Laser based surface modifications to increase the corrosion resistance and antifouling of electrodes.

Mark Swayne.

The goal of this project is to address the challenge of electrode corrosion and fouling in the operation of electrodes used within food and bio-processing vessels. The corrosion and fouling of electrodes is a common problem due to electrochemical reactions which occur during the process. Electrode corrosion can result in the release of small quantities of metal from the electrodes which mixes with the fluid. The focus of this project is to develop a laser based surface modification to enhance the antifouling and anticorrosion properties of the PEF electrodes.

Corrosion is a way in which a substance is degraded usually due to the presence of oxygen in the contact fluid. The oxygen will combine with the metal causing an oxide which is commonly seen as rust, for example iron oxide on an iron alloy. A common method that is used to reduce the formation of rust on the surface is by painting it. This produces an outer layer over the metal stopping the oxygen from coming in contact with the metal which will minimize the oxide formation. The disadvantage with painting and other protective coatings is that they can contaminate a reaction vessel which would be a huge concern in terms of possible contamination in the food and bio-processing industry.

In stainless steels, the surface can be passivated by the reaction of the chromium in the material with oxygen causing a chromium oxide layer. This layer stops the oxygen from coming into contact with the Iron which will cause rust. Since this layer is very thin oxygen can still get through the layer by a process called diffusion and cause corrosion of the electrode. A laser can produce really high amounts of energy into a very small spot on the work piece. This high energy can be converted into heat. This heat causes the elements inside the steel to move around more easily. Since chromium likes to react with oxygen more than iron, the oxygen will pull the chromium toward the surface so it can react with the oxygen more easily. This process causes a larger chromium oxide layer to be produced. This will make it harder for the oxygen to go through the layer increasing the corrosion properties of the metal. Since the protective layer is already present on the surface, this process can make this layer thicker further avoiding degradation of the electrode surface and any contamination issues. The energy in the spot divided by the spot area is called the fluence. As the fluence Is increased the temperature of the surface also increases. This makes it even easier for the atoms to move around causing a larger oxide layer. A secondary effect of this is the change of colour caused by this increased thickness of the oxide layer or the change in surface chemistry due to the diffusion of atoms.

Antifouling is the property of a surface that minimizes substances sticking to it. This is commonly seen in boat hulls where sea life such as barnacles attach to the hull causing it to wear away faster. One way in which a laser can be used to reduce fouling is by either producing a defined surface texture. The surface texture may be applied such that the smoothness of the surface is increased, thereby decreasing the opportunity for foreign entities to stick. Alternatively, the surface texture can be defined to make the surface profile hydrophobic such that it will not allow organic matter to easily remain. Looking at the surface under high magnification, it can generally be seen that it is not flat and there are ridges and valleys present on the surface. Laser texturing can be implemented is by scanning the laser over the surface of the material. By doing this it can melt the top of the ridges allowing them flow into the valleys causing them to fill up. One measure that can be used for the surface roughness is the distance between the top of the ridge and the bottom of the valley.