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Preparation and Characterization of Carbon Dots Obtained from Different Low Molar Mass Precursors

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Carbon dots (CDs) have attracted considerable attention in recent years, as they represent a relatively new class of carbon nanomaterials with interesting properties such as excellent water dispersibility, good biocompatibility, easy surface functionalization and photoluminescence that can be tuned to different wavelength emissions [1]. These carbon nanoparticles consist of quasi-spherical carbonaceous materials ranging in size normally from 2–10 nm, exhibiting sp^3-hybridized amorphous carbon containing small regions of sp^2-hybridized carbon atoms [2]. Because of their properties, the CDs can be applied in multiple potential applications in different fields such as in biomedical, photocatalysis, data security and sensors [3].

In this work, CDs were prepared from different low molar mass precursors using hydrothermal carbonization. Firstly, a specific amount of an aqueous solution of the carbon source (maleic or succinic acid) was added to an aqueous solution of one of the nitrogen sources (p-phenylenediamine or ammonium citrate) to form a 1:1 molar ratio of carbon to nitrogen source in the reaction mixture. The material was then transferred to an autoclave which was sealed and heated at 180°C for 8 h. Afterwards, the system was cooled until room temperature and the CDs suspension was filtered through a 0.22 µm membrane. The sample obtained from maleic acid and p-phenylenediamine was named MAPP whereas the sample obtained from succinic acid and ammonium citrate was named SUAC. The CDs were characterized by different techniques including FTIR, UV-VIS, Fluorescence spectroscopy and transmission electron microscopy (TEM).

The FTIR spectra of the CD samples (not shown here) showed the presence of several functional groups on the nanoparticles surface such as OH, NH_2, and C=O of carboxylic acids. These functional groups are the result of the formation process of the nanoparticles from the precursors and play an important role in the optical properties of the CDs.

Figure 1 shows UV-VIS absorption and photoluminescence spectra obtained at different excitation wavelength (shown in each figure) for the samples SUAC and MAPP. The insets in each figure show photographs of the samples dispersed in water illuminated with natural light (left) and with a UV light source (right). Both samples showed absorption bands with a maximum ~ 320–370 nm due to $n \rightarrow \pi^*$ transitions of C=O from different functional groups. The sample MAPP also showed a strong absorption band around 230–270 nm associated with aromatic π-π^* transitions of the conjugated C=C. The photoluminescence spectra of the sample SUAC show only one fluorescence emission peak which shift as a function of the excitation wavelength. This excitation dependent emission can be described in terms of a broader distribution of the different surface functional groups with different energy levels found on the surface of the CDs [2]. On the other hand, the sample MAPP showed two fluorescence emission peaks centered in two different regions, resulting in a yellow fluorescence emission. The development of CDs with yellow fluorescent emission can be important for biological applications because tissues and cells normally emit in the blue range and the signals of tissues and the carbon nanoparticles will overlap in applications such as biological fluorescent markers.

Figure 2 shows transmission electron microscopy (TEM) images obtained from dilute aqueous suspensions of the CDs. The TEM images for both samples reveal some aggregates and mainly relatively monodisperse nanoparticles with a quasi-spherical morphology. The size distribution of isolated nanoparticles was measured from different images, and the diameter for both samples was found to be in the range of 1.5–3.5 nm with an average size ~2.7 nm.

