Selective sorption of argon in carbon honeycombs of different sizes

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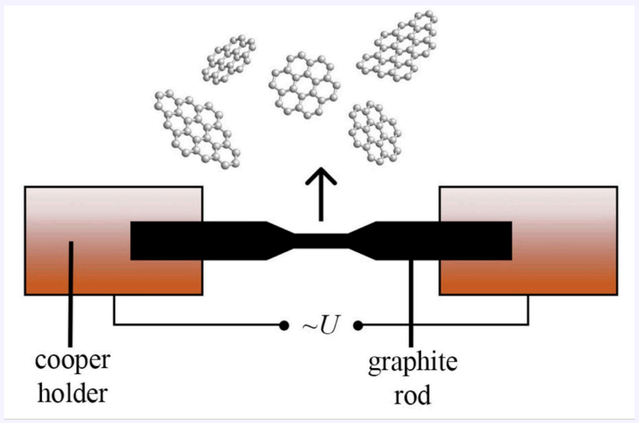
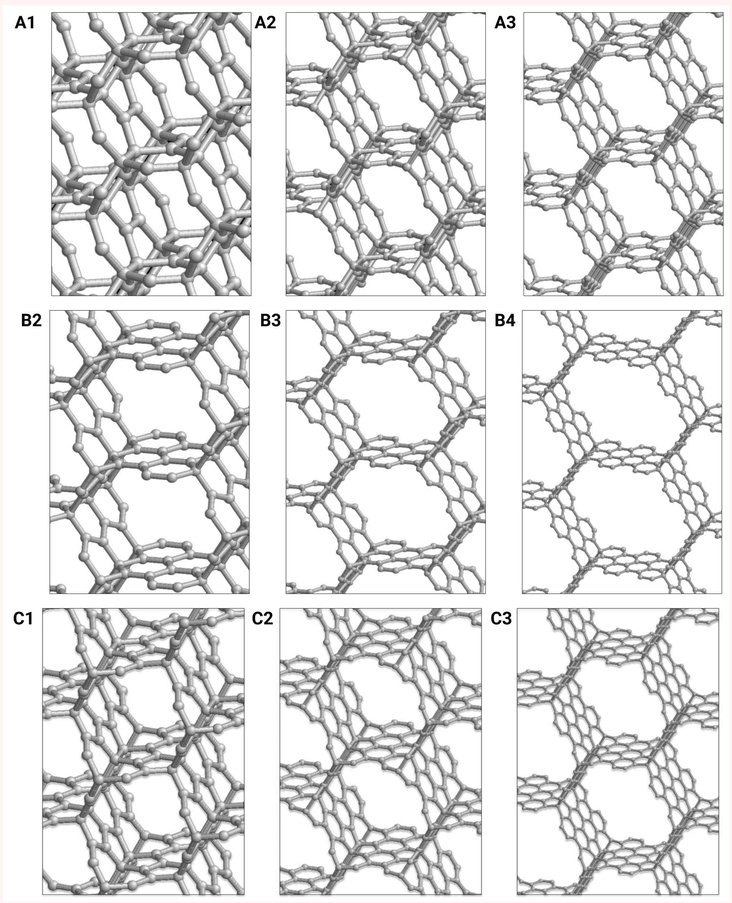
Carbon honeycomb (CH) cellular structures have been experimentally discovered and first reported in [1]. These structures are built from monolayer graphene nanoribbons joined in a three-fold manner around the junction lines [1-3]. They are produced from graphite heated in vacuum up to the sublimation temperature when graphene patches are separated from graphite while preserving sp2 bonds within the patches, and then either collide in vacuum forming 3-fold junction lines and/or deposit on substrates as upright standing graphene fragments.



CHs have been proved to possess high absorption capacity for several gases Kr, Xe, CO2 [1-3]. In this study we analyze the Al uptake in the CHs by means of high-energy electron diffraction applying the advanced structural analysis comparing experimental and calculated diffractograms.



The carbon honeycomb structures can be realized in three structural model groups depending on mutual wall orientations: type A (armchair), B (zigzag, monoclinic), and C (zigzag, hexagonal) [4]. They may have different wall widths.

