

SUPPLEMENT

Table S1. Raman scattering spectra parameters (I_D/I_G and I_{2D}/I_G) and their dispersion within the each sample ($\Delta(I_D/I_G)$ and $\Delta(I_{2D}/I_G)$).

Sample No.	Co, nm	Temperature during the ion beam irradiation, °C	Annealing temperature, °C	Ion beam energy, eV	I_D/I_G	$\Delta(I_D/I_G)$	I_{2D}/I_G	$\Delta(I_{2D}/I_G)$
1	25	700	-	800	0,960	0,018	0,776	0,003
2	25	800	-	800	1,080	0,014	0,206	0,002
3	25	600	-	800	1,270	0,005	0,389	0,005
4	25	700	-	500	0,925	0,030	0,337	0,097
5	25	700	-	300	0,980	0,018	0,530	0,018
8	10	600	-	800	1,161	0,016	0,422	0,014
9	55	600	-	800	0,842	0,014	0,591	0,014
10	40	600	-	800	0,958	0,028	0,669	0,086
11	25	400	700	800	1,618	0,016	0,505	0,014
12	10	400	700	800	1,839	0,002	0,302	0,003
13	40	400	700	800	0,969	0,012	0,452	0,033
14	30	400	700	800	0,983	0,036	0,401	0,002
15	40	400	600	800	0,914	0,028	0,551	0,001
16	40	400	500	800	No gr.*	No gr.	No gr.	No gr.
17	40	400	-	800	No gr.	No gr.	No gr.	No gr.
18	40	400	550	800	No gr.	No gr.	No gr.	No gr.

* - No gr. means „no graphene“.

Table S2. Graphene layer number evaluation using the I_{2D}/I_G ratio (the estimation was done for graphene synthesized on Si(100)).

Sample No.	Co, nm	Temperature during the ion beam irradiation, °C	Annealing temperature, °C	Ion beam energy, eV	I_{2D}/I_G	Graphene layers number *	Average graphene flake thickness (nm)**
1	25	700	-	800	0,776	1-2	-
2	25	800	-	800	0,206	~7	2,85
3	25	600	-	800	0,389	~4	1,62
4	25	700	-	500	0,337	~5	1,97
5	25	700	-	300	0,530	~2	0,67
8	10	600	-	800	0,422	3-4	1,40
9	55	600	-	800	0,591	1-2	0,26
10	40	600	-	800	0,669	1-2	-
11	25	400	700	800	0,505	~2	0,84
12	10	400	700	800	0,302	5-6	2,20
13	40	400	700	800	0,452	~3	1,20
14	30	400	700	800	0,401	~4	1,54
15	40	400	600	800	0,551	1-2	0,53
16	40	400	500	800	No gr.	1-2	-
17	40	400	-	800	No gr.	~7	2,85
18	40	400	550	800	No gr.	~4	1,62

* Estimated according to [1]. The original equation can be used for thickness evaluation when graphene layer number is two or more [1].

** The average graphene flake thickness was evaluated using the graphene layer number estimated according to [1], and the graphene monolayer thickness was set at 0.4 nm [2]. It should be mentioned that the original equation can be used for thickness evaluation when graphene layer number is two or more [1]; therefore, it was impossible to estimate the graphene flake thickness for some samples.

S_OP. Optical photos

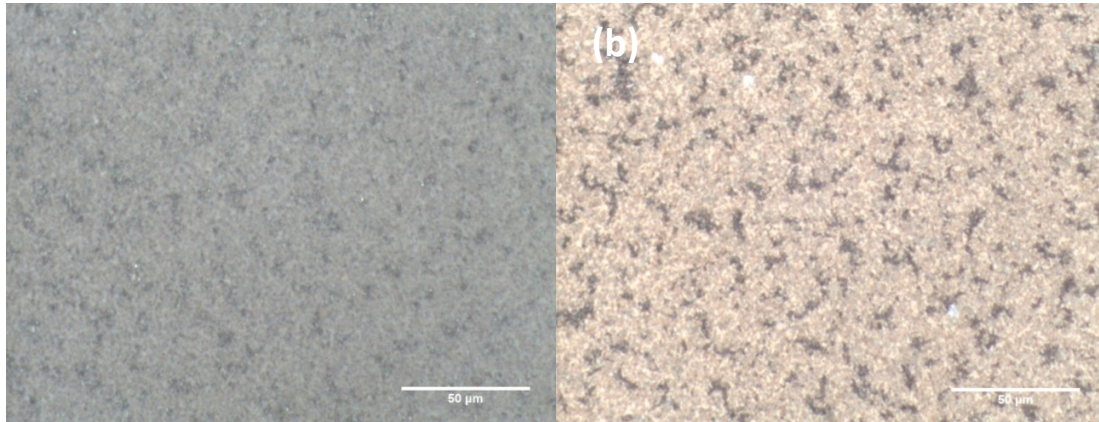


Figure S1. Optical microscopy photos, comparing a sample surface, synthesized at 800 °C, after synthesis (a), and after the cobalt interlayer removal (b), the scale bar represents 50 μm.