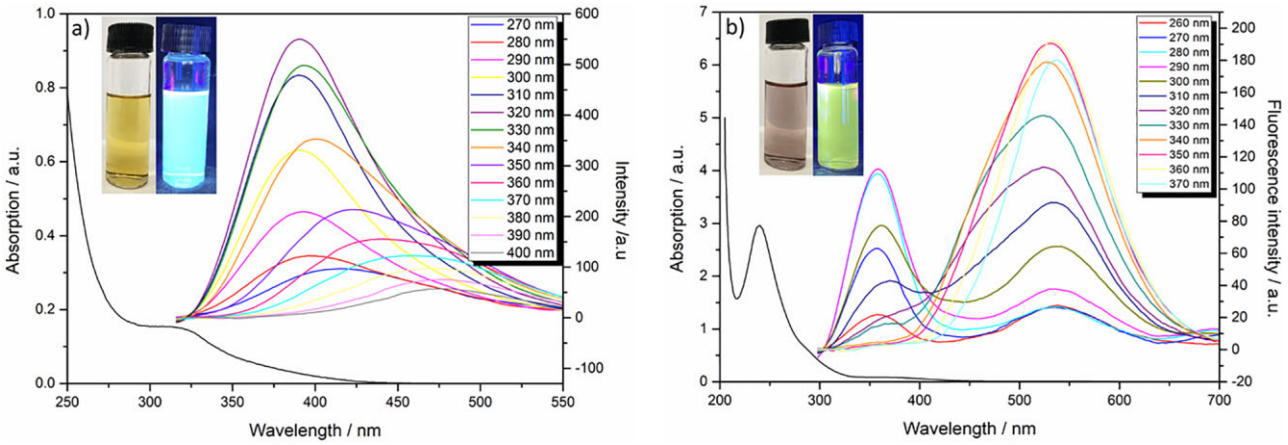

Fig. 1. UV-VIS absorption and photoluminescence spectra obtained at different wavelength excitation for the samples a) SUAC and b) MAPP. The insets show the samples dispersed in water illuminated with a natural day light (left) and under UV radiation (right).

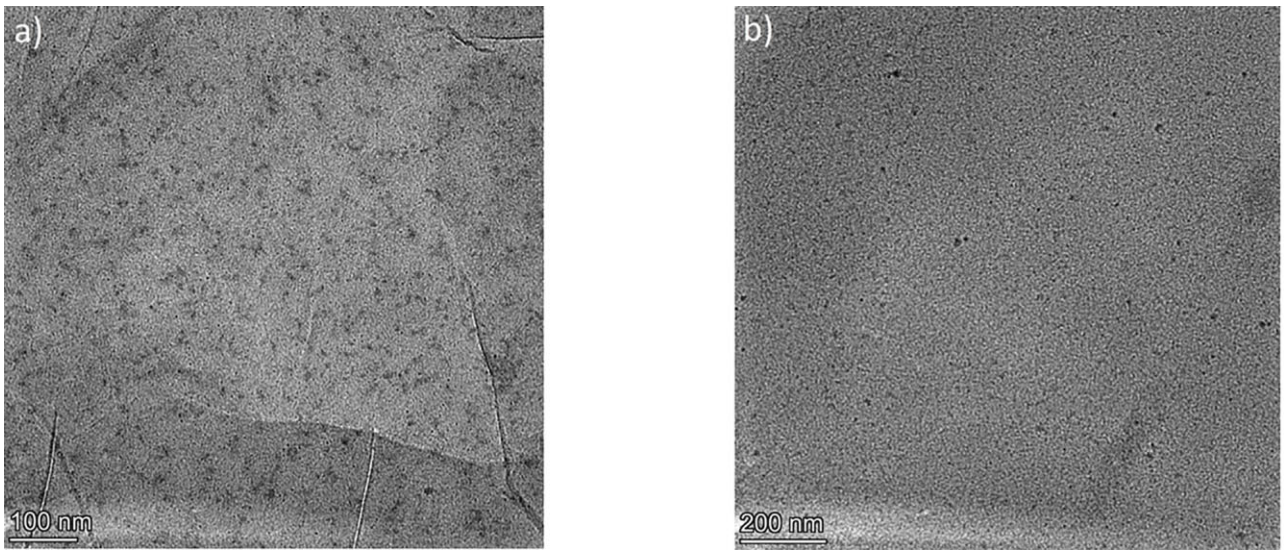

Fig. 2. Transmission electron microscopy images of the (a) SUAC and (b) MAPP samples.

Since the average size (diameter) for both samples was found to be very similar, the obtained results show that the difference in fluorescence color is mainly due to the different functional groups present on the surface of the CDs and not due to the difference in size of the nanoparticles. X-ray photoelectron spectroscopy (XPS) analysis are underway to highlight the differences found in the obtained samples and establish a structure-property relationship in relation to the precursors used and the final properties of the obtained fluorescent nanoparticles, which still constitutes an open question in the research area of carbon dots [4].

References

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