

Direct graphene growth on GaN and Au materials using the PECVD method

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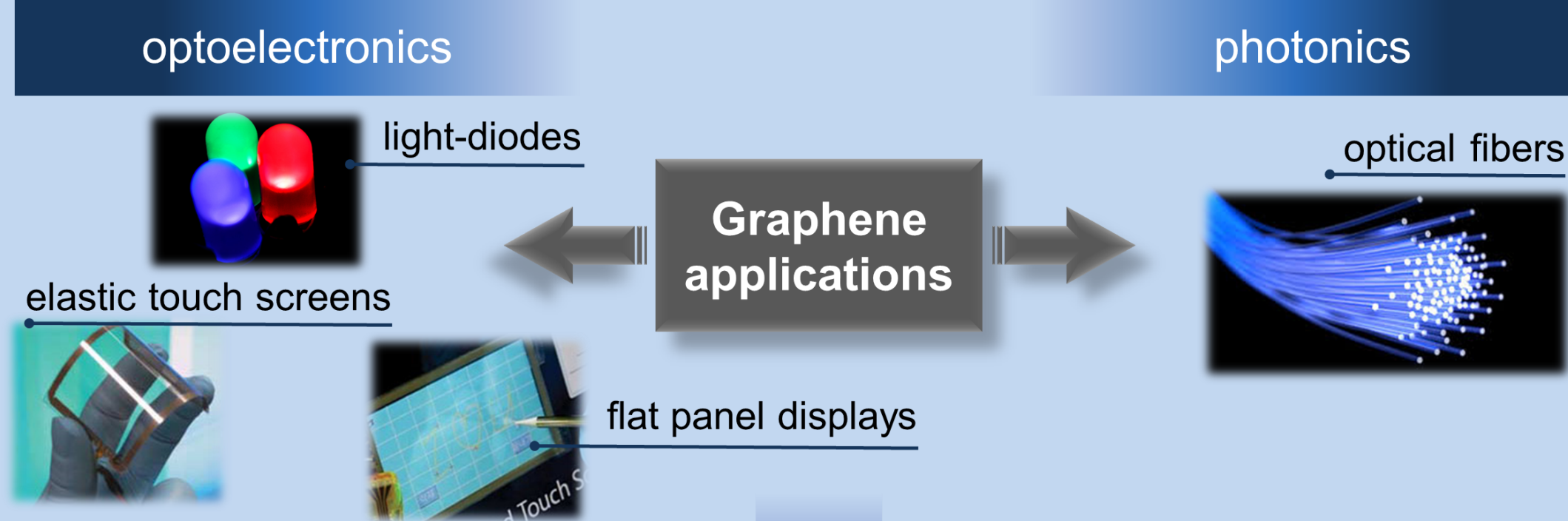
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Introduction

Great interest in graphene applications in photonics and optoelectronics **still requires alternative methods of obtaining high-quality graphene.**



For these applications, **the transfer of the graphene layer onto target substrate** is the most widely used method today despite its limitations

Cons of transfer method:

- mechanical damage, e.g. holes, wrapping, wrinkles
- introduction of mechanical or thermal stresses
- contamination by reagent residues, ex. PMMA.

Therefore, in this work we present the alternative method of obtaining graphene directly on target substrates

Aim of the studies

The present work aim to examine the possibility of using plasma-enhanced chemical vapor deposition (PECVD), as an alternative method for obtaining graphene.