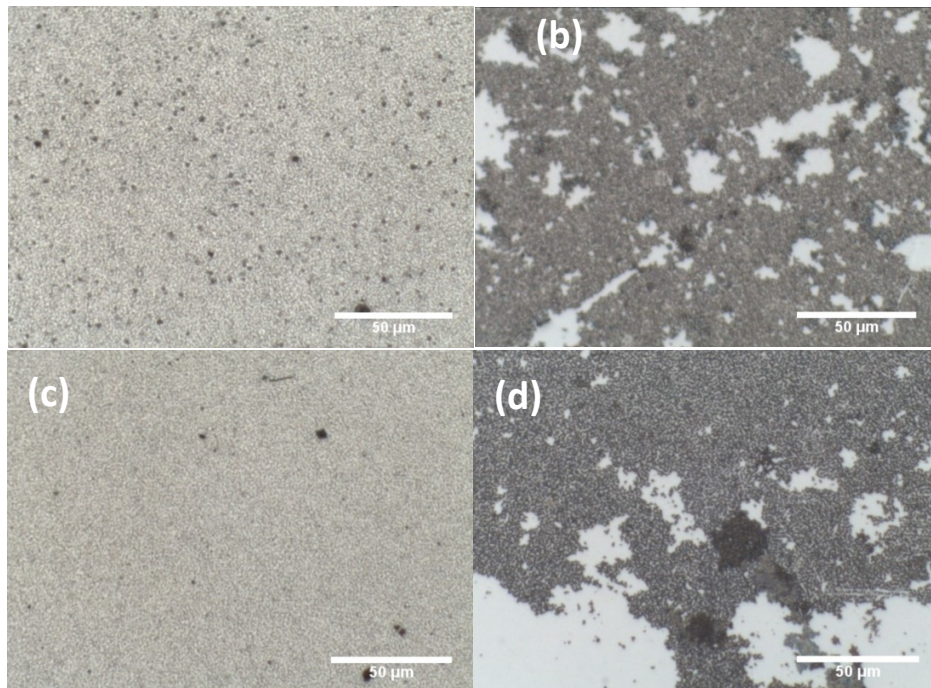


Figure S2. Optical microscopy photos of the samples synthesized using 40 nm thickness Co layer before (a) and after the etching (b); optical microscopy photos of the samples synthesized using 55 nm thickness Co layer before (c) and after the etching (d), the scale bar represents 50 μm.

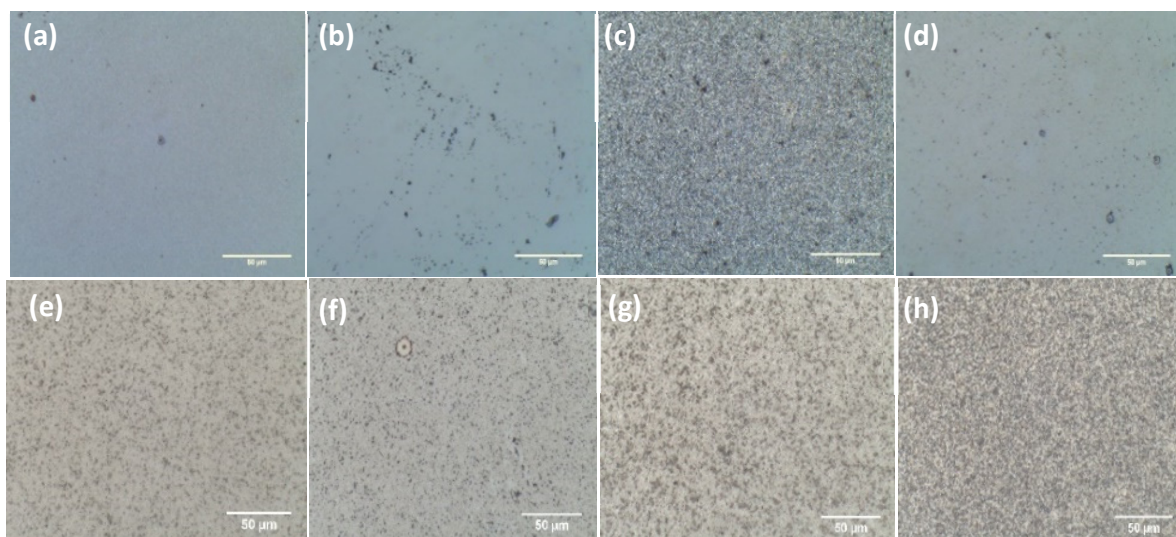


Figure S3. Optical microscopy photos of the sample synthesized using Co=10 nm (a), Co=10 nm – after the etchings (b), synthesized with Co=25 nm (c), Co=25 nm – after the etchings (d), Co=30 nm (e), Co=30 nm, after the etchings (f), Co=40 (g), Co=40, after the etchings (h), the scale bar represents 50 μm .

