Plasma growth and functionalization of carbon nanotubes

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Abstract: CNTs are promising for biomedical applications. For best application, CNTs need to be functionalized using additional processes. Therefore, this work proposes to use the PECVD technique to synergistically obtain the growth and functionalization of CNTs. The results show that the PECVD technique is effective for the obtention of functionalized CNTs during the growth process, obtaining more hydrophilic structures in aqueous media.

1. Introduction

Studies on carbon nanostructures have intensified in recent decades, as they possess specific physical and chemical properties that make them attractive for application in various fields. Structures such as carbon nanotubes (CNTs) have been investigated for biomedical applications due to their biocompatibility with the human body. However, for biomedical applications, CNTs need to undergo a functionalization process so that these carbon nanostructures become more hydrophilic and better interact with aqueous media. One of the widely used techniques to obtain CNTs is chemical vapor deposition (CVD), which produces high-quality materials. However, it requires the use of high temperature, which can reach over 1000° C, which is a limitation of the technique. CVD can be optimized with the application of plasma, resulting in the Plasma Enhanced Chemical Vapor Deposition (PECVD) technique, which produces carbon nanostructures at a lower temperature than CVD. With the PECVD technique, the CNTs obtained have a greater number of defects in their structure compared to the CVD technique [1]. Considering these defects in the growth of CNTs, this work proposes the introduction of nitrogen during the growth of CNTs so that nanotube growth and functionalization occurs synergistically.

2. Methods

The carbon nanotubes were grown on a nickel substrate using the PECVD technique with a pulsed DC source. The growth process started with plasma ablation of nickel for cleaning. Then the CNTs were grown with the precursor gases methane (CH_4) (25.5%), H_2 (12.8%) and Ar (61.7%) with a total gas flow of 235 sccm, at 800 V for 30 min. Nitrogen (N_2) was introduced in two proportions (2.1% and 4.2%). The CNTs were characterized by Raman, XPS and aqueous solubility tests.

3. Results and Discussion

The spectra presented in Figure 1 shows that the characteristic bands of CNTs are D, G, D', 2D and D+G. However, CNTs with nitrogen doping presented other bands that characterize disorder in the structure. This disorder is also identified in the Id/Ig ratio with a reduction in the value with the increase in the proportion of nitrogen added during the growth of CNTs, indicating greater disorder in the structure [2]. The elemental chemical composition obtained by XPS showed, as expected, that with the increase in the flow of nitrogen added to the growth of CNTs, the elemental composition of nitrogen also increases, with a maximum incorporation of 1.24% nitrogen [3]. Thus, the disorder of the structure favors the solubility of CNTs in aqueous medium, increasing the hydrophilicity of the structure due to the doping of CNTs with nitrogen.

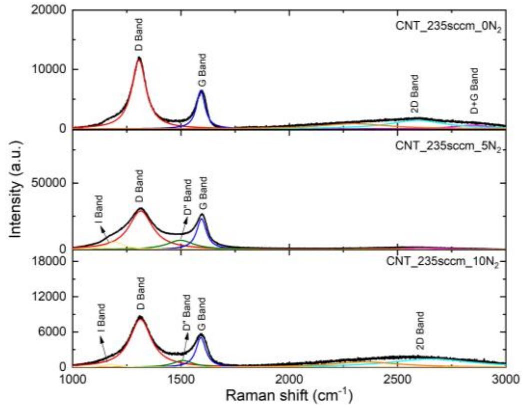

Fig. 1. Raman spectra of CNTs without and with nitrogen incorporation

4. Conclusion

The results proved the effective incorporation of nitrogen into the surface of carbon nanotubes, considering the percentages of nitrogen incorporated. Thus, demonstrating the effectiveness of the PECVD technique to produce functionalized CNTs during growth in just one step of the process, without the need for additional treatments for the functionalization of the CNTs.

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