Literature reports that for epitaxial growth of graphene, plasma is another and additive source of energy to thermal energy, which allows to decrease the growth temperature (Md. S. A. Bhuyan, *Int Nano Lett* (2016) 6:65–83)

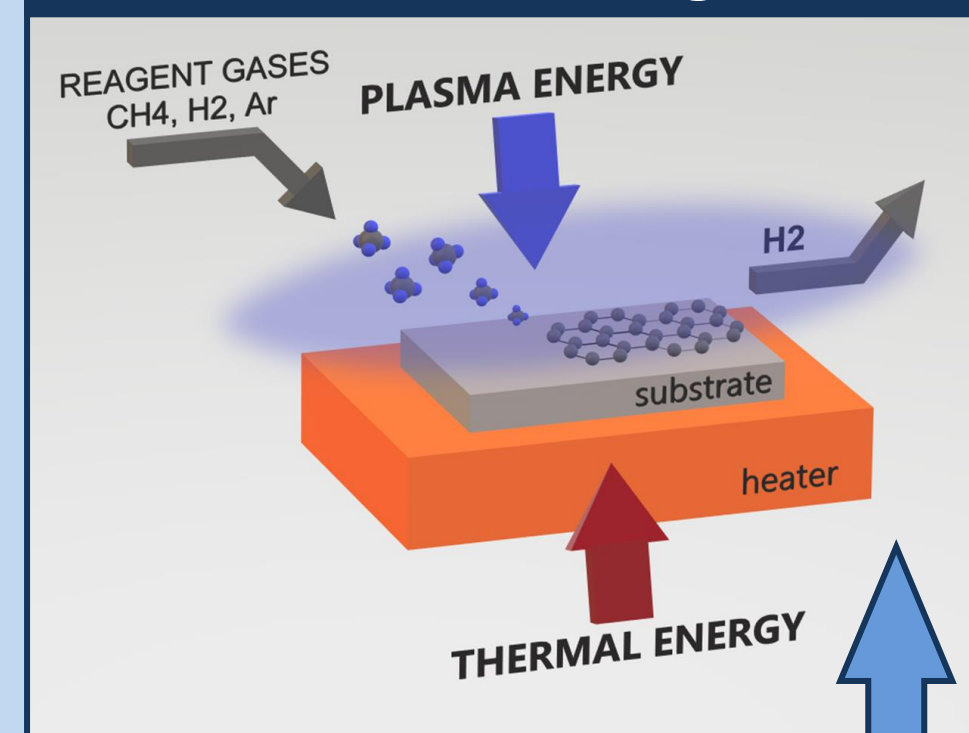
Sample preparation and PECVD system

Substrates used for graphene growth:

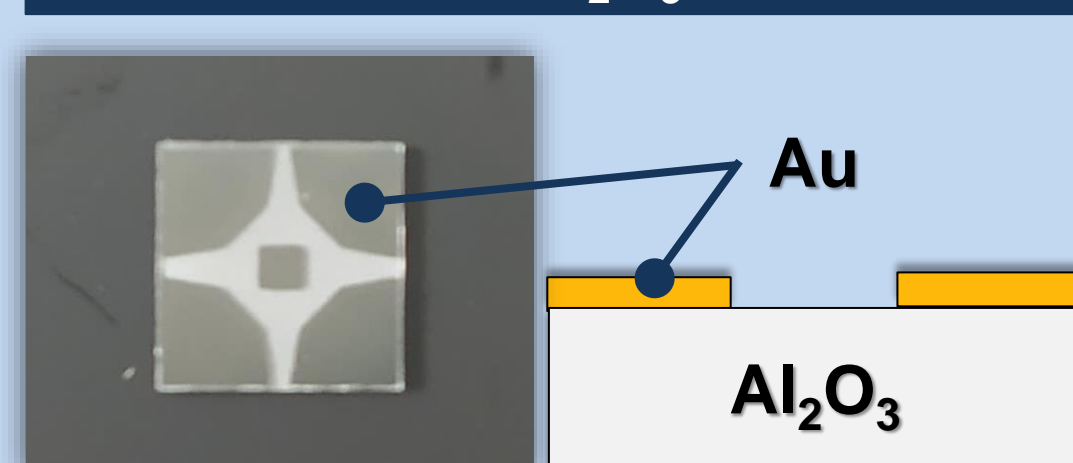
- 20 nm Gold deposited on sapphire (**Au/Al₂O₃**)
- 1400 nm highly resistive gallium nitride epitaxial structure on sapphire (**HR-GaN**)

