Opto-Electronic Advances

Supplementary information

September 2023, Vol. 6, No. 9

DOI: 10.29026/oea.2023.230004

Rapid inactivation of human respiratory RNA viruses by deep ultraviolet irradiation from light-emitting diodes on a high-temperature-annealed AlN/Sapphire template

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Supplementary information for this paper is available at https://doi.org/10.29026/oea.2023.230004

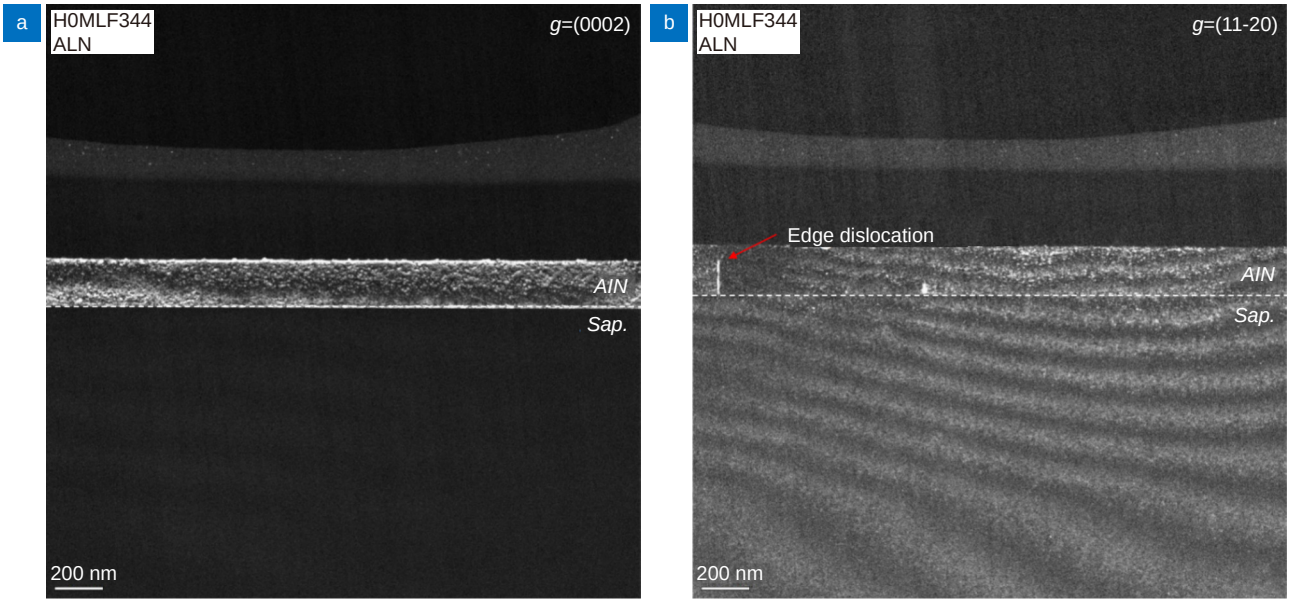

Fig. S1 | Cross-sectional dark-field transmission electron microscopy images of the high-temperature- annealed (HTA) AlN/Sap. Template along <1-100> direction at the diffraction vectors of (**a**) *g*=(0002) and (**b**) *g*=(11-20). The thickness is approximately 200 nm. As is seen, there are no observable screw dislocations and mixed dislocations and there is only one edge dislocations observable in the image, indicating the high-quality of the HTA AlN/Sap. template.