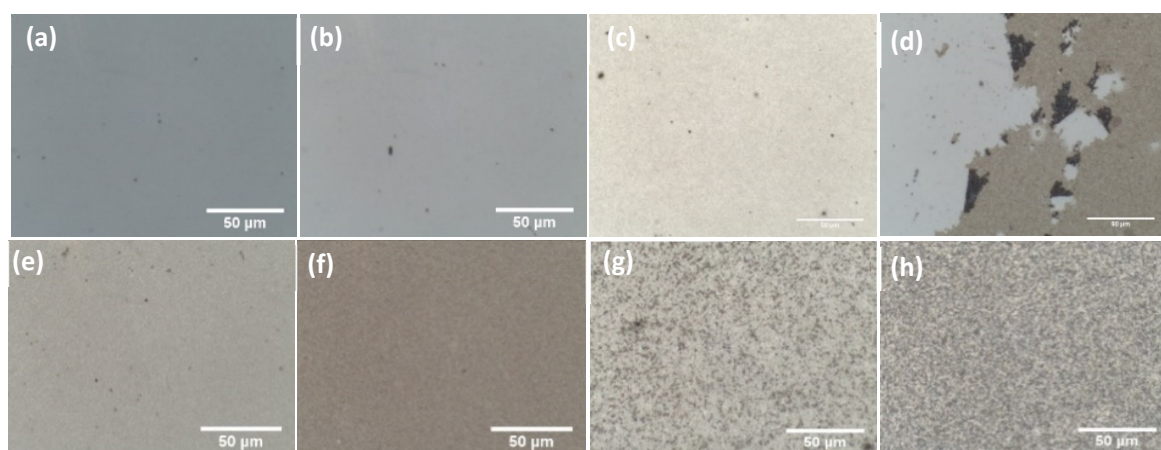


Figure S4. Optical microscopy photos of the sample annealed at 500 $^{\circ}\text{C}$ temperature before (a) and after the etching (b); optical microscopy photos of the sample annealed at 550 $^{\circ}\text{C}$ temperature before (c) and after the etching (d); optical microscopy photos of the sample annealed at 600 $^{\circ}\text{C}$ temperature before (e) and after the etching (f); optical microscopy photos of the sample annealed at 700 $^{\circ}\text{C}$ temperature before (g) and after the etching (h), the scale bar represents 50 μm .

S_AFM. AFM study of the graphene surface morphology and phase structure before and after the cobalt film wet chemical etching

