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Investigating nitrogen doped nanocarbon materials as potential carbon dioxide adsorbers

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Background

The climate crisis, propelled by the continuous rise of carbon dioxide emissions, has spurred research to find technical solutions for this problem. One possibility is to directly capture carbon dioxide from the atmosphere and sequester it inside suitable long-term storage. Unfortunately, the success of this method strongly depends on the efficiency of the adsorber material. Here, nanocarbon materials such as graphene and carbon nanotubes could come into play, as they offer several beneficial characteristics like high surface area and stability. However, the catch is their nonreactive nature. To enable chemical adsorption one could alter the chemical structure of the nanocarbons by inserting new elements through doping. Nitrogen is a promising candidate, as it can be exchanged with the carbon atoms inside the crystal lattice of the materials. It is known to be a crucial component in other carbon dioxide fixating mechanisms, for example in plants. One goal of this research is to find novel routes for nitrogen doping of these materials and try to understand and control the process of ion implantation. Furthermore, the nitrogen doped nanocarbons are investigated as carbon dioxide adsorbers.

Methods

Nitrogen doping is realised by different methods of ion bombardment. HRTEM is used to examine the effects of doping on the atomic level. Further investigation is conducted with STEM coupled with EDX, FIB-SEM coupled with ToF-SIMS, AFM and XPS. A self-built setup is established, dedicated to measure the carbon dioxide capture performance of the materials, a scheme of it is shown in part A of the figure.

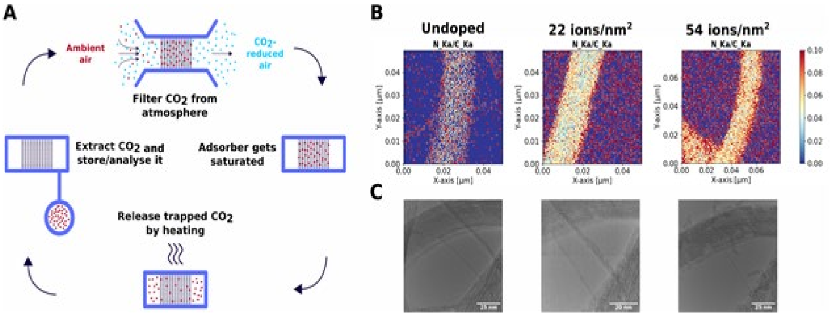
Results

Various methods of ion bombardment were successfully used to dope graphene with nitrogen. This was verified by HRTEM, observing implanted nitrogen atoms as well as defects introduced by nitrogen ion bombardment. The same treatment is conducted with carbon nanotube films. These films are produced via filtration of carbon nanotube suspension in a controlled manner and various thicknesses, which are checked by AFM. FIB-SEM with ToF-SIMS as well as XPS verify that nitrogen is present in the upper 100 nm of the films that have been bombarded with nitrogen ions. Further investigation through STEM coupled with EDX give insight into the ion dosage dependent distribution of nitrogen in thicker carbon nanotube bundles after doping, as shown in part B of the figure. Additionally, HRTEM shows the deterioration of the carbon nanotube crystal structure after excessive ion bombardment, which can be seen in part C of the figure. Carbon dioxide capture performance of various carbon nanotube films has been measured with the dedicated setup. An increase in performance was observed after treatment with nitrogen ions.

Conclusion

Different ways of ion bombardment were used to implant nitrogen into the crystal structure of graphene and carbon nanotubes. This was verified by various microscopic and spectroscopic methods. The effects of the doping procedure were investigated on atomic as well as microscopic level, giving insights in the doping mechanisms during ion bombardment. Furthermore, it was shown that nitrogen doping changes carbon nanotube films in a way, that improves their ability to sequester carbon dioxide from the atmosphere.

Graphic:



Keywords:

Nanocarbons, nitrogen doping, carbon capture