Carbon Nanotubes and Strong Composites Focus Area

Objective: Synthesis and study of carbon dots and carbon onions

The project is driven by Dr M.S. Maubane-Nkadimeng, and Prof N.J. Coville is part of the team. Much work has been done in this area making carbon nano-onions (CNOs) and carbon dots (Cdots). The focus has been on using these carbons as supports and in batteries etc.. Papers will be published in 2021 on this topic, e.g. the role of castor oil versus paraffin oil in making CNOs (*Nanotechnology* 32 (2021) 135603 (12pp)). The study overlaps with those projects involving uses of the carbons. (T. Mongwe, B. Matsoso, A. Magubane, N.J. Coville, D. Wamwangi and M.S. Maubane-Nkadimeng)

Objective: Use of the new carbons as supports in catalysis

This project provides one of the most important uses of the carbons that the Group synthesises. A focus is to use the novel carbons in unique ways. For example, a current project entails placing Ni inside hollow carbon spheres (HCSs) and to grow carbons from these Ni catalysts (MSc by Mtolo), similar to the work on Cu@HCS materials. This study has been extended to making Ni and Cu Schiff bases inside the HCSs. In other studies, Co@HCS catalysts were made and their ability in oxidation and hydrogenation reactions was studied (Ms Mente), as well as Pd/Cdots materials that were studied for their auto-catalytic reduction reactions (Ms Magubane). (B. Mtolo, A. Magubane, P. Mente, A. Boudjemaa (CRAPC, Algeria), N.J. Coville, M.S. Maubane-Nkadimeng and J van Wyk)

Objective: Synthesis of carbons from chlorinated carbon reactants

This study is now complete. The focus has been on the use of chlorinated hydrocarbons to make carbon nanofibres (CNFs) and carbon nanotubes (CNTs). In the most recent study, the use of N and Cl sources to make Cl-doped NCNTs was reported (*W.K. Maboya, N.J. Coville and S.D. Mhlanga. Fabrication of chlorine nitrogen co-doped carbon nanomaterials by an injection catalytic vapor deposition method, Materials Research Express, 8 (2021) 015007).* One final paper on the use of the chlorinated carbons in a spin coated polymer will be produced in 2021. (W. Maboya, M.S. Maubane-Nkadimeng, S.D. Mhlanga and N.J. Coville)

Objective: Use of carbons in solar cells, sensors, batteries and capacitors

This objective is focused on the synthesis, functionalisation and characterisation of chain-like solid carbon nano onions for application in volatile organic solvent gas sensing devices/systems. Catalyst free onion-like carbons were produced from olive oil using a flame pyrolysis method, with yield and quality optimised using a brass collecting plate. A composite material (CNOs/Metal-Ox/Polymer) was synthesised and its properties were tested in sensing devices. The sensor performance was optimised for the sensing of acetone at room temperature. The study was completed by the PhD student, Mr Thomas Mongwe.

A collaborative project with Prof. K.I. Ozoemena was a study using N doped CNOs in supercapacitors *(B. Shaku, T.P. Mofokeng, T.H. Mongwe, N.J. Coville, K.I. Ozoemena and M.S. Maubane-Nkadimeng. Physicochemical properties of nitrogen doped carbon nano-onions grown by flame pyrolysis from grapeseed oil for use in supercapacitors, Electroanalysis* 32 (2020) 2946-2957). Other studies have already been accepted for publication in 2021 on the use of Pd/CNOs in electrochemical studies (*International Journal of Hydrogen Energy).*
(B. Matsoso, T. Mongwe, N. Khoza, J. Serbana (Universidade Federal do Parana Curitiba PR, Curitiba, Brazil), M.A. Mamo (U. Johannesburg), D. Wamwangi, N.J. Coville and M.S. Maubane-Nkadimeng)

Objective: The use of carbon onions (CNOs) for the removal of hexavalent chromium in the presence of cations in aqueous solution

The aim of this project was to study the effect of parameters such as the solution pH, concentration and contact time of the CNOs on the adsorption of Cr (IV) in aqueous solution. To test the selectivity of the adsorbent, other cations were added to the aqueous solution. The

CNOs used were synthesized from olive oil using a flame pyrolysis method. When CNOs were used as adsorbents, they weres selective to Cr(IV), even in the presence of other contaminants such as Cu(II) and Ni(II). (T. Ntuli, T.M. Mongwe, N.J. Coville, E. Nxumalo and M.S. Maubane-Nkadimeng)

Objective: Synthesis and characterisation of doped carbon nanomaterials for use in photocatalysis and Dye-sensitised Solar Cells (DSSCs)

One part of the project involves the synthesis of doped non-metal carbon nanospheres (CSs) from onion (the vegetable) as a C, N and S source. The materials were then used to make composites of CSs/TiO_2 photocatalyst to remove toxic dyes from polluted water.

The properties of the synthesised materials were studied and characterised using electron microscopy and other relevant techniques. Strong nanomaterials, particularly multiwalled carbon nanotubes (MWCNTs) exhibit exceptional adsorption properties and have proved to be very effective in removing chemical and biological contaminants from wastewater, mainly due to their high surface active site-to-volume ratio and controlled pore size distribution.

