Summer Project 2021 – Tara Biddle

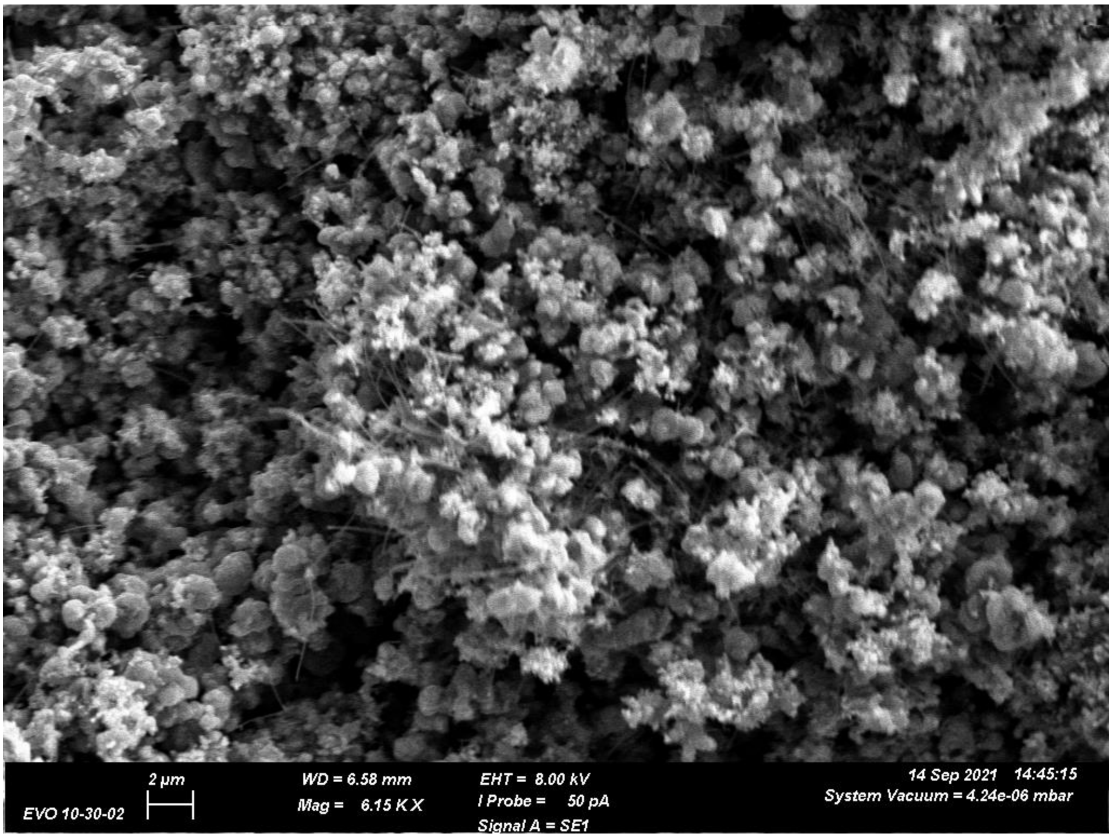
This summer I undertook a summer research project in the Department of Chemistry in the PPE group under the supervision of Dr. Xiangyu Jie, a Junior Research Fellow at Merton College. During this project I investigated different catalyst's ability to form high value carbon products, such as multi walled carbon nanotubes, when mixed with plastic and heated via microwave.

Sustainability and fixing the present overconsumption and disposal of plastics which is currently a hotly debated topic is an interest of mine. Dr. Xiangyu Jie's previous research into hydrogen fuel production and storage and fossil fuel decarbonisation first attracted me to this research group. I am honoured to have been a part of the process of furthering their research into using waste plastic to create hydrogen fuel.

