Lanthanide Catalysts on Silicon Surfaces: a DNA-Based Approach to the Design of More Efficient Catalytic Materials

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Background

A catalyst improves the efficiency of a chemical reaction by reducing the amount of energy needed for the process to be feasible. Catalysts actively take part in the reaction, but are regenerated at the end and can be re-used repeatedly.

Homogeneous catalysts (which will dissolve alongside the starting materials in a typical chemical reaction) are crucial in both the fine chemicals and pharmaceuticals industries. However, they are often hard to recover from the reaction mixture afterwards, meaning they may be lost. The main advantages of heterogeneous catalysts (which remain as solids in the mixture) are that they are easier to recover for re-use in later reactions, simply by filtering them out, and that their large surface area can be highly chemically active.

The research presented here explores a potential route to making heterogeneous catalysts by binding homogeneous catalysts to a solid surface. These materials would be able to catalyse reactions in the same way as the homogeneous catalyst, yet have advantageous heterogeneous properties.

Aims

- Chemically clean, then functionalise a silicon surface with a linker molecule (see **Figure 1**) which has comparable lanthanide-binding properties to the 'backbone' of DNA.
- Bind ions of two of the lanthanide elements used in catalysis, cerium and terbium, to functionalised surfaces.
- Determine (via fluorescence microscopy) the effect of this material on the fluorescence properties of different DNA sequences deposited on the functionalised and lanthanide-bound surface.

Results

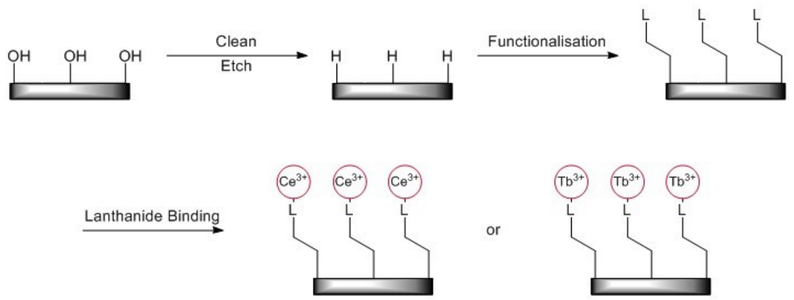

Figure 1 Scheme for the functionalisation of the silicon surface and lanthanide binding.

Vast network structures were seen under the microscope when DNA was dropped onto the surface. There was little difference between wafers bathed in different lanthanides, or with a control experiment using a lanthanide-free wafer, but varying structures in the DNA networks (or no networks at all) were observed depending on the sequence of bases.

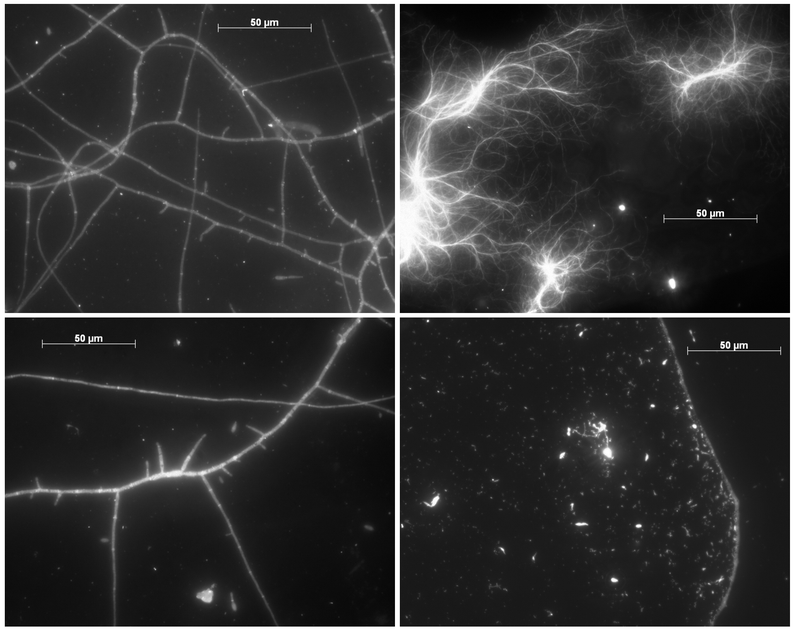

Figure 2 Varying network structures formed by DNA dropped onto the silicon surface.

Conclusions

Fluorescence microscopy experiments were unsuccessful in confirming the functionalisation and binding of lanthanide ions to the silicon surface, because the control experiment yielded very similar results to both lanthanide experiments.

However, the nature of DNA deposited on the surface of the silicon wafers was very surprising, appearing to form clumps and complex network structures which had not been expected. Given their size, orders of magnitude longer and thicker than individual strands of DNA would be, the objects shown in **Figure 2** appear to be comprised of many strands of DNA found very close together. These unusual shapes may be the result of DNA deposited on the surface remaining where it fell, giving an interesting picture of its appearance in solution. This could imply that it interacts with the surface, and may warrant further investigation.

Future Work

- Examination of the silicon wafer surface using alternate methods, such as by atomic force microscopy (AFM).
- Exploration of alternate linker systems, such as full DNA strands with differing sequences and lengths.

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