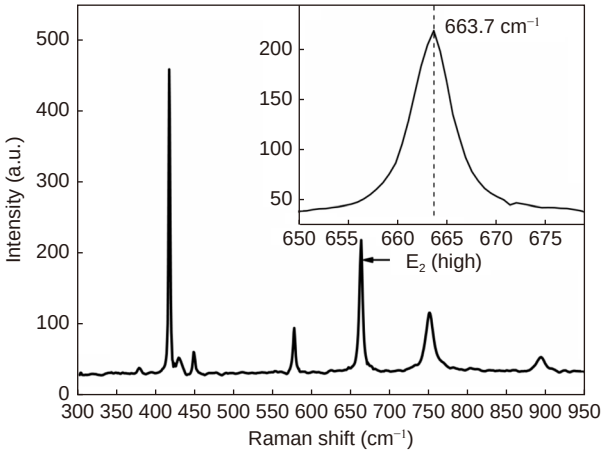

Fig. S2 | Raman spectrum of the HTA AlN/Sap. template at normal incidence to the surface at room temperature (RT). The inset is the enlarged E_2(high) phonon mode. Due to the high Raman scattering cross-section of the E_2(high) phonon mode, strain information can evidently be extracted from the frequency of the E_2(high) phonon mode. For AlN, the Raman peak will shift to higher frequency as a result of compressive stress and to lower frequency as a result of tensile stress. The E_2(high) phonon frequency of an unstrained AlN is 657.4 cm^{-1} at RT. The E_2(high) phonon frequency of the HTA AlN/Sap. template is 663.7 cm^{-1}, indicating the strong compressive stress. The compressive stress can be roughly estimated by the Eq. (S1) [S1]

$$\omega = 657.4 - 2.589 \times \sigma \tag{S1}$$

where σ is the basal plane stress in the AlN layer and ω is the E_2(high) position with the unit of cm^{-1}. The calculated stress of the AlN layer is about –2.4 GPa, which is very strong for AlN layer.

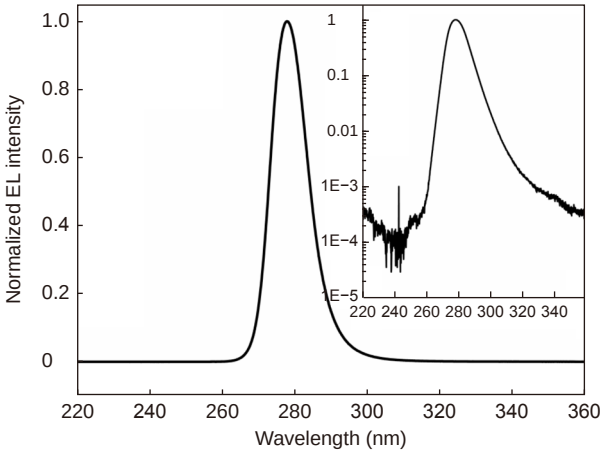

Fig. S3 | Normalized EL spectra at 100 mA for the 278 nm-LED. The inset is the log-scale graph. There are no obvious other parasitic peaks observed.

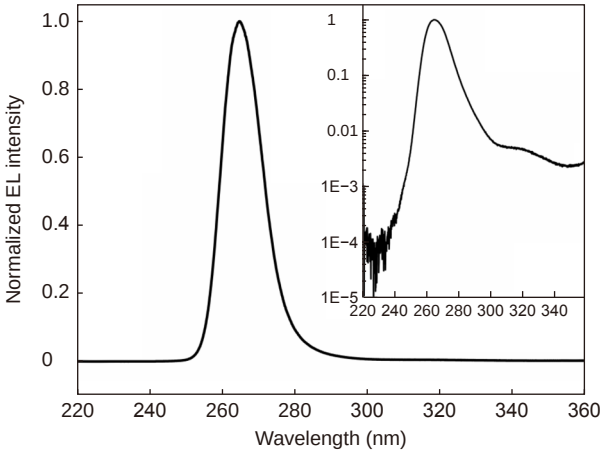

Fig. S4 | Normalized EL spectra at 100 mA for the 265 nm-LED. The inset is the log-scale graph. There is just a longer wavelength shoulder peak located at near the wavelength of 320 nm, which may be related to the point defect level. However, the intensity is less than 1% of the peak intensity.

