Enhancing optoelectronic and structural properties of ALD-grown aluminum doped zinc oxide by pulse composition tuning

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In recent years, there has been great interest in inexpensive and scalable technologies for manufacturing of semiconductor structures. Among them, the atomic layer deposition (ALD) growth technique gained a lot of attention for its versatility, scalability and ability to provide materials of sufficient quality for many optoelectronic applications. This technique is widely used for depositing a vast variety of oxides, sulfides, nitrides, and pure metals [1,2] in an easily accessible environment that does not involve very high temperatures (typically below 250 °C) or high vacuum. The ALD growth is a self-limiting process, which means that when the precursor saturates the dangling bonds of the surface, the reaction stops, prohibiting the excessive growth of the material during the single cycle of growth. In this way, a highly precise thickness control is achieved by adjusting the appropriate number of cycles.

An important feature of the ALD method is the ability to change the length and sequence of precursor pulses, which allows for controlling the stoichiometry, concentration of natural defects, and the crystalline quality of the deposited material. This feature is not widely exploited in the literature.

In the presented work, research was undertaken to obtain an aluminum-doped zinc oxide (AZO) –commonly known in the literature material, using the ALD method. The primary goal was to improve structural and optical properties of AZO via changing sequence and duration of precursor pulses. We aimed to enhance carrier concentration and mobility in AZO and to study tuning of the band gap as well. We observed significant differences in the photoluminescence and absorption spectra, such as increase in the photoluminescence intensity (Fig.1), which could indicate the improvement in structural quality, and energy gap widening, due to higher aluminum incorporation. Grown AZO layers were studied with different structural characterization techniques to gain a deeper understanding of mechanisms of the ALD process.

Photoluminescence, absorption and SEM measurements revealed that pulse doubling improves crystal quality without changing its composition, while longer pulse increases Al content.

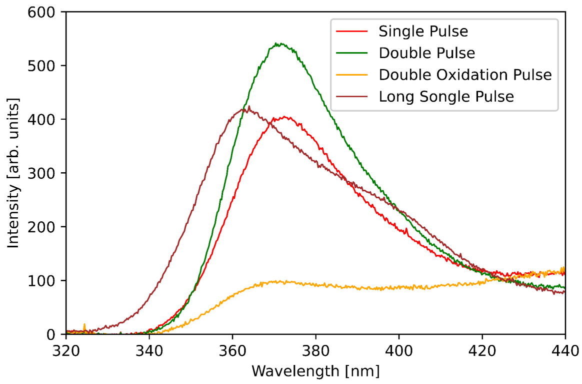

Figure 1. Photoluminescence spectrum of AZO layers with different pulse sequences. Single pulse lasts 120 ms.

1. D.J. Hagen, et. al., Appl. Phys. Rev. 6 (2019). https://doi.org/10.1063/1.5087759.

2.H.C.M. Knoops, et. al., J. Vac. Sci. Technol. A. 37 (2019) 030902. https://doi.org/10.1116/1.5088582.