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Functionalized carbon nanotubes as sensitive layers for BTEX and TIC sensing

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The control of air quality is a huge preoccupation to keep a safe environment. The BTEX (benzene, toluene, ethylbenzene and xylene) volatile organic compounds constitute an important class of indoor air pollutants. Human exposure to these compounds can cause serious damages on human health due to their carcinogenic nature. In addition, toxic industrial chemicals (TIC) such as chlorine, ammonia, ..., are potential pollution sources. Therefore, there is a strong interest to detect and quantify such pollutants either in indoor or outdoor environments.

Carbon nanotubes (CNTs) have received considerable interest over the last decade as new sensing materials due to their high specific surface area and their electronic properties^{1,2,3}. In this context, the objective of our work is to develop chemical sensors based on carbon nanotubes to detect BTEX or TIC compounds and especially either benzene and toluene or chlorine and ammonia.

Multi-walled carbon nanotubes (MWNT, outer diameter: 40 nm) used for sensing device preparation are synthesized using catalytic chemical vapour deposition (CCVD) process⁴. The raw MWCNTs are annealed at 2000°C under Ar atmosphere and, eventually, functionalized to increase sensing selectivity. Carboxylic groups⁵ and poly(phenylene) coatings⁶ bearing carboxylic groups were investigated for BTEX detection (figure 1). The functionalisation process with poly(phenylene) coatings is derived from the diazonium salt chemistry. Detection tests performed at room temperature demonstrate that simply annealed CNT-based sensors are able to detect benzene diluted in nitrogen at concentrations in the tenth of ppb range which is appropriate for indoor air qualification.

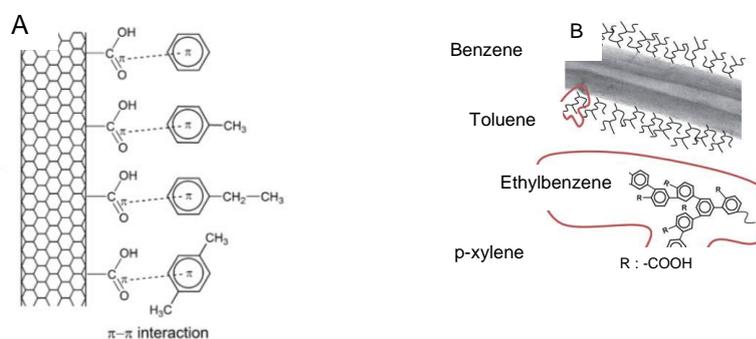


Figure 1: (A) π - π stacking interactions between carboxylic groups and BTEX⁵, (B) Poly(phenylene) derivative grafted onto CNTs.

Regarding the detection of TIC (Cl_2 , NH_3), the sensor sensitivity and selectivity are adjusted by tuning MWCNT network morphology and electronic properties, as well as surface chemistry through different functionalisations (poly(phenylene)-like or vinyl polymer groups). The devices are operating at room temperature, for the detection of pollutants such as Cl_2 , HCl , NH_3 . Such sensors are able to detect down to 30 ppb chlorine and selective detection of NH_3 and HCl and at low concentration is possible down to 300 ppb and 1 ppm respectively.

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