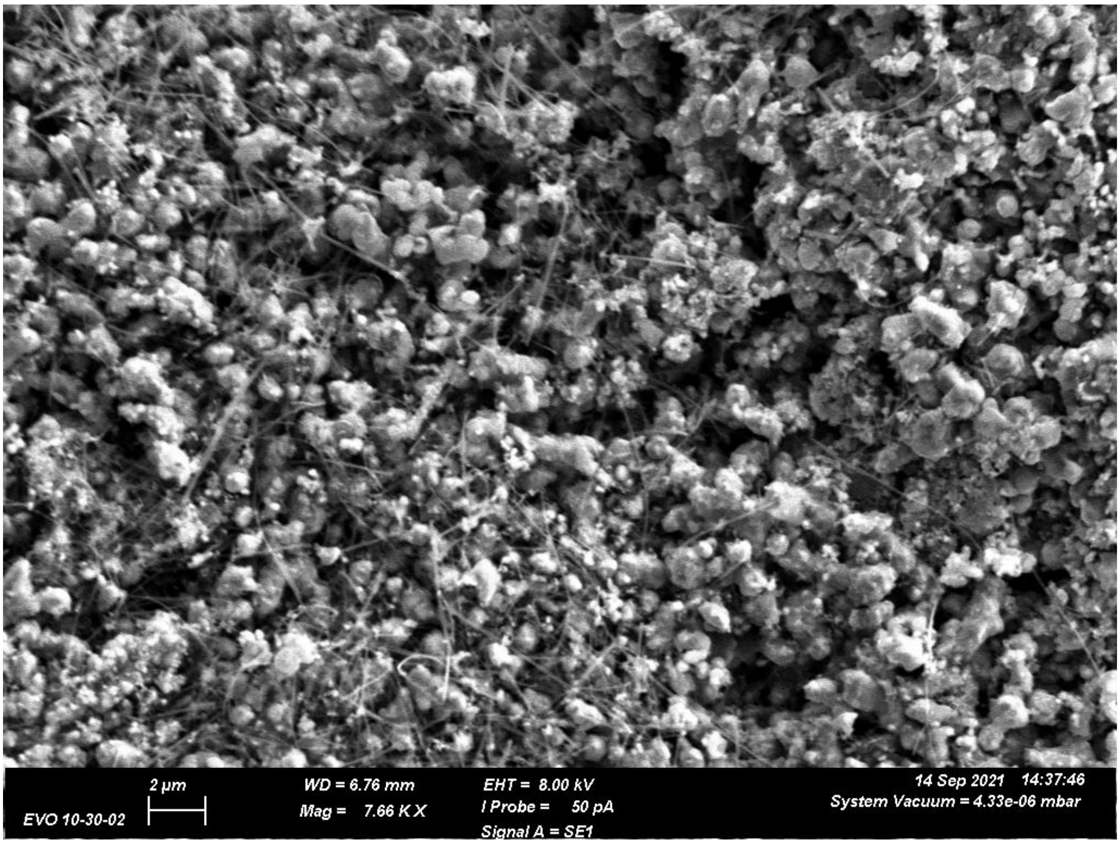
Waste plastic has been a focus of research recently as this is a hydrogen rich resource for producing hydrogen fuel. Previously a pyrolysis technique has been used to extract the hydrogen, however, this is a complicated process which requires very high temperatures and releases considerable carbon dioxide and carbon monoxide by-products. These environmentally harmful emissions make this process redundant in producing a cleaner energy resource in place of fossil fuels.
During my summer project microwave heating was used instead of pyrolysis. This is a quick one step process, far simpler than pyrolysis. The microwave heats only certain bonds in the catalysts, which in turn heat the plastic in direct contact with it. This more directed heating reduces side reactions and allows this process to be more easily controlled.

The first part of my summer project involved the initial preparation of various catalysts involving an impregnation technique to insert various transition metals into carbon nanotubes. This gave me an opportunity to familiarise myself using two new furnaces and practise my general chemistry laboratory skills. Further catalysts prepared involved the combination of aluminium with various transition metals using similar techniques in a citric acid combustion method.

