Supplementary Materials: Molecular Dynamics Simulations of DNA Adsorption on Graphene Oxide and Reduced Graphene Oxide-PEG-NH2 in the presence of Mg^{2+} and Cl^- ions

Sebastian Muraru [1,*], Cosmin G. Samoila [2], Emil I. Slusanschi [2], Jorge S. Burns [1,3] and Mariana Ionita [1,*]

[1] Faculty of Medical Engineering, University Politehnica of Bucharest, Gh Polizu 1-7, 011061 Bucharest, Romania
[2] Computer Science Department and Engineering, Faculty of Automatic Control and Computers, University Politehnica of Bucharest, Bucharest, Romania; gabrielcsmo@gmail.com (C.G.S.); emil.slusanschi@cs.pub.ro (E.I.S.)
[3] Laboratory of Cellular Therapies, Department of Medical and Surgical Sciences for Children & Adults, University Hospital of Modena and Reggio Emilia, Modena, Italy; Jorge.Burns@Unimore.it
* Correspondence: sebmuraru@gmail.com (S.M.); mariana.ionita@polimi.it (M.I.)

Table S1. The number of Mg^{2+} and Cl^- ions added in each of the different set-ups.

	GO–MG & dsDNA	GO–MG & ssDNA	PN–MG & dsDNA	PN–MG & ssDNA	PN & dsDNA	PN & ssDNA
Mg^{2+}	84	73	26	26	-	-
Cl^-	84	73	157	168	105	116

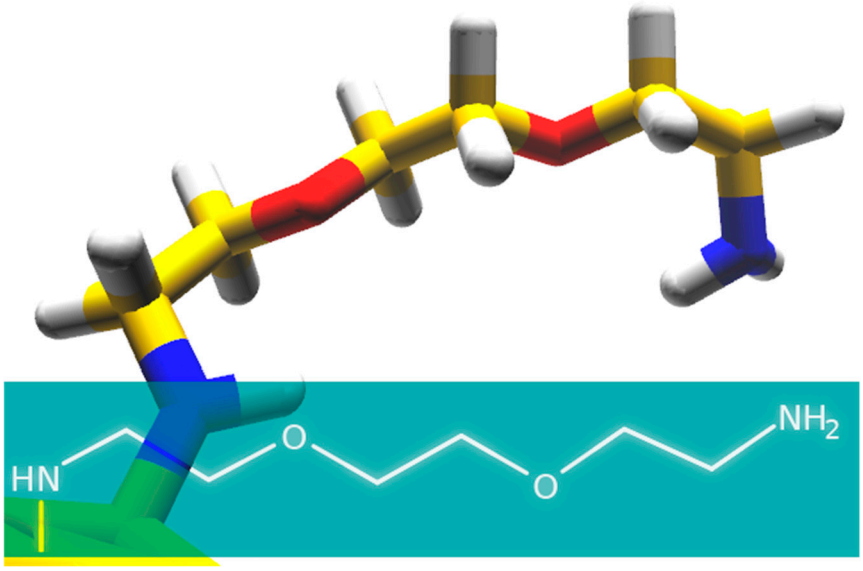

Figure S1. Model displaying the chemical formula of the –NH-PEG-NH_2 molecule used to create the rGO-PEG-NH_2 graphenic species.