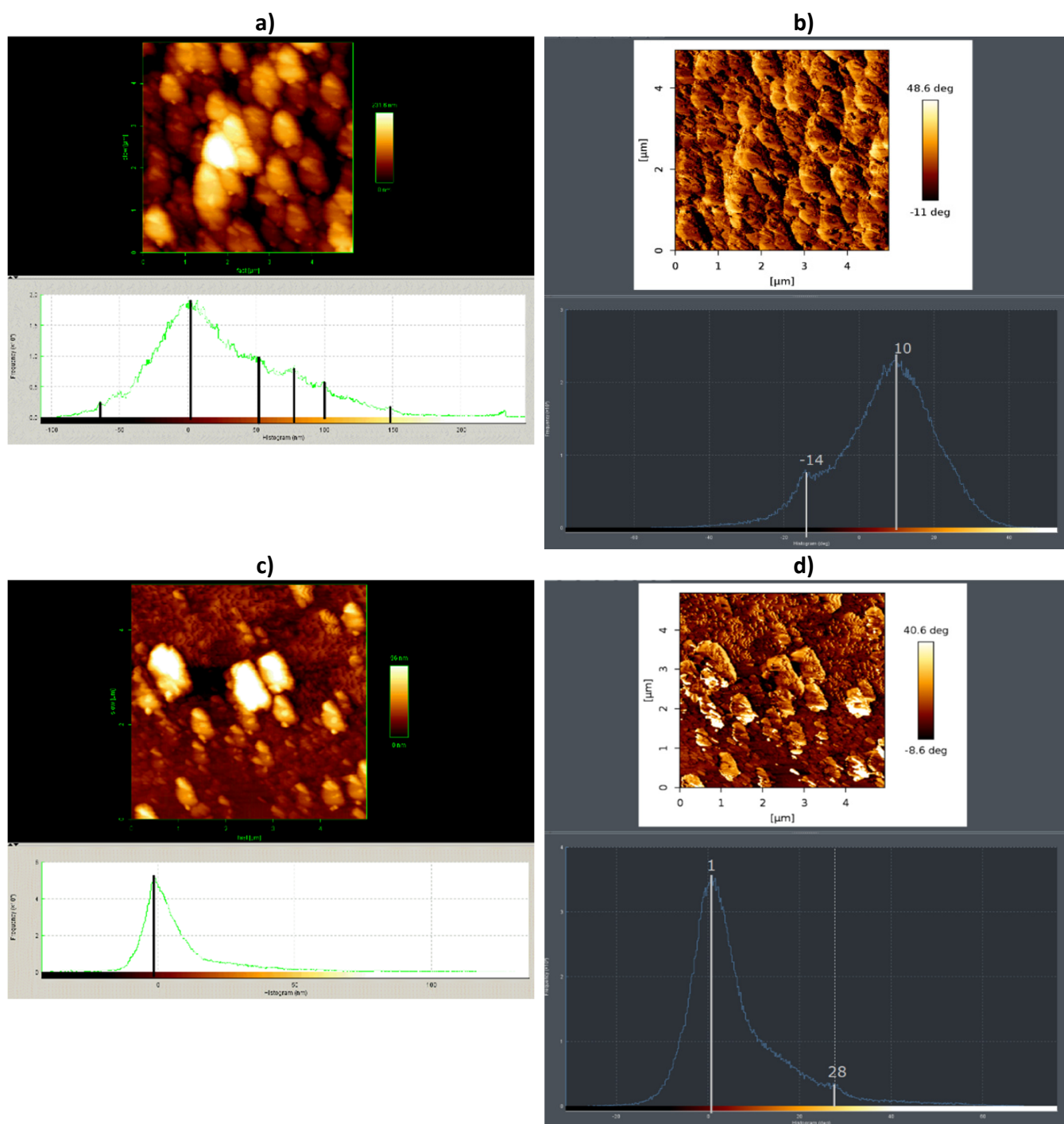


Figure S5. Microscopic analysis of the surface of the graphene layer grown in a single-step process, thickness of Co 25 nm, carbon layer growth temperature 700° C, Energy 800 eV, time 15 min: AFM 2 D images and histograms (measured before etching by H₂ plasma and HNO₃) topography (a), phase (b) and (measured after etching by H₂ plasma and HNO₃) topography (c), phase (d).

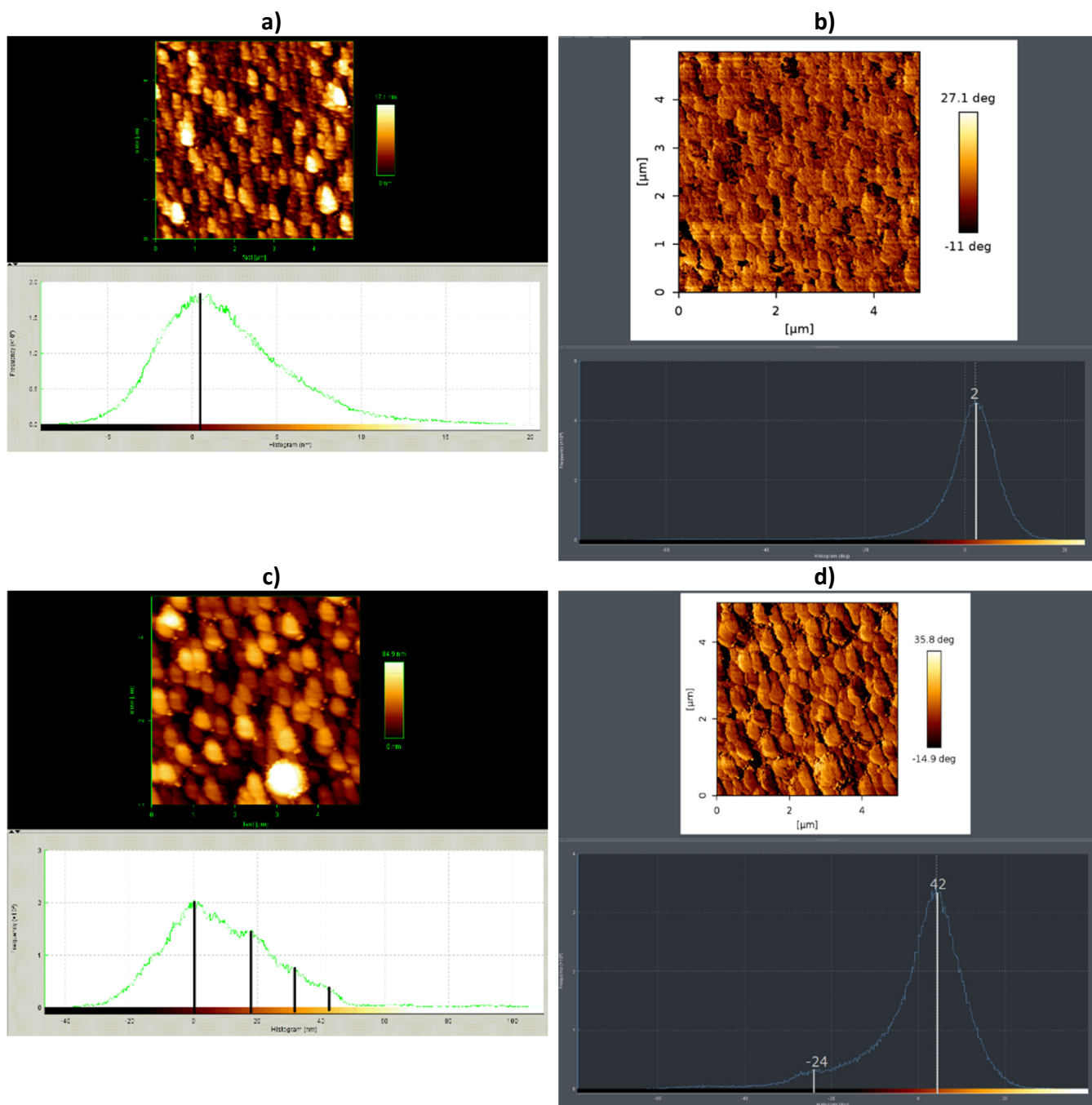


Figure S6. Microscopic analysis of the surface of the graphene layer grown in a two-step process, thickness of Co 25 nm, carbon layer growth temperature 400° C, Annealing temperature 700°C, Energy 800 eV, time 15 min: AFM 2 D images and histograms (measured before etching by H₂ plasma and HNO₃) topography (a), phase (b) and (measured after etching by H₂ plasma and HNO₃) topography (c), phase (d).