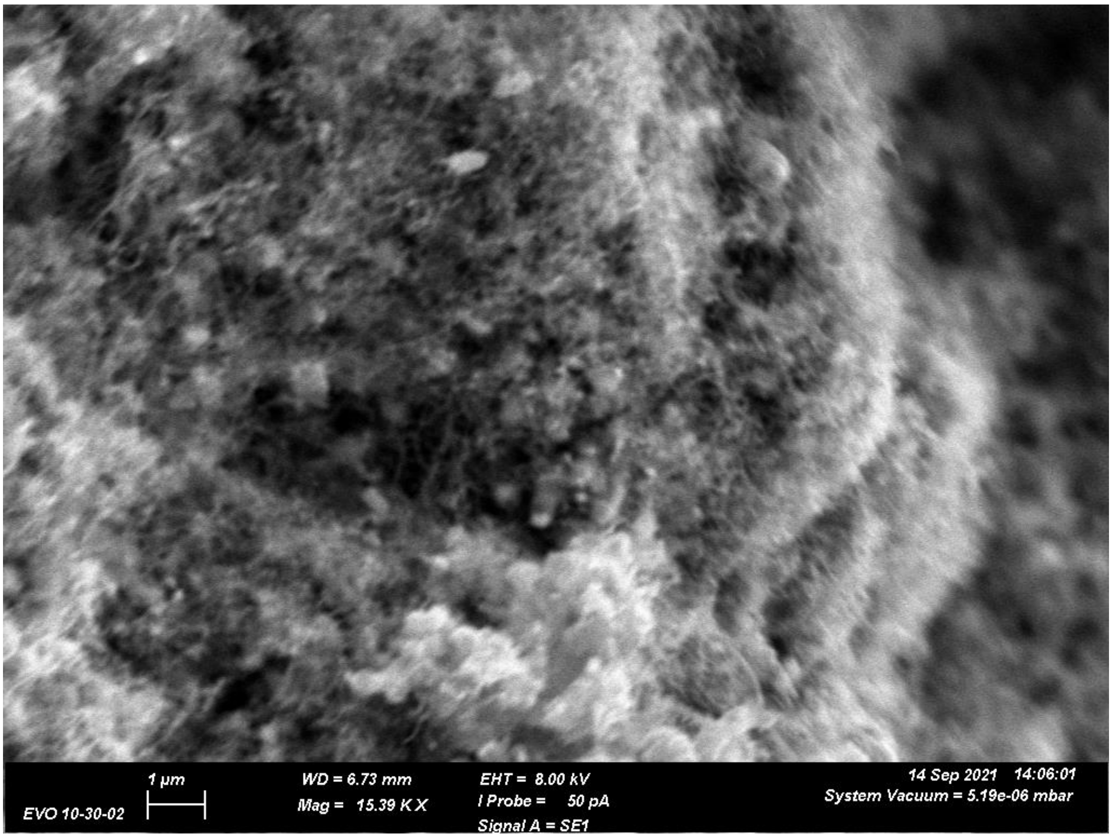
Once the catalysts were prepared, they were mixed in a 1:1 ratio with waste plastic and heated in the microwave reactor. For each catalyst 1 cycle, 3 cycles and 5 cycles of microwave heating were undertaken. Each cycle lasted 5 minutes at 1000W. Hydrogen is rapidly evolved from the sample and carbon material is left behind in this process. Unfortunately, at the time of my project the gas chromatographer, which would be used to determine the make up of the gas evolved from each sample, was not in use.
The carbon material left behind was analysed using thermogravimetric analysis and X-ray diffraction. I was extremely privileged to be trained to use both machines. Further scanning auger microscopy analysis was also carried out by my supervisor which provided compositional maps of the surface of the products collected from the microwave heating.
Each catalyst gives a different yield of hydrogen evolution and carbon product distributions. Below are some of the images collected from the microscopy analysis. The line-like shapes which can be seen in the first three images are the fibrous structures of carbon nanotubes which we aimed to produce. The iron impregnated carbon catalysts are observed to be the most efficient for producing these carbon nanotubes, although the 20% carbon to nickel catalyst also proved to be effective.