Black Magic PECVD System Pro 2-inch AIXTRON Nanoinstruments

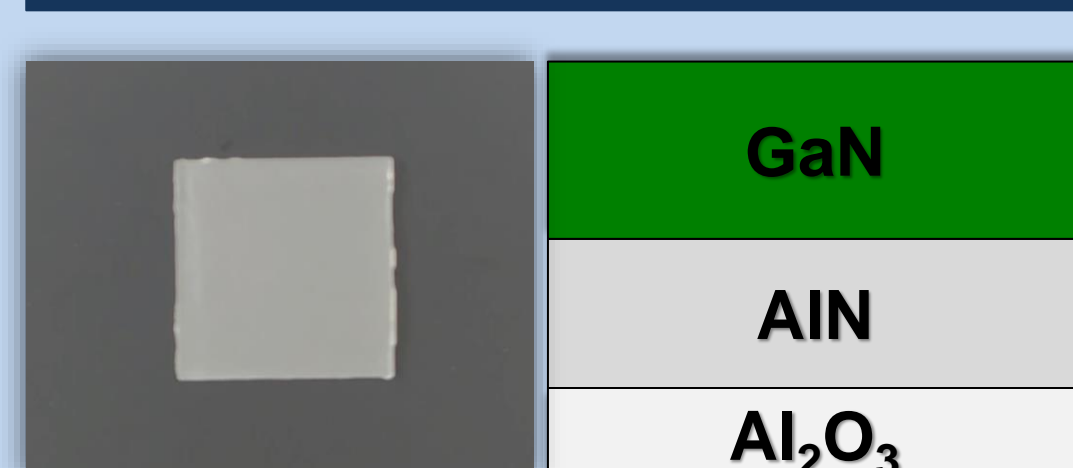
Scheme of PECVD growth



Au/Al₂O₃



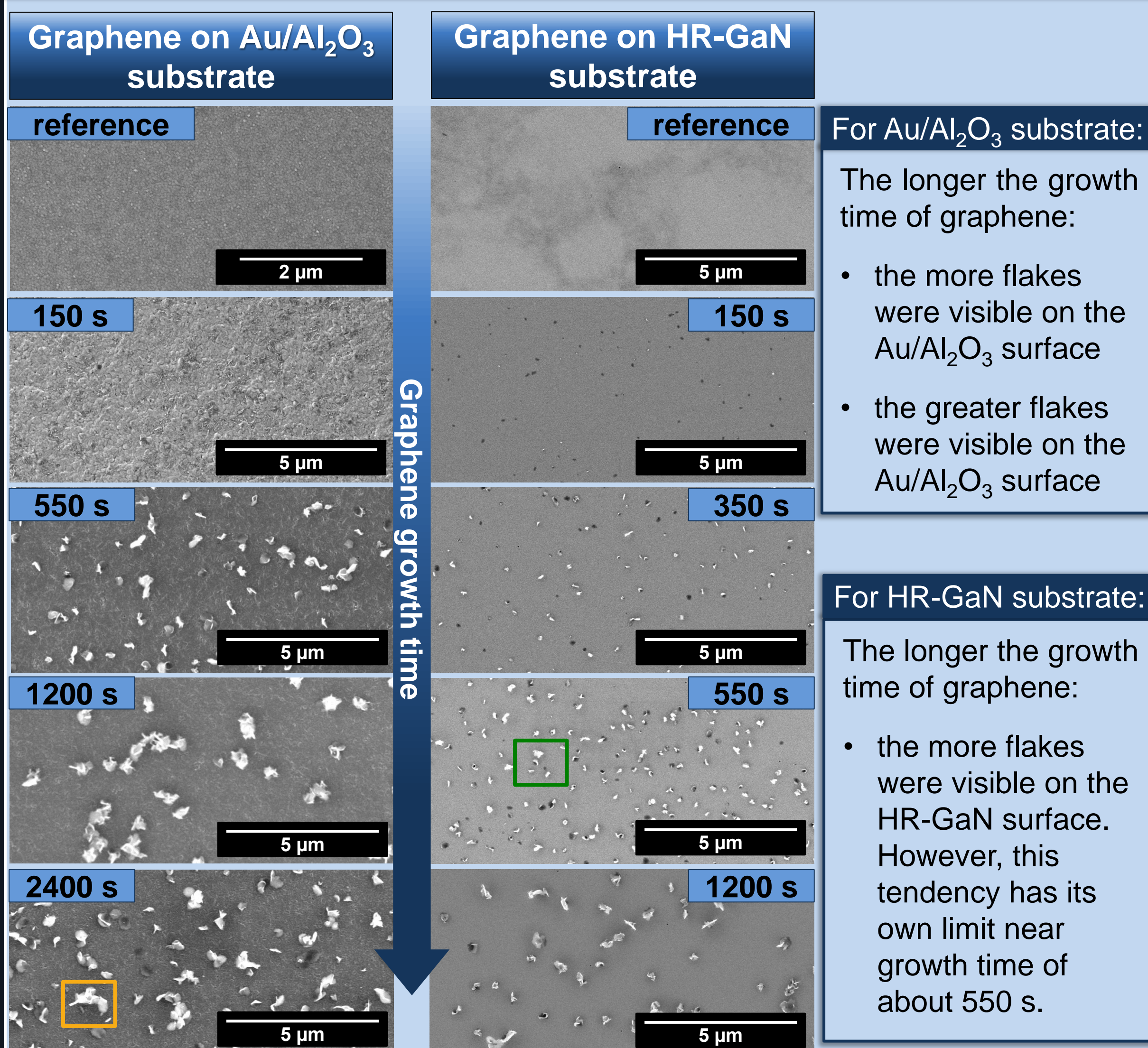
HR-GaN



Process parameter	Value
Plasma voltage [V]	400-700
Temperature	600 °C
Pressure	2 mbar
CH ₄ :H ₂ :Ar flow ratio	2:5:50
Growth time [s]	150s - 2400s

Results

SEM observations show that after plasma-enhanced growth of graphene, spatial flakes with lighter contrast were visible on both Au/Al₂O₃ and HR-GaN substrates. These flakes were non-homogeneously distributed on the whole surface of the substrates.



For Au/Al₂O₃ substrate:

