Carbon Dots: Exciting New Frontiers for Anticounterfeiting

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Counterfeit goods cost the global economy over $500 billion annually, according to the Organization for Economic Co-operation and Development (OECD) and the European Union Intellectual Property Office (EUIPO). This significant economic and societal burden underscores the urgent need to develop innovative product authentication and security solutions. Nanomaterials have become an effective alternative for developing advanced anti-counterfeiting applications. In particular, inorganic, organic, and hybrid luminescent tracers have shown great promise because of their unique optical properties. Carbon dots (CDs) have emerged as one of the most promising options due to their high chemical stability and optical versatility. CDs consist of a carbon-rich core and a surface domain rich in functional groups. These surface functional groups strongly influence the photoluminescence (PL) behavior of CDs, primarily due to surface-bound molecular fluorophores. This study explores how their chemical structure affects PL under different stimuli. While interactions between core and surface states are known to influence photophysical properties, the origin of PL is still debated. CDs' luminescence was found to be affected by various factors, including reaction precursors, synthesis conditions, purification methods, temperature, and pH. In addition, PL and decay times can be influenced by excitation and de-excitation processes, as up-conversion, delayed fluorescence, phosphorescence, and persistent luminescence. Customizable CDs can be engineered for anti-counterfeiting, product tracing, and information encryption due to their tunable luminescence. By selecting precursors and controlling reaction parameters, CDs with high quantum yield and versatile PL across the UV–VIS–NIR range can be created. This customization enables the development of CD-based nanocomposites for secure applications, showcasing their potential for future technological advancements.

Reference

[1] R. Simões, J. Rodrigues, V. Neto, T. Monteiro, G. Gonçalves, Carbon Dots: A Bright Future as Anticounterfeiting Encoding Agents. Small 2024, 20, 2311526. https://doi.org/10.1002/smll.202311526

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FIGURE 1
Schematic representation of (A) the main optical properties of CDs; (B) the optical transitions that may occur in CDs; and (C) persistent luminescence mechanisms in inorganic hosts.[1]

FIGURE 2
Potential applications of CDs as anti-counterfeiting agents.[1]