Our increasing energy demand and the concern about environmental pollution is driving the research towards renewable energy resources. Most of the renewable sources of energy generate electricity from wind, water or the sun. A fairly new option is the direct production of fuel, such as hydrogen, from sunlight. The advantage over wind and solar electricity is that hydrogen can be stored and used when the energy demand is high.

TiO$_2$ is one of the most important oxide semiconductor materials used to split water into hydrogen and oxygen, due to its high photocatalytic activity and stability in water-based electrolytes. The geometry of the nanotube arrays can be controlled. This is important because it facilitates the optimization of the light absorption and propagation characteristics. However, TiO$_2$ can only use UV radiation to transform water into hydrogen. With 3 to 5% UV comprises just a small fraction of the energy of the solar spectrum, compared with 45% for visible light. Therefore, any broadening of the optical response of TiO$_2$ to the visible light range, while maintaining its robust properties, would render this material very efficient in water splitting.

In this PhD I have extended the absorption range into the visible light by adding nickel and molybdenum to the titanium, to increase the efficiency of hydrogen production. My results demonstrate the ability to grow Ti–Mo–Ni mixed oxide nanotube arrays that are several microns thick. These materials have a profound effect on the light absorption capability of the material, shifting the absorption into the visible light range. This results in a 10 time increase in photoconversion efficiency compared with pure TiO$_2$ nanotubes fabricated under the same conditions. From an energetic point of view this is a double break through as not only the efficiency increased enormously but also the external bias (energy input) is no longer needed.