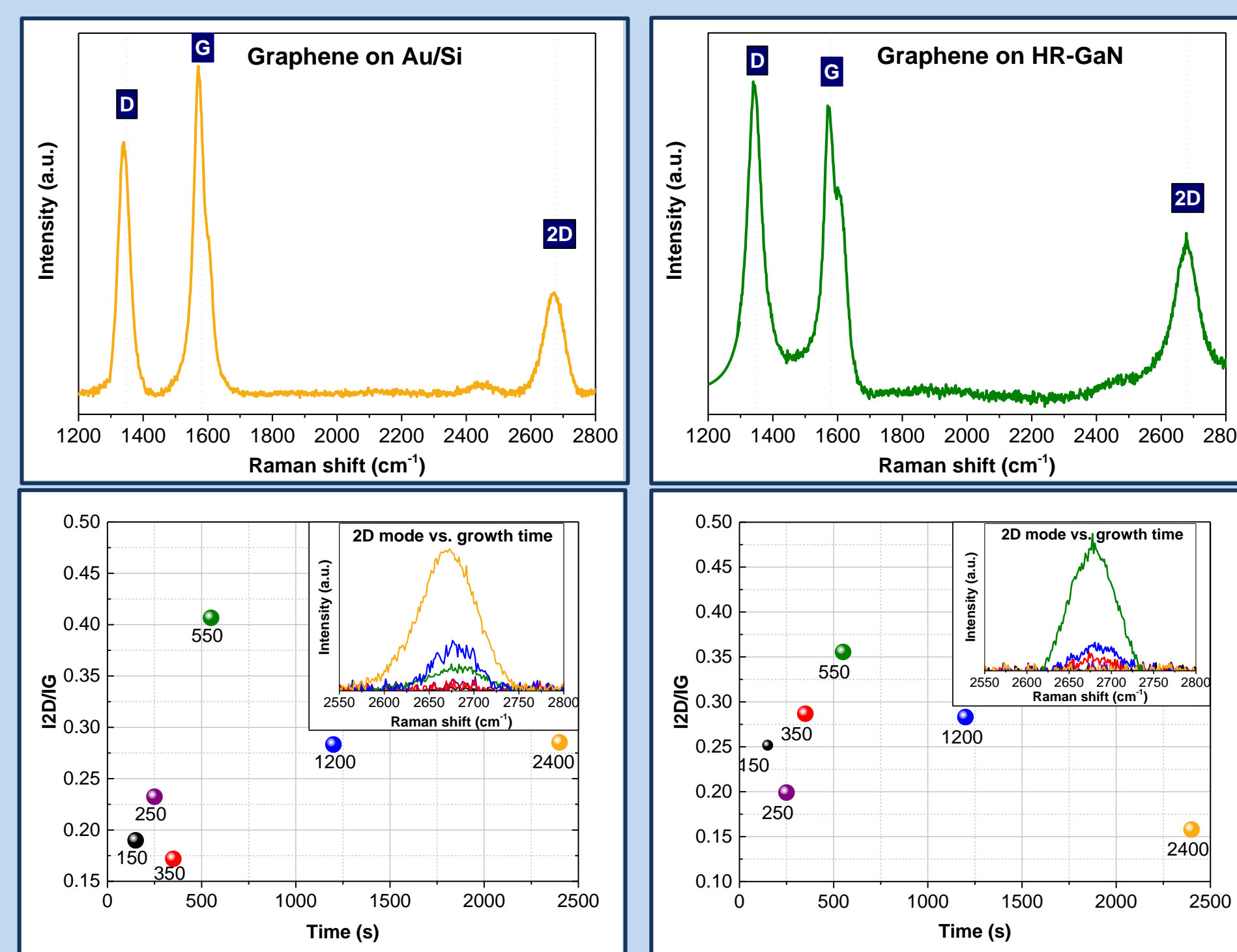
The longer the growth time of graphene:

- the more flakes were visible on the Au/Al₂O₃ surface
- the greater flakes were visible on the Au/Al₂O₃ surface

For HR-GaN substrate:

The longer the growth time of graphene:

- the more flakes were visible on the HR-GaN surface. However, this tendency has its own limit near growth time of about 550 s.



Raman measurements show **the presence of the 2D mode at 2700 cm⁻¹**, that characterizes the hexagonal arrangement of carbon atoms in graphene, independently from the used substrate. However, the intensity of 2D mode is lower than of G peak (1580 cm⁻¹), indicating that obtained carbon structure has not fully organized. The 2D/G intensities ratio are in the range from 0.15 to 0.40, with the highest value for growth time of about 550 s.

For graphene on Au/Al₂O₃, as well as graphene on HR-GaN the intensity of defective D mode at 1350 cm⁻¹ is high, indicating low quality of graphene.

Summary & conclusions

Plasma-enhanced chemical vapor deposition method allows to obtain graphene on Au and HR-GaN substrates. The growth of graphene is non-homogeneous and has a form of spatial flakes. Investigations indicate that growth time has a key role in controlling graphene flakes:

1. The growth time has influence on the number and size of graphene flakes on Au substrate. The optimum time for graphene growth on Au is 2400 s
2. Using a shorter growth time is more beneficial for graphene on HR-GaN. The growth time about 450-550 s is a optimal time for graphene growth.

However, there is a need for further research concerning other proces parameters to obtain continuous layer with high quality.