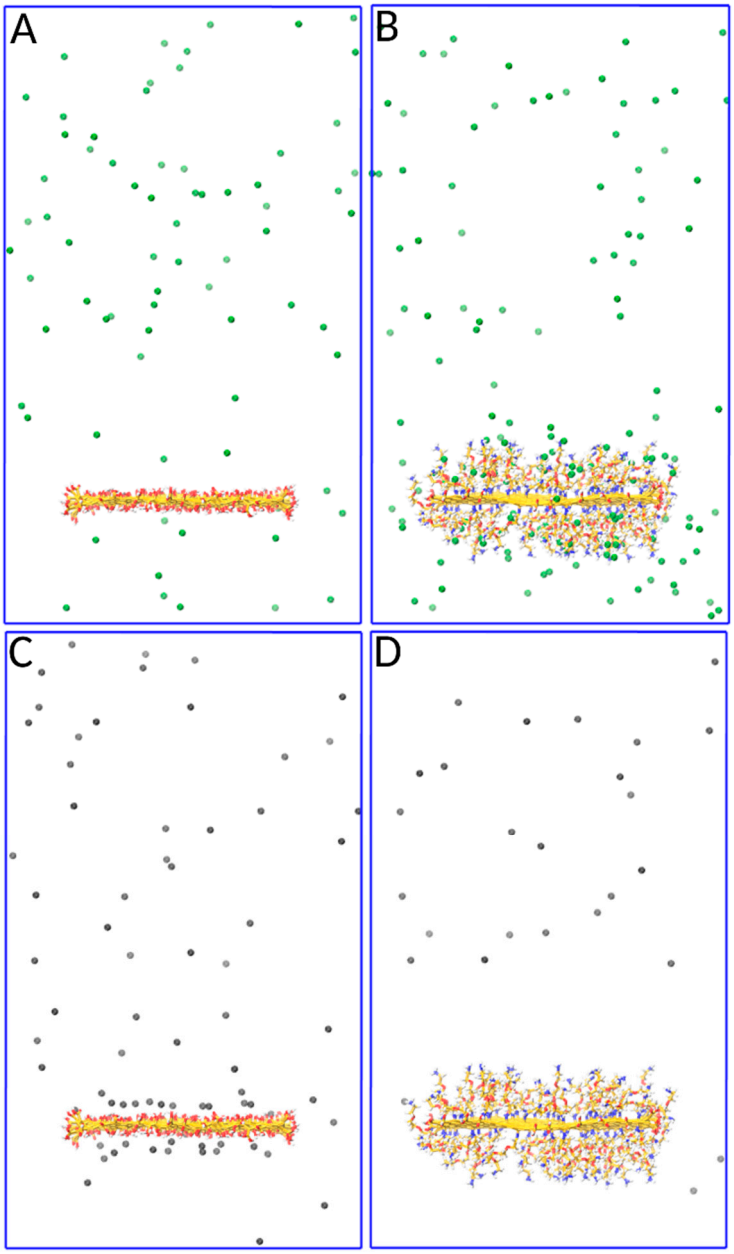

Figure S2. Ion distribution at the end of the equilibration step: (**A**) Cl^- ions with GO; (**B**) Cl^- ions with rGO-PEG-NH_2; (**C**) Mg^{2+} ions with GO; (**D**) Mg^{2+} ions with rGO-PEG-NH_2.

1. Single-Stranded DNA Adsorption on rGO-PEG-NH_2 in the Presence of Cl^- Ions

We found that the process of adsorption of ssDNA on the rGO-PEG-NH_2 species in the presence of Cl^- ions was strikingly similar to the case when Mg^{2+} ions were also present. Again, the ssDNA molecule may either lie entirely on top of the PEG-NH_2 chains at the end of the 300 ns or have one of its ends slide through the chains to reach the graphene surface, eventually forming π–π interactions with one of its rings. The observations regarding the shape adopted by the ssDNA molecule made in the situations, which included Mg^{2+} ions, applied in this case as well. Similarly, the main forces involved were due to the electrostatic interactions between the PEG-NH_2 chains and the DNA molecule, hydrogen bonds and eventually π–π stacking interactions. The distribution of the Cl^- ions following the equilibration step was similar to that previously described for rGO-PEG-NH_2 cases.

For a typical example of the dynamic process of adsorption, most of the contributing relevant events took place early on, within the first 2 ns. As one end reached the PEG-NH_2 chains, the other end could not freely lie down, but was conditioned by the torsion of its backbone and the

electrostatic forces that influenced the negative backbone. Given the influence of the PEG-NH_2 chains, a loop was formed (Figure S3A). At t = 0.4 ns, the CSA began to increase (Figure S3F), and at t = 0.435 ns, the first hydrogen bonds were formed (Figure S3D). The intermolecular distance decreases from 4 nm to 1.9 nm in the first 1.01 ns, decreasing further to 1.0 nm in the following 9.72 ns (Figure S3G). The subsequent intermolecular distance trend was mostly constant, reaching 0.98 nm at t = 300 ns.

