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Two-Dimensional Materials in Nanobiophotonics for Oncological PDT/PTT

Associated Centre in ADIRAC: Centre for Advanced Materials

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Project Description and its implementation

Aim of the project:

The scope of the project is to understand the potentiality of two-dimensional materials towards effective agents in Photo dynamic and Photo thermal therapy. The main interest is to have perspectives in the above-mentioned application.

Illustration of Possible therapy in Cancer Treatment

Introduction

Cancer has been a chronic life-threatening disease for centuries and the researchers have been actively working to find effective diagnosis and treatment for different types of cancer. . The financialphysical and emotional stress that cancer causes are tremendous not onlyfor patients but also for the supporting society. As stated in a recent report, an approximate medical cost for cancer is estimated about 80.2 billion Dollar in United States (2015) and is tremendously increasing every year. The conventional cancer therapeutic and diagnostic tools comprise of surgery, chemotherapy, radiotherapy, targeted therapy and photoacoustic imaging (PA), computerized tomography (CT) and magnetic resonance imaging (MRI). Compared to the conventional modalities, nanoparticles show advantages in cancer treatment and/or diagnosis such as: (1) it tiny size allows enhanced permeation and retention effect (EPR) and easy penetration into various cells and physiological barriers; (2) large surface allows easy surface modification and easy functionalization with multiple molecules for ensuring bioavailability, biocompatibility, biodegradation, attaching of tumor-specific cell markers and combing both imaging and therapeutic functionalities. Even though numerous therapeutic and diagnostic strategies are available, their performance and efficiencies are still unsatisfactory and is questionable. The efficiency reliable of devices and medicines depend on the type of material chosen for their respective modalities.

Material Selection

The factors to be considered for material selectionincludes size, morphological shape/structure, active surface area, stability, biocompatibility, toxicity, electronic configuration, surface charge, magnetic properties, optical characteristics, surface plasmon and luminescent properties. Based on their aspect of high active surface, two-dimensional (2D) ultrathin graphene like MXenes are thick-layered material with superior metallic conductivity determined by their free electrons and hydrophilicity caused by surface terminations. In the past 2 years, research and publication on MXenes has seen significant rise and till now, Ti_3C_2, Ti_2C, V_2C, Cr_3C_2, Fe_2C, Nb_4C_3, Nb_2C, $Mo_{1.33}C$, Mo_2C, Hf_3C_2, (V_2C, Cr_2C, and Ta_2C), Cr_2N, Ti_4N_3, etc are experimentally synthesized successfully. The first application that came into light with MXenes is in energy storage devices such as electrochemical capacitor, micro-supercapacitor, batteries and extraordinary surface interactions with the material's specific target molecules making them an interesting candidate for surface-active therapeutic agents in drug delivery and optical therapy. In recent years, 2D nanomaterials such as graphene, antimonene, black phosphorous, dichalcogenides and oxides, have successfully crossed material selection criteria and effectively walked through the oncological sector as biomedical agents.

MXenes are suitable for diagnostic, therapeutic and theranostic applications in oncology sector due to their attractive properties such as (i) hydrophilic surface for easy functionalization of therapeutic agents and/or tumor targeting finds application in photothermal, photodynamic and radiation therapy, (ii) huge active surface for high drug incorporation efficiency allowing them to be used in chemotherapy as well as incorporation of targeting molecules for targeted therapy, (iii) good biocompatibility and non-toxicity causes less side effects without the need of surface coating with biocompatible material, (iv) strong light absorption in near-infrared (NIR) regions NIR-I & II which allows them to be used in in-vivo PA imaging and photothermal therapy

and (v) ferromagnetism suitable for MRI imaging. Another area in which MXene research is taking over other nanomaterials is in the fields which require electronic, structural and electromagnetic applications like electromagnetic interference shielding and printable antennas.

Associated Therapy

PDT is a quiet effective and non-invasive treatment strategy that involves the supply of photosensitizing agent, prodrug and activation agent, followed by light induced activation of sequential chemical and biological processes by the generation of ROS which cause acute damage to encircling tumor tissues. Owing to the recent entry and progress of MXenes in this research area, very limited reports are available. For instance, Ti_3C_2 nanosheets are reported as the first MXenes which has potential to induce ROS under the excitation of suitable wavelength of light. It is documented that during PDT treatment cancer cell death is also accomplished with combined photo thermal effect.

Research Collaborator:

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List of publications and Outcome:

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