PECVD Grown Graphene as Transparent Electrode in GaN-based LEDs

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Transparent electrodes are key components of numerous electronic devices like touchscreens, solar cells and light-emitting diodes (LEDs). Graphene combines large electrical conductivity and high optical transparency up to the UV spectral range and is thus a quite attractive transparent electrode for gallium nitride (GaN) based LEDs. A common method to realize graphene electrodes is the transfer of graphene grown via chemical vapor deposition (CVD) on metallic substrates (e.g. copper foil) onto the target device. However, such transfer processes are hardly scalable and potentially damaging to the graphene layers.

Here, we report on our latest results towards the direct growth of graphene on GaN based LEDs by a plasma-enhanced CVD (PECVD) process. The PECVD process is performed in a 4" Black Magic CVD system from AIXTRON and was originally developed for low temperature graphene growth on catalytic substrates [1]. Our single-step process uses a N_2-atmosphere instead of the commonly used H_2 atmosphere and growth temperatures below 800 °C for protecting the GaN LED surface [2]. By varying the growth time, we were able to control the thickness of the grown graphene layers starting from virtually a monolayer up to a few (~6) layers with increasing growth time (**figure 1 a**). Simultaneously, the sheet resistance decreases down to ~1 kΩ/□ when changing the growth time from 30 min. to 4 hours, while keeping the transparency losses below ~12% (**figure 1 b**). The excellent functionality of our graphene layers as transparent electrodes is demonstrated by a significant increase of the lateral current spreading, where an enhancement of the light emitting area around tailored contacts by almost an order of magnitude was achieved with respect to a reference device, where current spreading only occurs within the *p*-GaN cladding layer (**figure 1 c-d**).

References

[1] Bilge Bekdüz et al., Nanotechnology 29 (2018) 45, 455603
[2] Jan Mischke et al., 2D Materials, 7 (2020) 035019

Figures

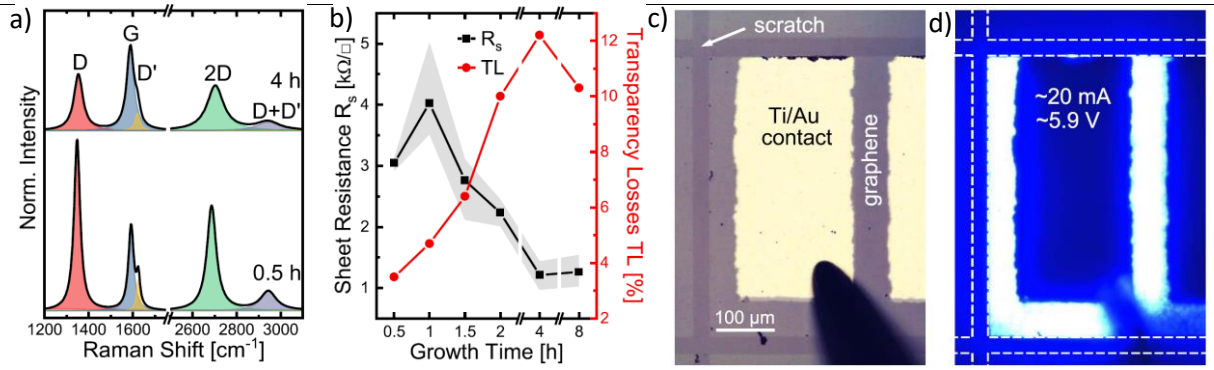

Figure 1: a) Raman spectra of graphene layers for a growth time of 0.5 h and 4 h, respectively. b) Average sheet resistance R_S (black) and average transparency loss TL in % (red) for various growth times. c) Image of the corresponding GaN LED surface with the graphene electrode and Ti/Au contacts. d) Light emission around the contact area of the biased GaN LED with graphene electrode at 20 mA.