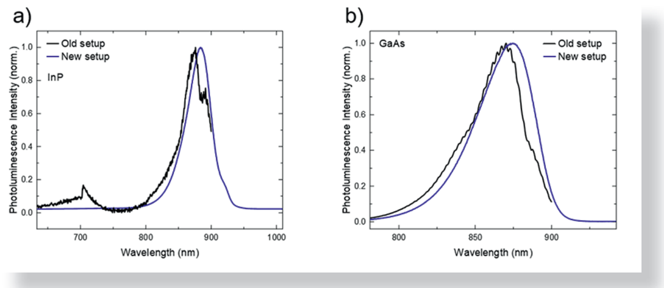

Figure 1. Photoluminesence spectra of (a) InP and (b) GaAs upon excitation with a 532 nm laser. The spectra recorded in the new setup (black) exhibit a much higher SNR compared to the data from the old setup (blue) and are free of calibration artifacts.

As can be seen from these two examples, the new setup not only offers us a significantly improved SNR, but above all the newly recorded spectra are free of calibration artifacts. Especially the latter are particularly critical, since they cannot be removed by measurement repetitions and can easily lead to a misinterpretation of the data.

One of the standout conveniences of the Andor setup is its versatility. The seamless transition between near-infrared and visible ranges without the need for substantial recalibrations or the exchange of equipment greatly enhances the efficiency of our experiments. We can now study a variety of energy materials with various optical properties without being encumbered by interrupting equipment changes. This adaptability not only saves precious time, but also reduces potential error sources introduced by equipment swaps, ensuring consistency in all measurements. Thus, we could accurately measure a broad spectral range of our various samples without altering the setup (Figure 2).

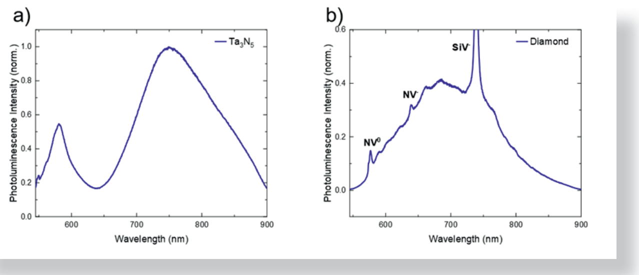

Figure 2. Photoluminescence spectra upon 532 nm illumination. (a) Ta_3N_5 exhibits photoluminescence from both, defect states and direct band-to-band transitions. (b) The spectrum of diamond exclusively stems from numerous defects within the bandgap. Here, most prominent are the characteristic zero-phonon lines and phonon sidebands of Silicon-vacancy (SiV) centers as well as both charge states of the nitrogen-vacancy center (NV0 and NV-).

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Conclusion

The introduction of Andor's advanced tools has undoubtedly enhanced the quality and precision of our study on energy materials. One of the standout conveniences of the Andor setup is its versatility, that allows a seamless transition between measurements in the near-infrared and the visible regime. Eliminating the need for setup modifications or recalibrations before each experiment not only boosts efficiency, but also ensures consistency between individual measurement series. Together with the improved SNR, this allows a broader and more thorough investigation of a wide range of energy materials and underlines the importance of integrated solutions in advancing our understanding of energy materials and their potential applications.

References

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