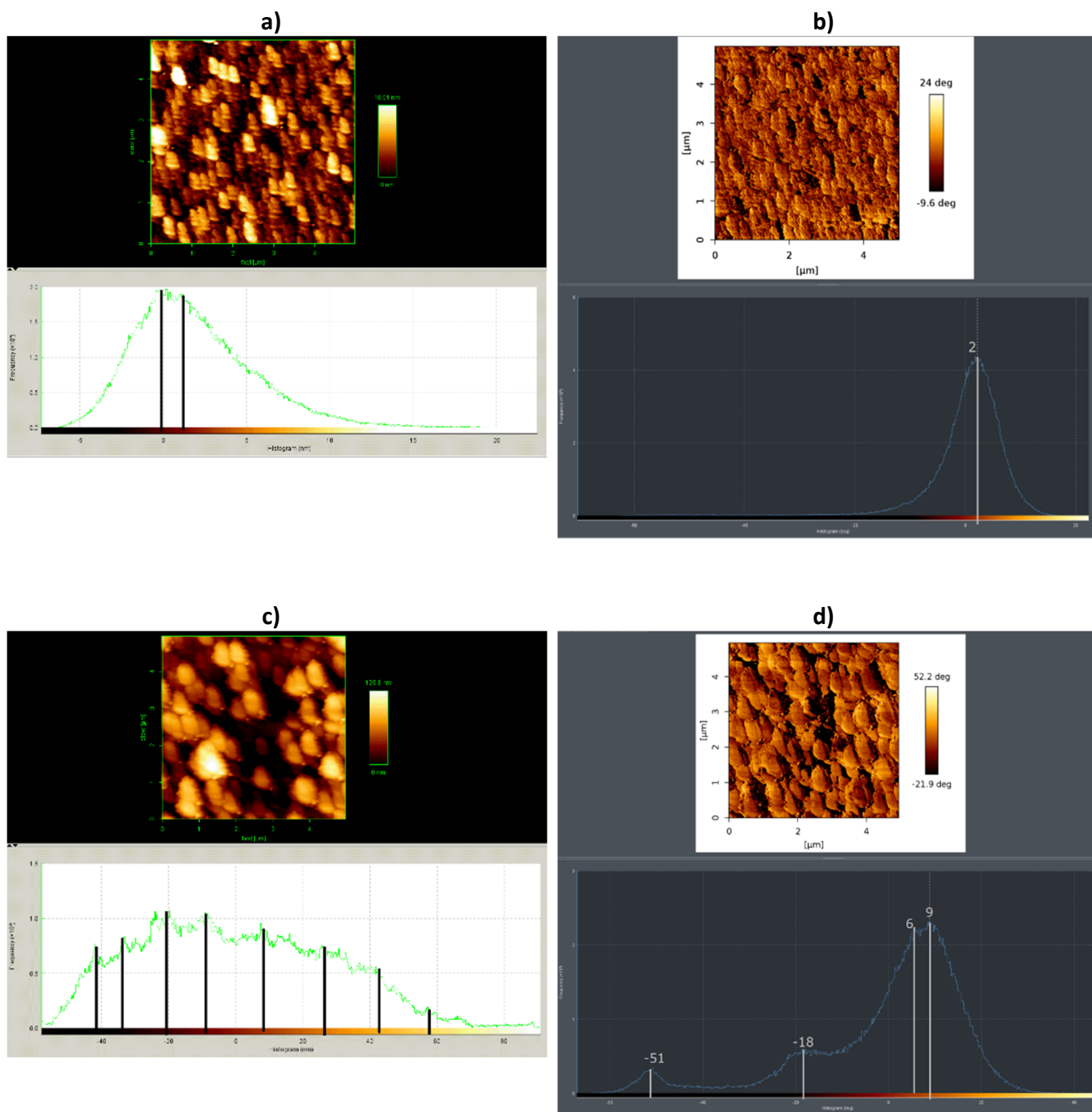


Figure S7. Microscopic analysis of the surface of the graphene layer grown in a two-step process, thickness of Co 10 nm, carbon layer growth temperature 400° C, Annealing temperature 700°C, Energy 800 eV, time 15 min: AFM 2 D images and histograms (measured before etching by H₂ plasma and HNO₃) topography (a), phase (b) and (measured after etching by H₂ plasma and HNO₃) topography (c), phase (d).