Two other projects involved the use of boron-doped MWCNTs/TiO_2 or nitrogen-doped MWCNTs/copper zinc tin sulphide (CZTS) composites used as highly efficient counter electrodes to replace the conventional platinum catalyst for redox reactions in DSSCs.
(W. Mokone, L. Mxakaza, Y. Mhlana, J. Moma, N.J. Coville, N. Moloto, D. Wamwangi and Z.N. Tetana)

Objective: Development of graphene-based gas sensor devices

Gas sensors are devices that convert a gas volume fraction into electrical signals. The current research focuses on the development of nanomaterial-based devices for applications in gas sensors, energy and environmental monitoring. These sensor materials include semiconductor-graphene, semiconductor-polymer and graphene-polymer composites. The sp^2-bonded carbon layers in two-dimensional graphene are beneficial for efficient charge transport through its conducting surface during adsorption/desorption of gas molecules. This is a desired attribute, especially for gas sensing applications. Recently, the fabrication of graphene-polymer hybrid nanocomposites with new properties which generate from interfacial interaction between the individual components has attracted much attention. This is promoted by the desire to produce materials with excellent electronic properties and good stability that can also be used at ambient temperatures. An ongoing study aims to use graphene-based strong materials together with conducting polymers (such as polyaniline) and metal oxides composites to achieve high performance (in gas detection) and ambient temperature nanomaterial-based working devices that are robust and stable. (C. Masemola, B. Tlhaole, E.C. Linganiso, Nosipho Moloto and Z.N. Tetana)

Objective: Development of energy storage and conversion systems

Two separate studies are ongoing. The first one involves the design, synthesis and characterisation of different nanostructured carbons (hard carbons, carbon nanofibres) and their metal oxide composites for the development of high-performance energy storage systems (e.g. supercapacitors and sodium-ion batteries). The second study conducts detailed electrochemical experiments of the carbon nanotube/carbon nanofibre composites, to understand their properties as viable energy materials for the development of next-generation energy storage devices. One article was published and another was in preparation.
(S. Shabalala, T. Mofokeng, Z.N. Tetana and K.I. Ozoemena)

Objective: Green synthesis of metal oxide nanoparticles, zinc ferrite and metal sulphide nanoparticles supported on various carbon nanomaterials for the treatment of dyes and microorganisms

The main aim was to synthesise green derived metal oxide nanoparticles, metal sulphides and zinc ferrite nanoparticles supported on carbon nanospheres and carbon nanofibres for photocatalytic and biological applications.

Ms L.M. Mahlaule-Glory has completed her MSc and will be submitting in April 2021. The work was the synthesis of ZnO and AgO using the *Sutherlendia frutescence* plant for reducing agents during the synthesis. The materials were synthesised via a green route, fully characterised using SEM, TEM, XRD, FTIR and UV-Vis techniques. These materials were later applied in wastewater treatment as photocatalysts and antibacterial agents against methylene blue dye and microorganisms such as *E. coli, S. aureas, E. faecalis and P. auregenosa.*

Another student, M.N. Ngoepe synthesised TiO_2/ZnO nanomaterial and conducted photodegradation experiments. To enhance the photocatalytic properties of his green syntheszed metal oxides, he also synthesised carbon-based nanomaterials such as carbon nanofibres and carbon spheres and also deposited a low bandgap material (CuO nanoparticles). He succesfully synthesise the composite and in 2020 published his second MSc paper and a book chapter. He has completed his MSc and will submit in April 2021.

Ms S. Munyai started her MSc in 2019, and is synthesising metal sulphides on carbon dots. She is currently writing up her MSc and will be submitting in May 2021. She currently has two manuscripts in preparation, with one to be submitted in February 2021.

Mr Mokafane started his MSc candidate in 2020, and is progressing well. He is working on the synthesis of metal ferrites supported on carbon spheres and carbon dots for the degradation of pharmaceutical pollutants and textile dyes. He has a book chapter under review, hopes to submit in October 2021. (M.N. Ngoepe, L.M. Mahlaule-Glory, S. Munyai, A. Makofane and N.C. Hintsho-Mbita)

Objective: Application of carbonaceous nanomaterials (MWCNTs, carbon nanoparticles and reduced graphene oxides) - semiconductor metal oxides-polymer nanocomposites in solid state sensors for the detection of volatile organic compounds

This project focuses on the fabrication of chemi-resistive solid-state gas sensors with advantages of being user-friendly, portable, fast, sensitive and reliable. These sensors consist of carbonaceous materials, semiconducting metal oxides (SMOs, such as MnO_2, TiO_2, ZnO and SnO_2) and polymers as the sensing matrix. The carbon materials used include carbon nanotubes, graphene oxide and carbon nanoparticles, which were easily synthesised from candle soot. The sensing mechanism of these materials for different analyte vapours has been investigated (and an article was published) and is very important to understand the selectivity for the analytes. (G.E. Olifant, K. Kulsum and M.A. Mamo (U. Johannesburg)).