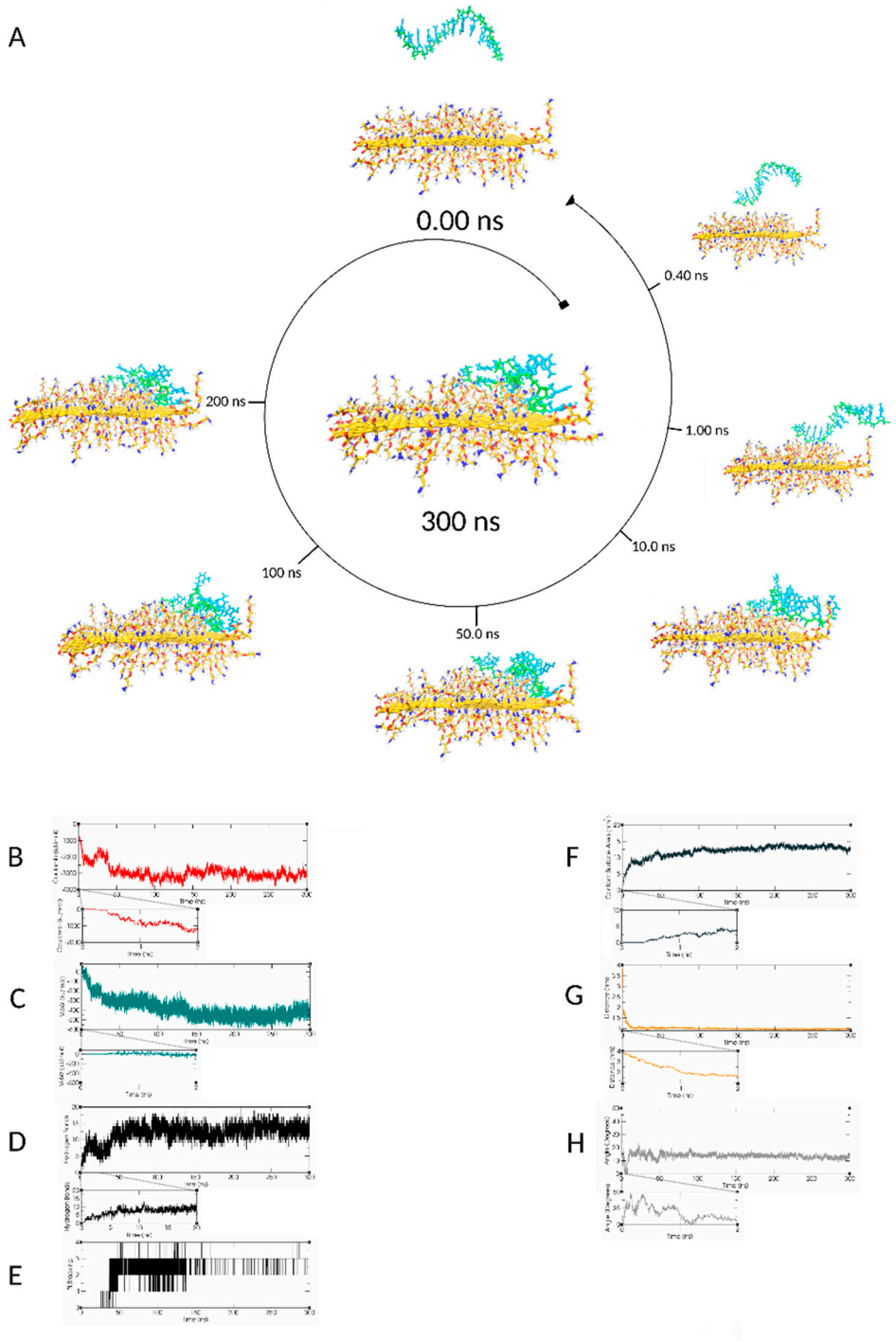

Figure S3. ssDNA adsorption on rGO-PEG-NH_2 in the presence of Cl- ions: (**A**) Trajectory snapshots ranging from 0 to 300 ns of single-stranded deoxyribose nucleic acid (ssDNA) and rGO-PEG-NH_2 in the presence of Cl^- atoms alone (ions not shown); (**B–H**) Evolution of different parameters over the 300 ns simulation time: (**B**) Coulomb interactions between rGO-PEG-NH_2 and ssDNA; (**C**) VdW interactions between rGO-PEG-NH_2 and ssDNA; (**D**) Hydrogen Bonds; (**E**) Pi Stacking; (**F**) Contact Surface Area; (**G**) Distance; (**H**) Angle.

2. Double-Stranded DNA Adsorption on rGO-PEG-NH_2 in the Presence of Cl^- Ions

We found that double-stranded deoxyribose nucleic (dsDNA) was adsorbed on the rGO-PEG-NH_2 species in the presence of Cl^- ions alone, with its backbone in an almost parallel orientation to the graphenic surface. The main forces involved in the simulated 300 ns occurred because of electrostatic interactions and to a lesser extent hydrogen bonds. Again, π–π stacking interactions were not found to play a role in the adsorption process for dsDNA.

The distribution of the Cl^- ions at the start of the simulations was similar to the other setups involving the rGO-PEG-NH_2 (see Figure S2). Considering a typical example, the movement of the dsDNA molecule towards the rGO was quite straightforward and prompt, the intermolecular distance decreasing from 4 nm to 1.89 nm in 0.745 ns. From this point onward, the gradient of the distance curve changed significantly (Figure S4F); the intermolecular distance was 1.46 nm at t = 300 ns. The first hydrogen bond was formed close to 0.4 ns, but the value in Figure S4D quickly jumped to 12 at t = 6.5 ns. Once the first hydrogen bonds were formed, the oligonucleotide did not significantly change its position in the x–y plane, whereas the angle that the backbone of the dsDNA formed with the carbon atoms making up the graphenic molecule oscillated by ±5°. During the rapid dynamic phase, the CSA value in Figure S4E jumped to 4.75 nm^2. Similarly, in the same time period, the Coulomb energy value in Figure S4B reached −1200 kJ mol^{-1}. The trend of the attractive VdW forces followed that of the electrostatic interactions, its modulus increasing with time. Given the observations made and taking into account that the CSA value at the end of the simulation reached 11.45 nm^2, we may assume that the dsDNA molecule very slowly sank among the PEG-NH_2 chains, with the attractive force between itself and the graphenic surface constantly increasing.