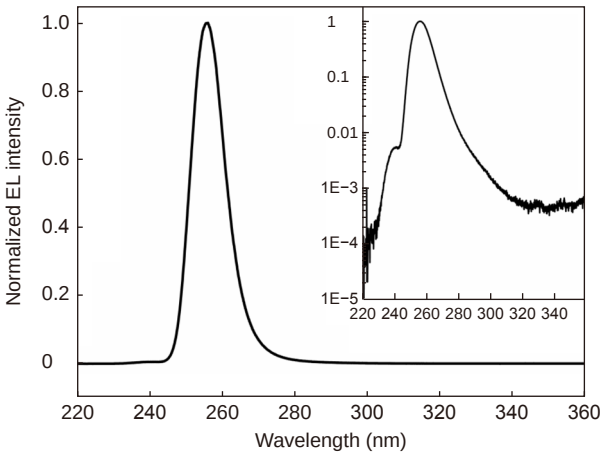

Fig. S5 | Normalized EL spectra at 100 mA for the 256 nm-LED. The inset is the log-scale graph. There is just a shorter wavelength shoulder peak located at near the wavelength of 240 nm, which may be related to the electron overflow from MQWs to the EBL. However, the intensity is less than 1% of the peak intensity.

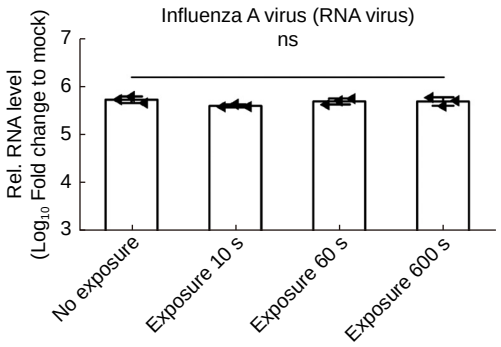

Fig. S6 | The viral titer is determined by qPCR. The virus suspension (60 μL, 1~2 mm depth) is placed in a defined well of a 24-well plate, and the virus suspension is exposed to the air for 10 s, 60 s, and 300 s. Another 24 hours later, the qPCR is performed to quantify the RNA of the influenza virus.

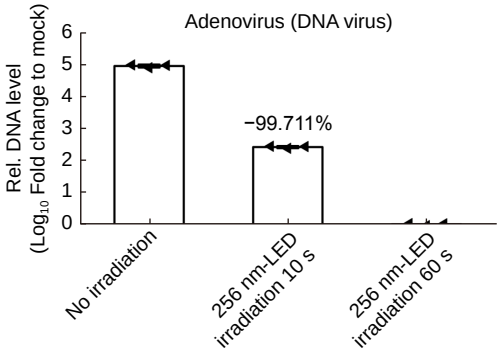

Fig. S7 | Inactivation ability of the 256 nm-LED for DNA virus adenovirus. Viral inactivation effects of the 256 nm-LED are determined within 10 s and 60 s at an irradiation distance of 4 cm at 100 mA. The initial titer of adenovirus is 1.8×10^5 PFU in 60 μL. After 24 hours, the real-time reverse-transcriptase-polymerase chain reaction (qPCR) is performed to quantify the DNA of the adenovirus. DNA is a double-stranded nucleotide, being more stable than RNA. Therefore, DNA virus disinfection might require a longer time than RNA virus disinfection.