In types A and C junction lines maintain a three-fold symmetry preserving overall hexagonal symmetry. The B-type structures break this hexagonal symmetry owing to specific sp^3 tetrahedral atomic orientations along the junction lines, resulting in the angles between walls 109.5° and 125.3°, forming monoclinic configurations. All these structures were proved theoretically to be very stable.

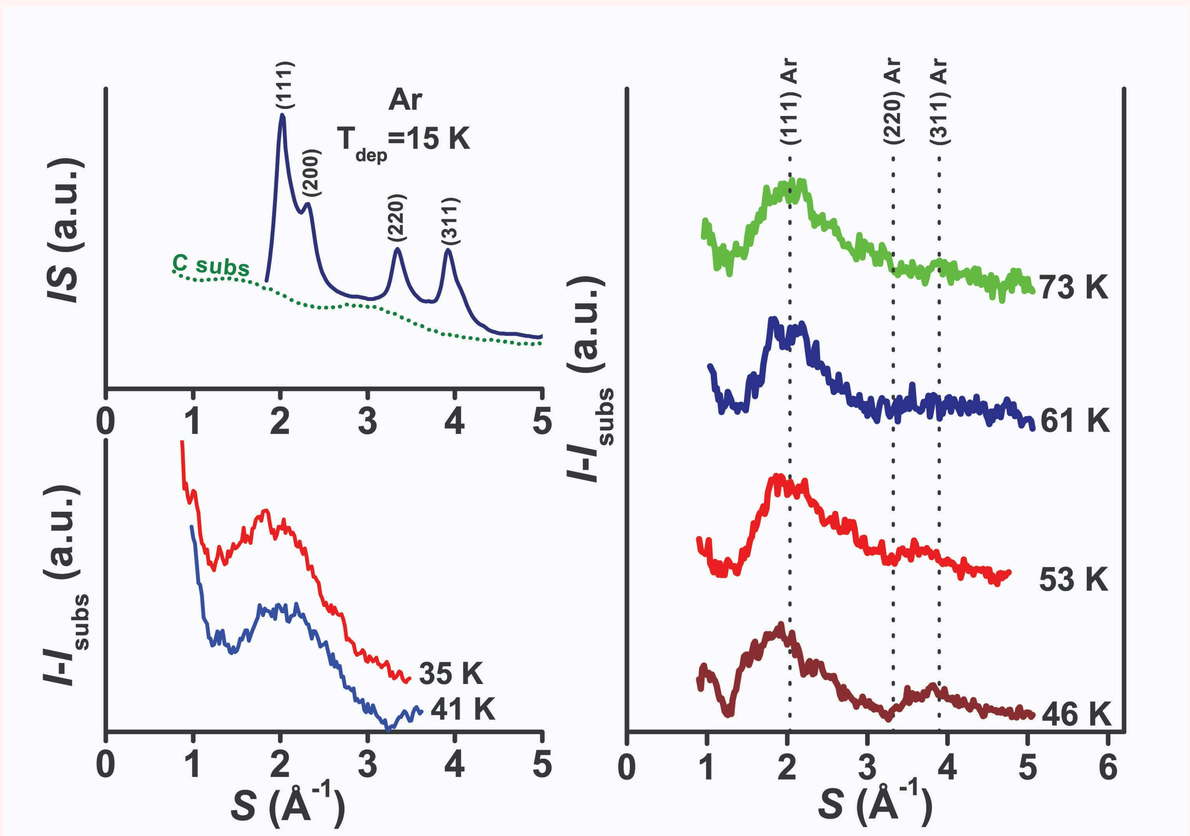
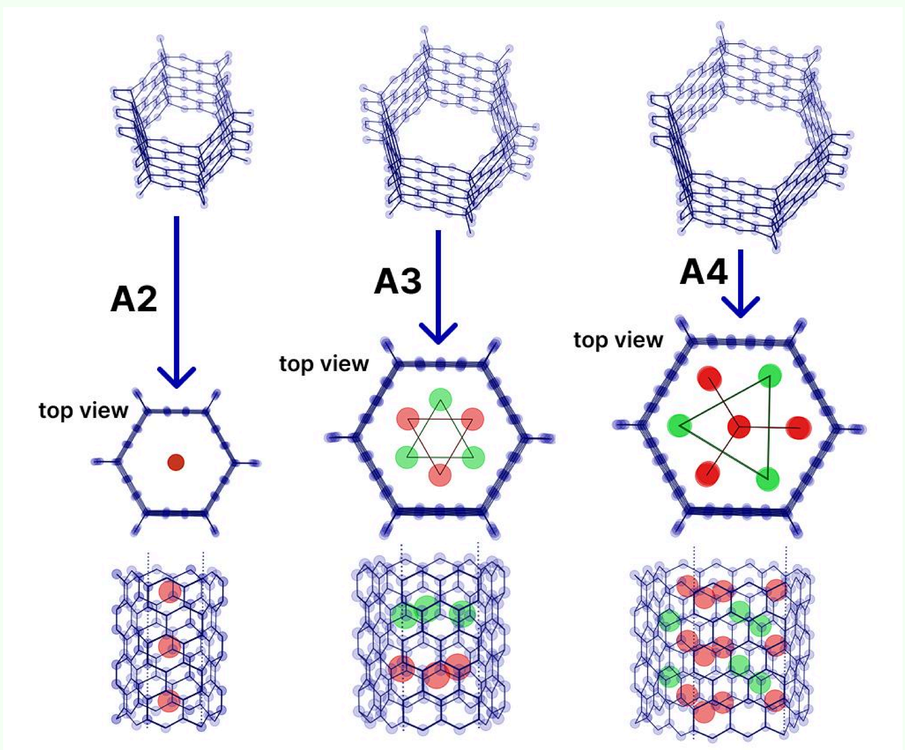
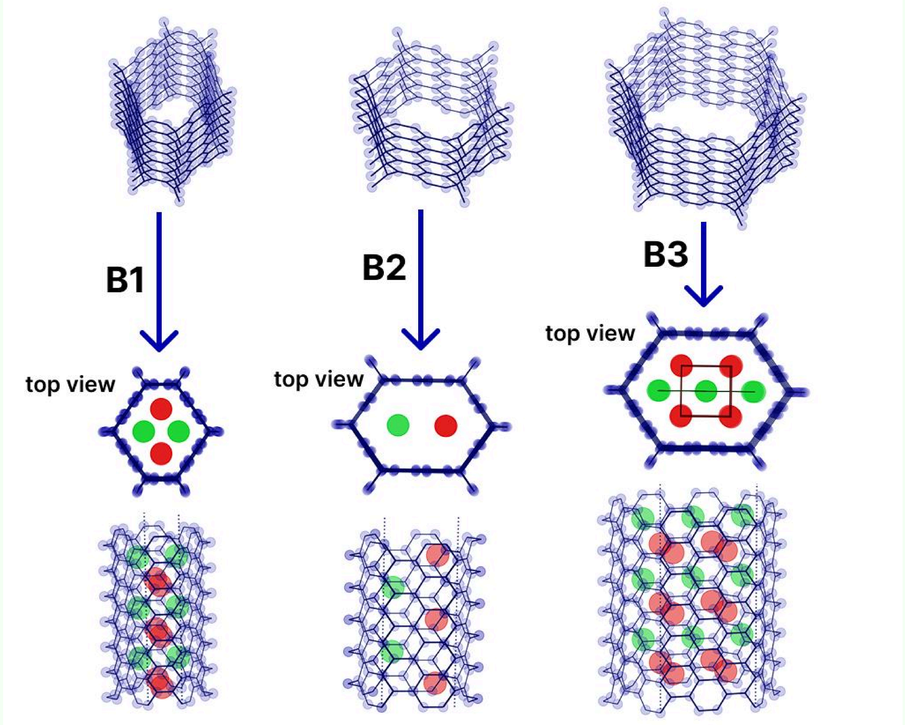
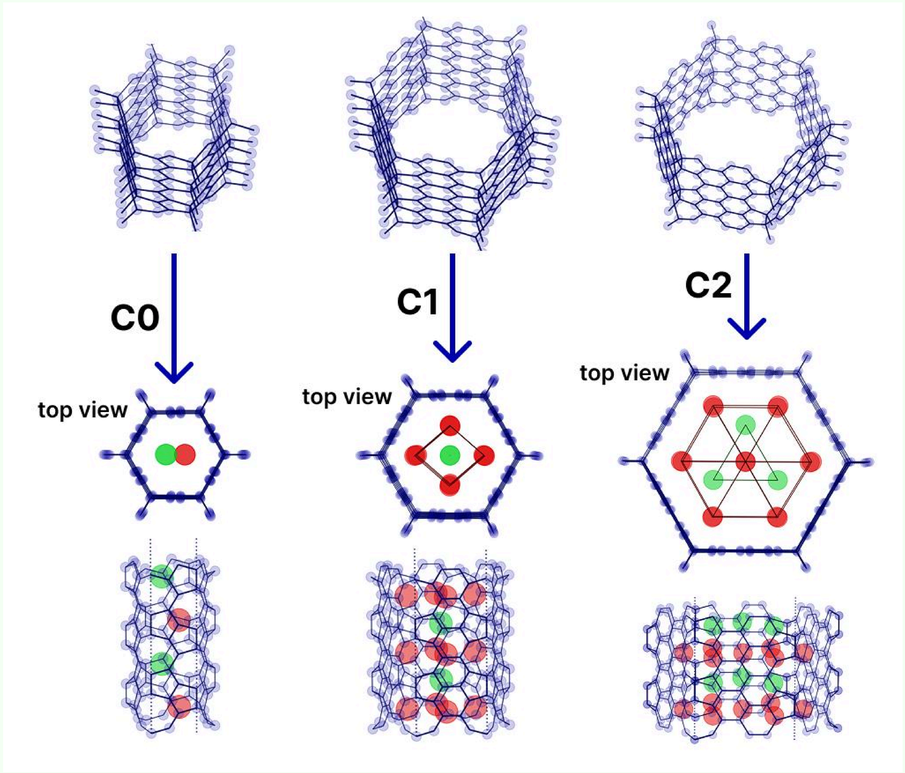