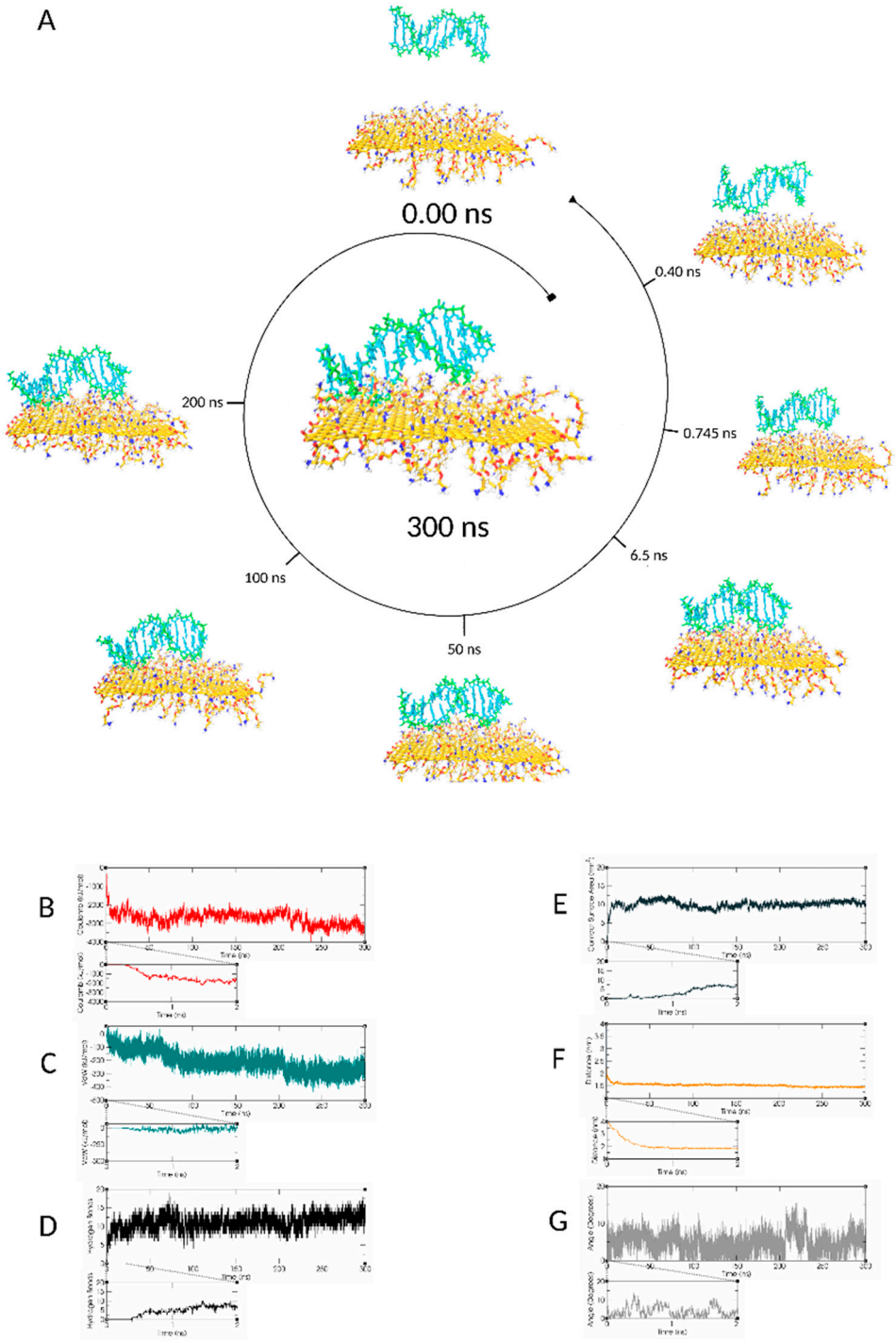

Figure S4. dsDNA adsorption on rGO-PEG-NH_2 in the presence of Cl- ions: (**A**) Trajectory snapshots ranging from 0 to 300 ns of dsDNA and rGO-PEG-NH_2 in the presence of Cl^- atoms alone (ions not shown); (**B–G**) Evolution of different parameters over the 300 ns simulation time: (**B**) Coulomb interactions between rGO-PEG-NH_2 and dsDNA; (**C**) VdW interactions between rGO-PEG-NH_2 and dsDNA; (**D**) Hydrogen Bonds; (**E**) Contact Surface Area; (**F**) Distance and (**G**) Angle.