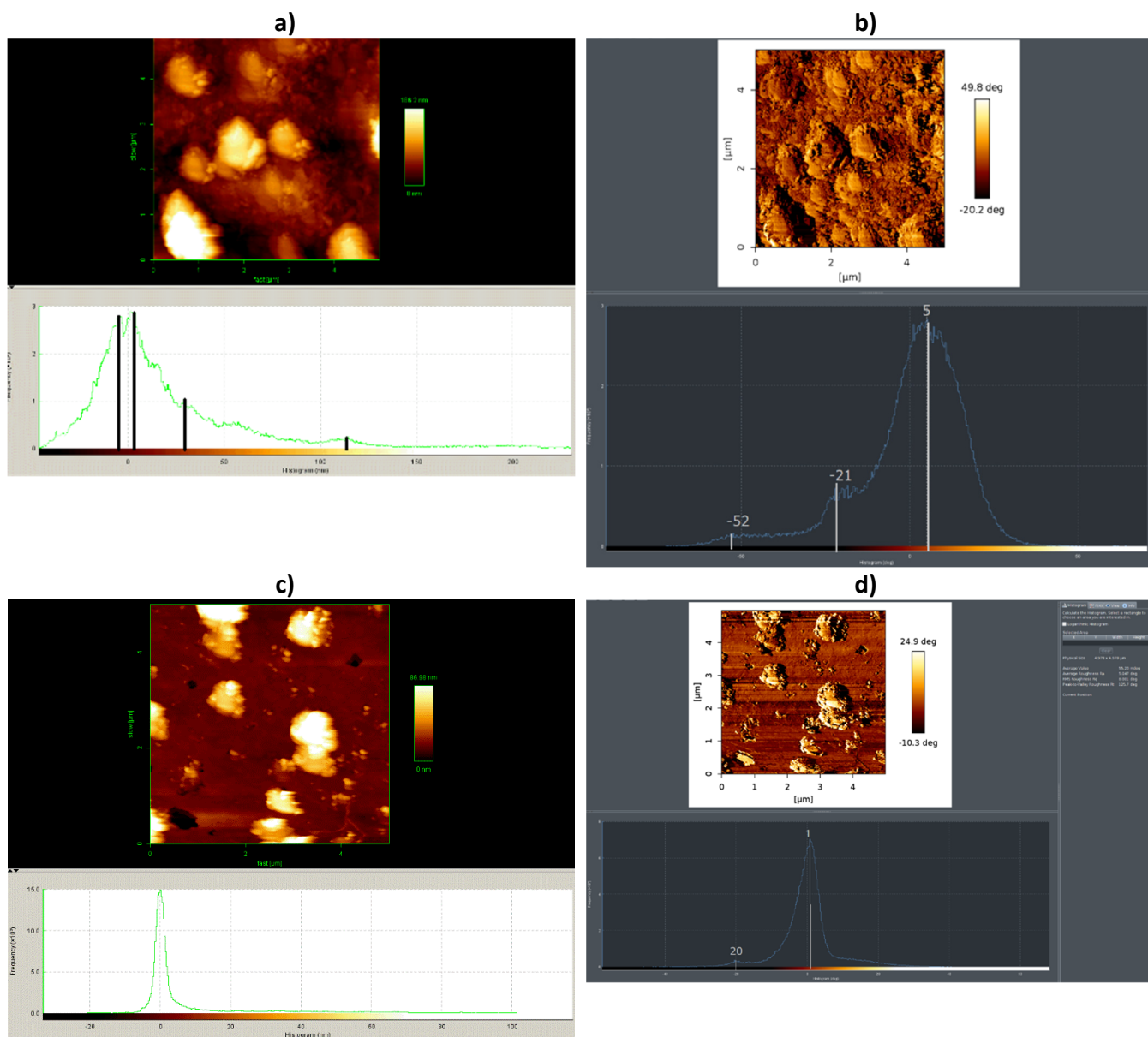


Figure S8. Microscopic analysis of the surface of the graphene layer grown in a two-step process, thickness of Co 40 nm, carbon layer growth temperature 400° C, Annealing temperature 700° C, Energy 800 eV, time 15 min: AFM 2 D images and histograms (measured before etching by H₂ plasma and HNO₃) topography (a), phase (b) and (measured after etching by H₂ plasma and HNO₃) topography (c), phase (d)

