

MOVPE grown InGaN/GaN core-shell microrods for photocatalytic water splitting

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INTRODUCTION

III-nitride (nano)structures have emerged as a promising platform for conversion the solar energy to the hydrogen fuel by the photoinduced water splitting. InGaN/GaN system is adopted for the application taking advantage of tunable InGaN bandgap across the whole visible spectrum from near UV to near infrared region. Nanowire/microrod arrays of these heterostructures benefit from enhanced charge transfer owing to its large surface area, short carrier collection pathways and light distribution¹ in comparison to planar counterparts.

Although the InGaN material is one of the promising candidates to be used for simple one-step photocatalytic (PC) water splitting, reports on that topic are rare² and the systematic study of growth aspects and their relationship to water splitting efficiency is missing. In this contribution, we present an experimental study on the self-assembled InGaN/GaN core-shell microrod array for PC water splitting focusing on the growth optimization conditions for MOVPE process (growth temperature, V/III ratio, growth rate, doping etc.).

EXPERIMENTAL STUDY

InGaN/GaN core-shell rods were prepared by MOVPE on sapphire substrates. The 3D growth mode was facilitated by SiH₄ injection at the start of the growth. First, GaN microrods cores were deposited and then the shell InGaN layer was grown at different growth conditions to find the most suitable material for PC water splitting.

Cathodoluminescence (CL) images were collected by a home-built setup in Scanning Electron Microscope Philips XL30ESEM. The setup consists of parabolic mirror, optical fiber, lens, single-grating monochromator and photomultiplier tube Hamamatsu H7711-13. Acceleration voltage of 10 keV was used.

Photocatalytic experiments were realized in a batch photoreactor in the presence of a reaction mixture containing 100 ml of 50% CH₃OH. A 365 nm LED was used as irradiation source. The gaseous samples were analyzed using a gas chromatograph (GC/BID, Shimadzu Nexis GC-2030). The reaction mixture was exposed to irradiation for 4 hours and samples of the gaseous phase were taken at time intervals of 1, 2, 3 and 4 hours for analysis.

RESULTS AND DISCUSSION

Fig. 1 (left) shows the distribution of rods grown at 700°C together with the In distribution in the rod as well as the CL map. Both the rod density and In distribution affect the water-splitting efficiency. Figure 1 (right) shows the H₂ generation time dependency for 3 samples in which InGaN shell was grown at different temperature, clearly indicating that the growth temperature is one of the key factors needing optimization for the intended application. However, a compromise between the In content (determining the portion of sunlight which can be harvested) and structural quality must be found, as both of these parameters are affected by the growth temperature of InGaN shell.

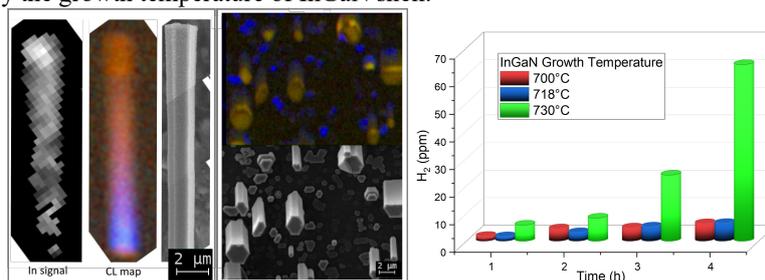


Fig. 1: Left – InGaN/GaN core-shell microrods grown at 700°C. Right: time evolution of H₂ generation for InGaN/GaN microrods with InGaN shell grown at different temperatures.

CONCLUSION

In this contribution we provide a systematic study of MOVPE growth conditions for InGaN/GaN microrods. We find that the quality of InGaN shell is strongly affected by growth temperature, while the In content is less sensitive to this parameter compared with the planar counterparts. Other growth parameters are also tested and discussed with the aim of finding an optimal structure for PC application.

REFERENCES

1. Osterloh, F. Chem. Soc. Rev. 42, 2294-2320 (2013)
2. Kibria, M., et al. Nat Commun 6, 6797 (2015)