Figure (a) shows the diffraction pattern of the initial polycrystalline Ar deposited on CH films at 15 K. Such films are then heated to temperatures close to the sublimation point of Ar in vacuum (~32 K in our vacuum) and kept at 3-4 degrees below this point. This process results in a high saturation of CHs with Ar that is well seen in the difference signals (figures (b) and (c)) between the Ar filled CH matrices and the diffraction curve for pure CHs (shown in figure (a)). At elevated temperatures (figure (c)) almost complete desorption of argon atoms captured in CHs occurs at temperatures more than twice higher than the sublimation point of argon in vacuum. This corresponds to the physical absorption of argon with strong bonding in a carbon matrix.







We analyze the effect of channel sizes and their configurations on the sorption capacity and the structure of clusters formed inside the channels of different sizes in quest of realistic models describing Ar distributions in CHs. The analysis is based on comparison of calculated diffractograms for all structural models shown in the figure and the experimental diffraction patterns after the Ar uptake in the CH films.

References

[1] N.V. Krainyukova and E.N. Zubarev, Phys. Rev. Lett. 116, 055501 (2016). http://dx.doi.org/10.1103/PhysRevLett.116.055501

[2] N.V. Krainyukova, Low Temp. Phys. 187, 90 (2017). http://dx.doi.org/10.1007/s10909-016-1727-1

[3] N.V. Krainyukova, B. Kuchta, L. Firlej and P. Pfeifer, Low Temp. Phys. 46, 219 (2020). http://dx.doi.org/10.1063/10.0000705

[4] D.G. Diachenko and N.V. Krainyukova, Low Temp. Phys. 48, 232 (2022). http://dx.doi.org/10.1063/10.0009542