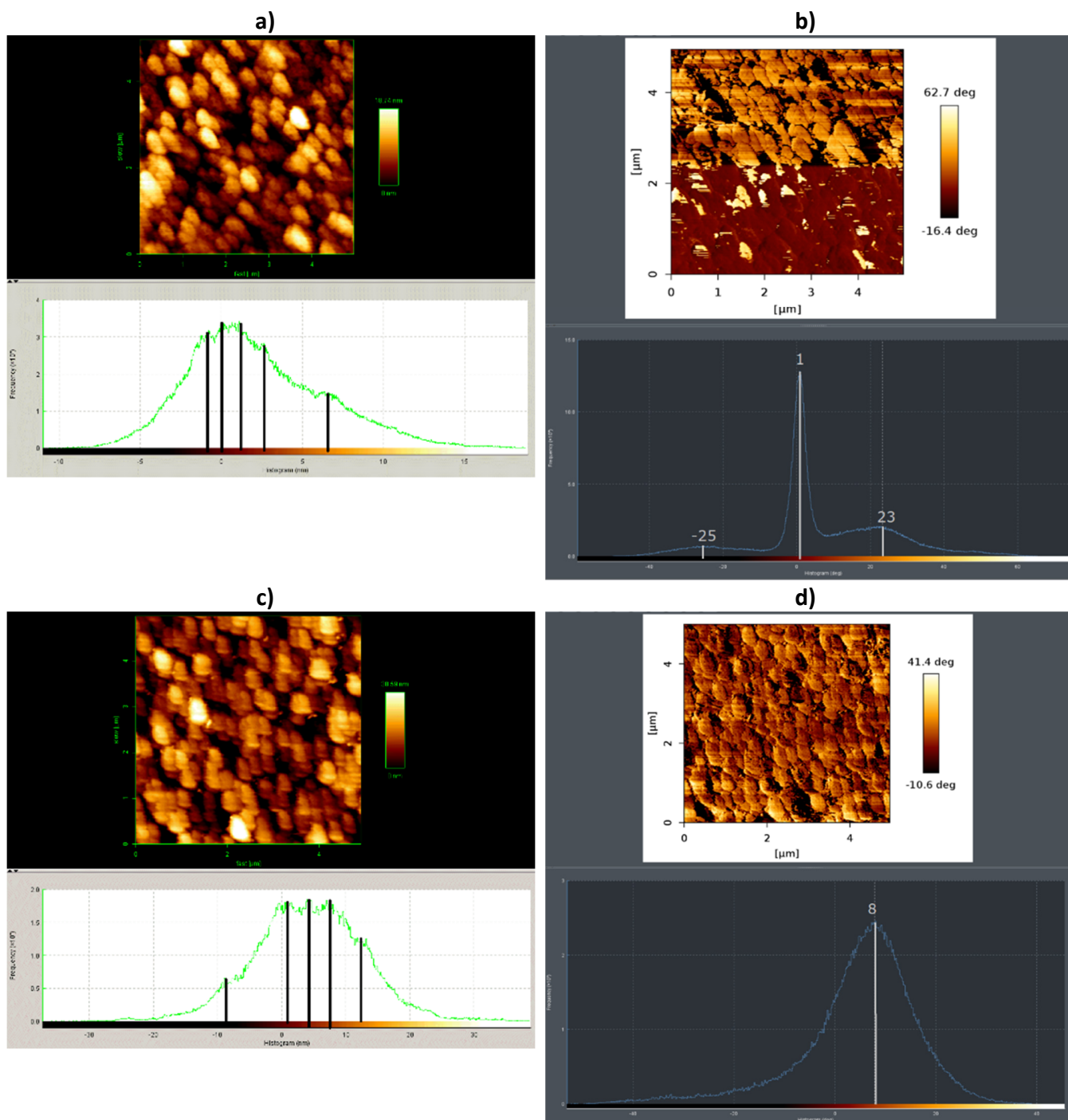


Figure S9. Microscopic analysis of the surface of the graphene layer grown in a two-step process, thickness of Co 25 nm, carbon layer growth temperature 400° C, Annealing temperature 600° C, Energy 800 eV, time 15 min: AFM 2 D images and histograms (measured before etching by H₂ plasma and HNO₃) topography (a), phase (b) and (measured after etching by H₂ plasma and HNO₃) topography (c), phase (d).