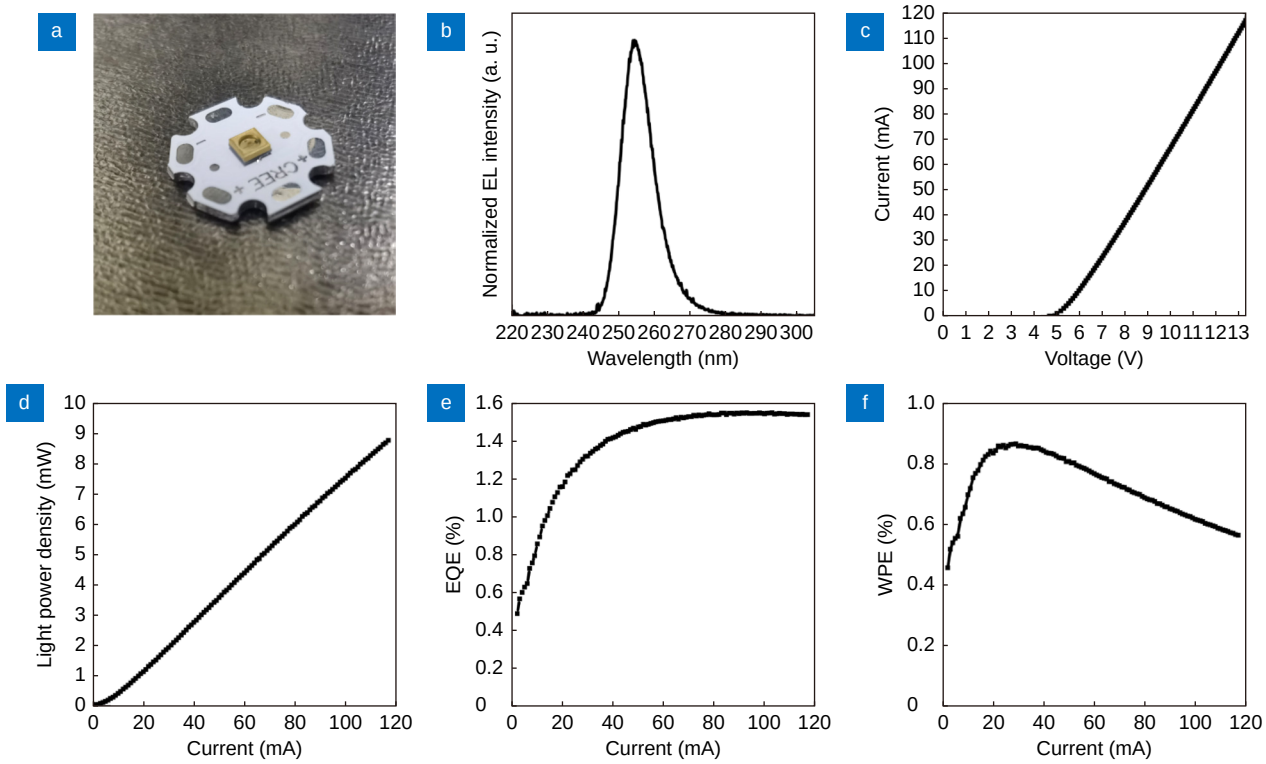

Fig. S8 | Characterization of a commercially available 254 nm-LED. (**a**) Photos, (**b**) EL spectrum at the current of 100 mA, (**c**) IV curve, (**d**) LOP curve, (**e**) EQE, and (**f**) Wall-plug efficiency (WPE). To compare the performance of our 256 nm-LED with the commercial available DUV LEDs with similar emission wavelength, we randomly purchased LEDs with a nominal 254 nm. The measured emission wavelength at the current of 100 mA is 254.5 nm. The IV characteristic is obviously not as good as our 256 nm-LED. At the current of 100 mA, the voltage is 12.2 V for the purchased one while that of our 256 nm-LED is 7.2 V. As for the LOP, the purchased one is slightly better than ours. At the current of 100 mA, the LOP is about 7.5 mW for the purchased one while that of our 256 nm-LED is 6.8 mW. From the perspective of energy conversion, the peak EQE and WPE of the purchased one are about 1.5% and 0.86% while that of our 256 nm-LED are about 1.4% and 1.3%. Therefore, on the whole, the performance of our 256 nm-LED is similar to the commercially available nominal 254 nm counterpart, indicating that sterilization and disinfection using DUV LED is not only high-efficiency but also very easy in today's public life.

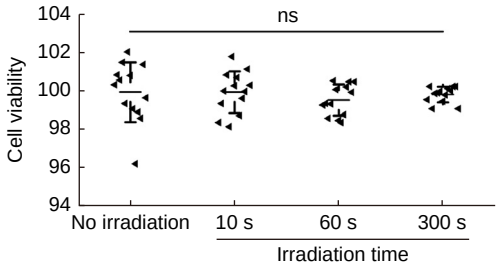

Fig. S9 | The cell viability is determined by the CCK-8 method. The A549 cells are seeded in 96-well plates. After 12 hours, cells with the culture medium of DMEM are irradiated by the 256 nm-LED for 10 s, 60 s, and 300 s under a distance of 4 cm at 100 mA. Another 24 hours later, fresh medium containing CCK-8 (Yeason, 40203ES80) reagent is replaced to each well, then incubated the plates at 37 ℃ for one hour. Finally, absorbance is measured at 450 nm. The results show that the 256 nm-LED irradiation causes little cell damage under this condition.

References

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