5% carbon nanotube to iron catalyst product following 5 microwave cycles.

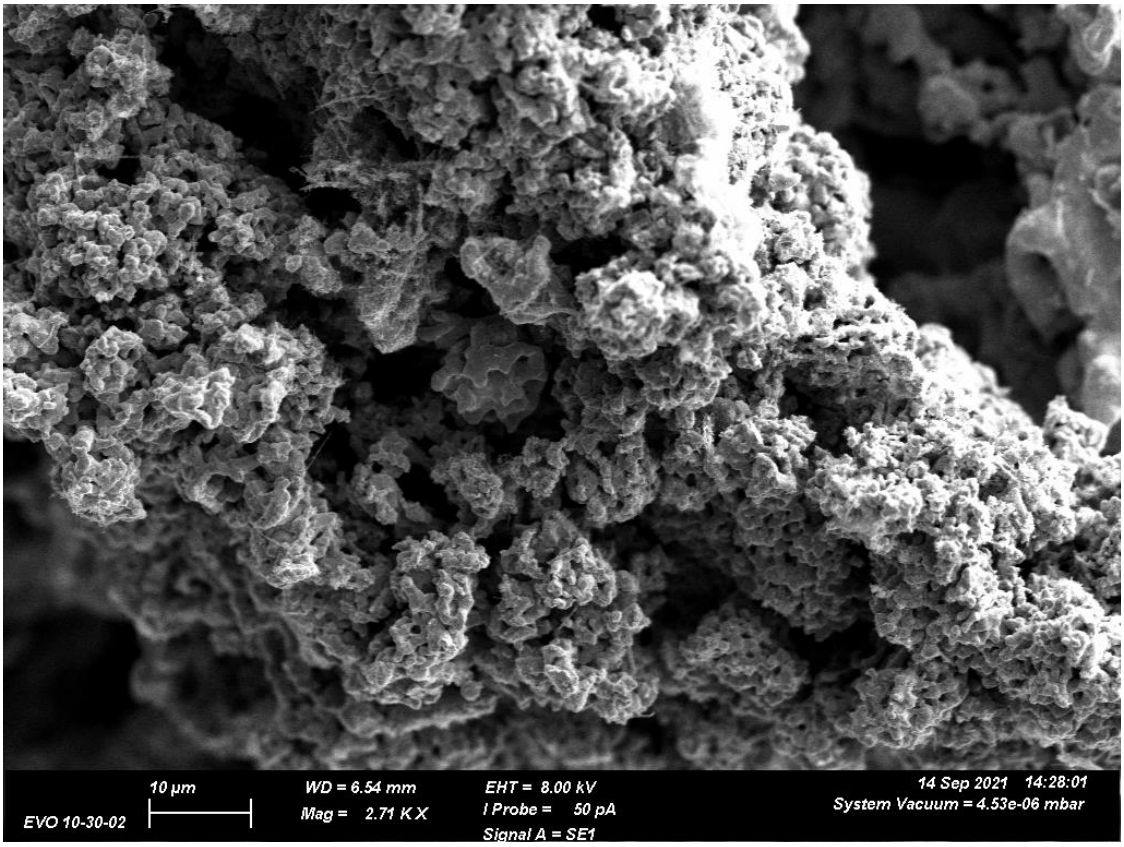


20% carbon nanotube to iron catalyst product following 5 microwave cycles.