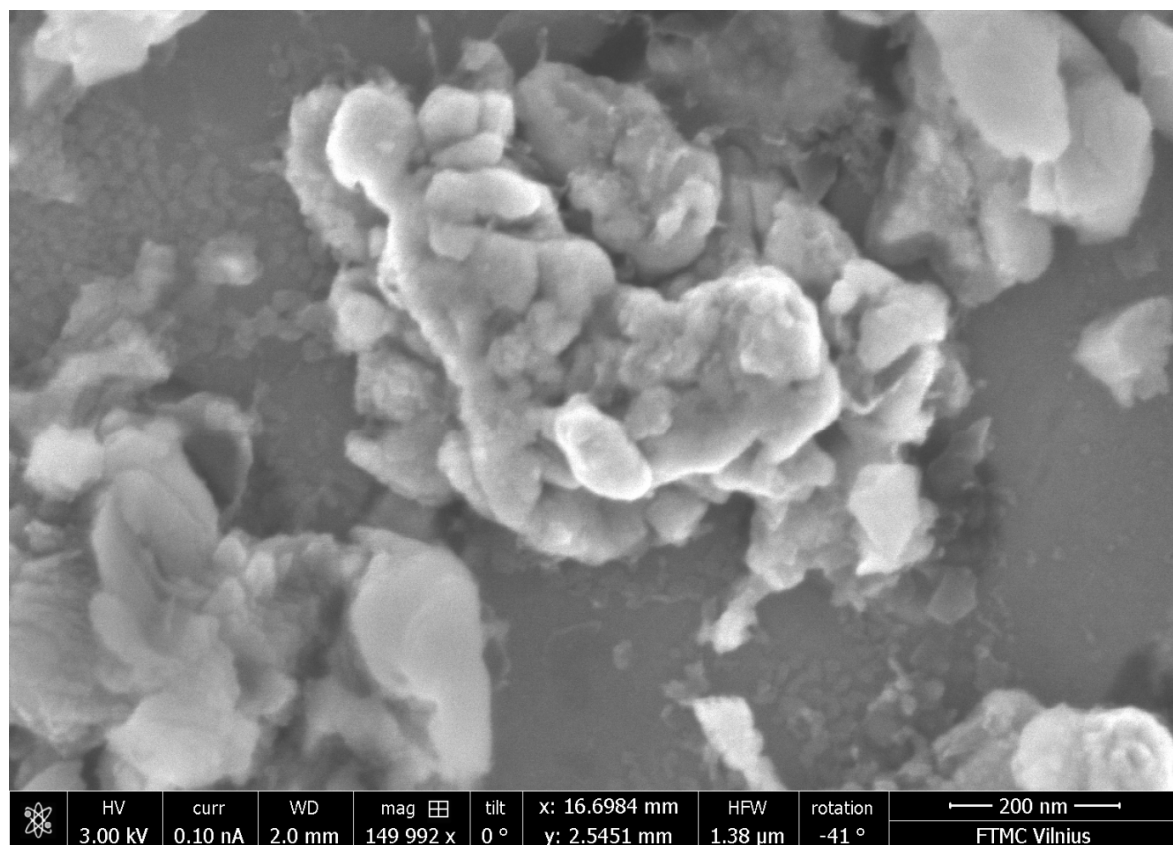


Figure S10. SEM image of the surface of the graphene layer grown in a single-step process, thickness of Co 25 nm, carbon layer growth temperature 700°C, ion beam energy 800 eV, time 15 min.

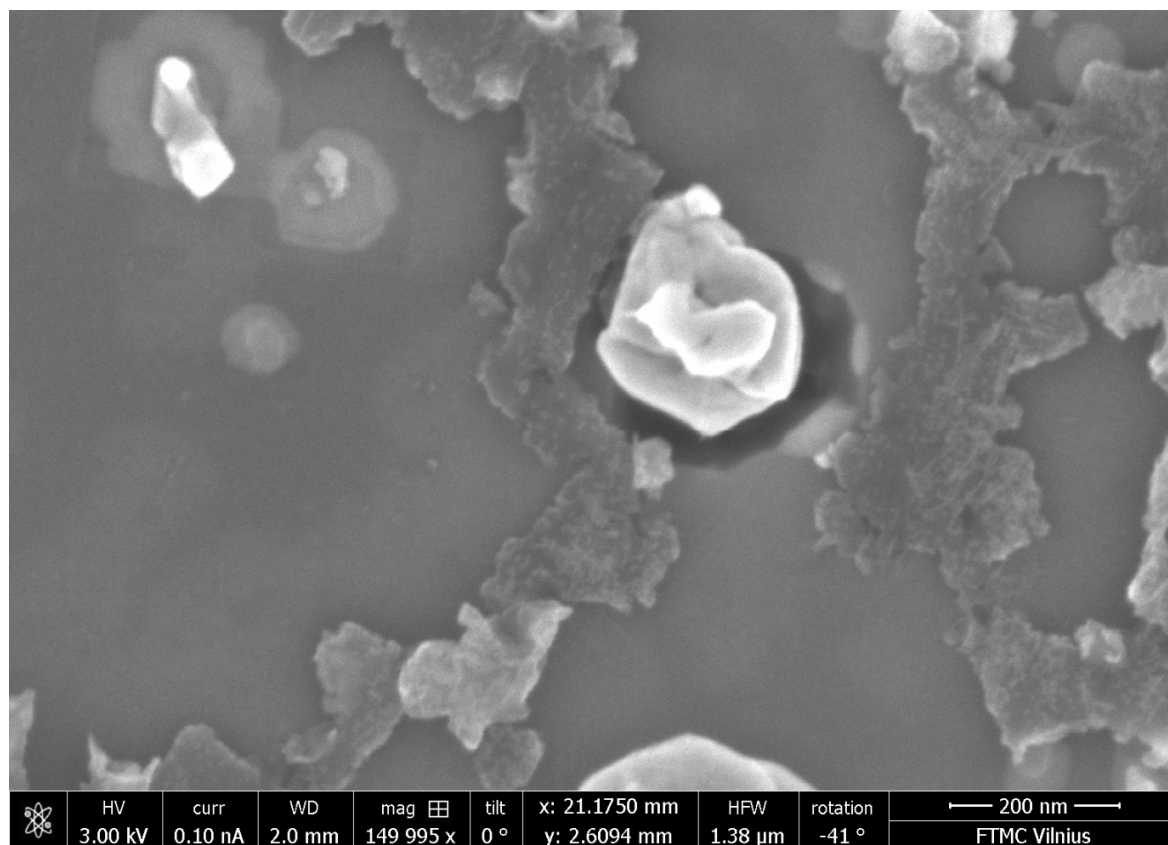


Figure S11. High-magnification SEM image of the graphene synthesized using a two-step process, measured after the etching of the cobalt film. The thickness of the Co layer was 25 nm, ion beam treatment temperature - 400° C, annealing temperature 700 °C, ion beam energy -800 eV, ion beam treatment time - 15 min.

References

1. Hwang, J.-S.; Lin, Y.-H.; Hwang, J.-Y.; Chang, R.; Chattopadhyay, S.; Chen, C.-J.; Chen, P.; Chiang, H.-P.; Tsai, T.-R.; Chen, L.-C. Imaging layer number and stacking order through formulating Raman fingerprints obtained from hexagonal single crystals of few layer graphene. *Nanotechnology*. 2012, 24(1), 015702. DOI: 10.1088/0957-4484/24/1/015702
2. Yaxuan, Y.; Lingling, R.; Sitian, G.; Shi, L. Histogram method for reliable thickness measurements of graphene films using atomic force microscopy (AFM). *J. Mater. Sci. Technol.* 2017, 33, 815–820.