Engineering Carbon Nano-onions for Drug Delivery

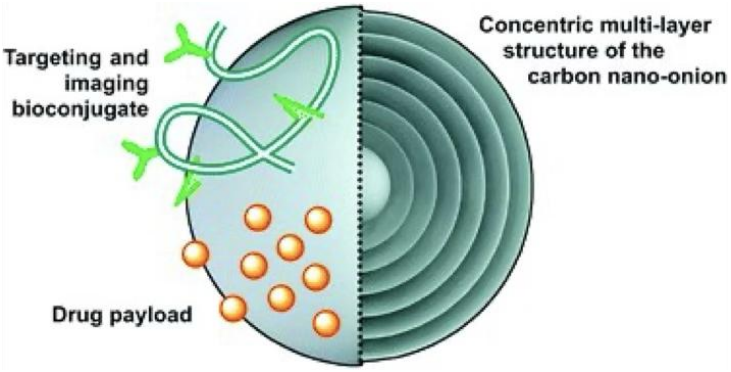
Carbon nano-onions (CNOs)—multi-layered fullerenes composed of concentric sp^2-hybridized carbon shells—are emerging as versatile nanocarriers for targeted drug delivery due to their small size, high surface area, tunable surface chemistry, and biocompatibility. We have developed a reliable method for synthesizing pure, monodisperse CNOs and engineering their surfaces with receptor-targeting and imaging units. These modified CNOs display high photostability in aqueous media and selective uptake by cancer cells with minimal cytotoxicity.

To achieve tumor-specific delivery, we employed supramolecular functionalization with a hyaluronic acid–phospholipid (HA-DMPE) conjugate, enabling selective recognition of CD44-overexpressing cancer cells. HA-DMPE–CNOs showed enhanced uptake and viability in CD44+ human breast cancer cells compared to CD44− ovarian cancer cells, while zebrafish studies confirmed strong biocompatibility in vivo.

In parallel, boron nitride–doped CNOs functionalized with HA-DMPE enabled pH-triggered release of doxorubicin (DOX). This platform achieved superior uptake and anticancer activity in multiple breast cancer cell lines (MDA-MB-231, MDA-MB-468, MCF-7) compared to free DOX and Caelyx®, while significantly reducing cardiotoxicity in AC16 cardiomyocytes.

Additionally, gemcitabine-loaded HA-CNOs demonstrated potent cytotoxic effects against pancreatic adenocarcinoma cells. Folic acid–modified CNOs (FA-CNOs) were engineered for receptor-mediated targeting of folate receptor–positive cancer cells, enabling efficient DOX loading and controlled release. Comprehensive spectroscopic, microscopic, and thermal analyses confirmed successful surface modification and drug incorporation. In vitro assays demonstrated that FA-CNOs significantly improve cellular uptake and drug delivery relative to non-targeted controls.

These studies establish CNO-based nanocarriers as safe, customizable, and effective platforms for targeted cancer therapy, underscoring their promise in advancing nanomedicine.



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