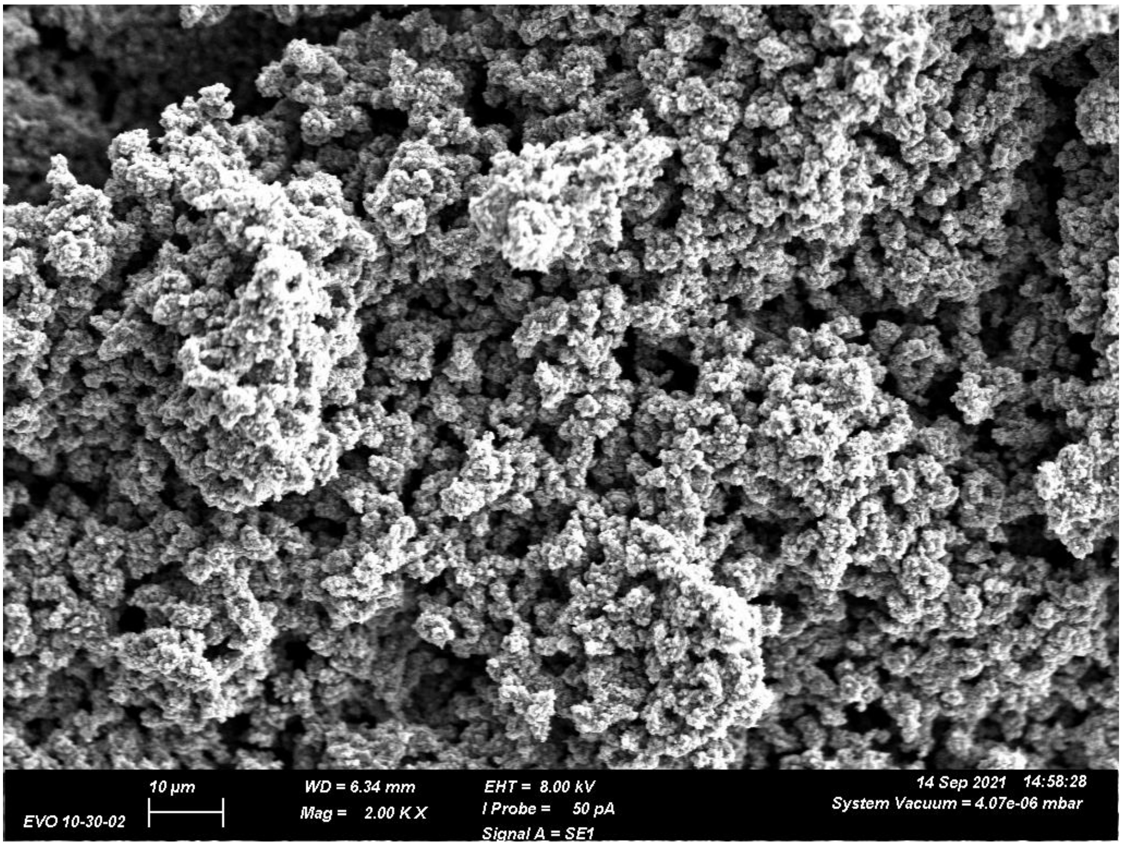


20% carbon nanotube to nickel catalyst product following 5 microwave cycles.

Other catalysts proved to be ineffective at producing carbon nanotubes and only the rounded nodule shapes can be seen on the structures in the images below. This is amorphous black carbon, a low value carbon product.



5% carbon nanotube to copper catalyst product following 5 microwave cycles.



5% carbon nanotube to cobalt catalyst product following 5 microwave cycles.

This method is a promising new approach to tackling waste plastic, and I am pleased to have been able to contribute further research into different catalysts, their efficiencies and product distributions.

From this project I have had an opportunity to further improve my laboratory skills, experience independent research, time management and organisation. I have had opportunities to train on and use various machines and equipment that I otherwise would not have experienced in any undergraduate study. Working alongside postgraduates and post doctorates has been a privilege and I enjoyed learning about their careers and learning from their experience. This project overall has given me valuable insight into what a career in research could look like for me and post graduate study certainly looks more promising.

I am very grateful to the Department of Chemistry and Merton College for supporting me in this project, and extremely thankful to Dr. Xiangyu Jie and group for guiding and encouraging me throughout this experience.