A NEW FOCUS FOR RESEARCH IN THE FOREST BASED SECTOR: THE DEVELOPMENT OF HIGH VALUE, BIOPOLYMER BASED MATERIALS

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The latter half of the 20th century saw real progress in the development of the forest products industry. Today, it provides essential materials for modern day life from the provision of fuel and structural materials through to paper, packaging, textiles, hygiene products, and a broad range of specialised cellulosic products for the food and pharmaceutical industries.

Excluding wood for fuel and construction, the largest consumption of wood in global markets takes the form of pulp and paper. Traditionally, Europe has been a dominant player in this industry and played a major role in research, development and innovation in both product and process development. Until recently the UK played a small but significant role in this industry. The last 20 years has seen traditional pulp and paper producers come under increasing pressure from emerging economies. To date the European industry has managed to minimise these impacts through technological innovation leading to increased automation, process efficiencies and higher value products. However, competitive pressures remain and are driving the industry down two parallel paths.

The first approach has been to focus capital investment in forests and manufacturing facilities in "low cost" developing countries. This is ensuring the future sustainability of European corporations but at the expense of a marked decline in European manufacturing capacity. The UK has suffered particularly badly from this process with very low levels of investment in competitive manufacturing technology. This has been paralleled by a marked decline in UK based forest products research capacity. By the year 2000, the UK was a relatively insignificant player in forest products research whilst at the same time being one of the world's largest consumers of imported forest products.

The second approach has been to invest in new, game changing technologies. The European pulp and paper industry has a limited window of opportunity to diversify and transform its manufacturing capability into new, higher value materials and products that can build on the forest industries sustainable credentials and replace existing high value, oil based products. The oil industry is an interesting comparator as the pulp and paper industry begins to rethink the pulp and paper mill as a bio refinery. This creates an opportunity to harness the creative potential of UK research capacity.

At the beginning of the 20th century, petroleum refinery was in its infancy producing only a few products and little energy production using the previous technologies developed for coal. The development of petroleum refinery was a protracted process that required an extensive effort to develop the existing petrochemical processes and allied catalysts leading to the highly efficient systems and an extensive range of oil based products that we know today. In the same way, the newly developing lignocellulosic biorefineries industries based on wood and agricultural materials are only just getting started. It will require the development of catalytic technologies and new

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integrated production systems combined with industry diversification to meet the chemical, material and fuel requirements of the 21st century.

Research over the past decade has highlighted a number of promising opportunities to utilise forest and agricultural biomass. Understanding the structure of biomass at a molecular level opens fascinating new ways for its utilisation. Research is moving beyond classical wood chemistry traditionally linked to large-scale pulping, bleaching, papermaking and fibre making. New research is directed towards an advanced understanding of biosynthetic pathways, molecular-level processes and novel technologies to deconstruct the cell wall, towards a complete utilisation of the various products generated. The three major renewable biopolymer classes – cellulose, hemi cellulose and lignin are moving away from being cheap commodity products. They are now being seen as valuable materials with interesting commercial potential.

One of the more promising areas of research has involved the extraction and utilisation of crystalline cellulose from wood and other plant material. Crystalline cellulose forms the skeletal structure for woody plant material (figure 1). These crystalline structures have a strength to weight ratio higher than that of Kevlar or carbon fibre. One of the biggest challenges has been to extract these nanometre scale structures and recombine them into macro-scale products that can utilise the inherent strength of these materials. There are now a number of chemical and mechanical techniques for extraction of cellulose and each gives different raw material characteristics for different potential applications. However, the development of new, high strength materials from this natural resource is still in its infancy.

Recently developed electron microscopy techniques are offering new insights into the cellulose skeleton within the cell wall, suggesting that it has a complex fractal architecture (figure 1), similar to a number of structures found in non-biological materials. This observation suggests that cellulose structure is largely determined by fundamental physical rather than biological processes. This raises some important questions.

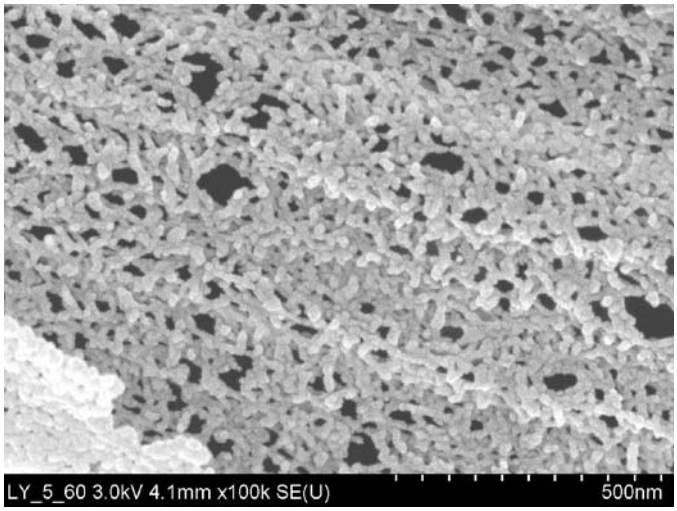

Figure 1. Cellulose skeleton within a wood fibre. Magnification 100 000x

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In the development of new materials, scientists often attempt to mimic biological processes, which can be extremely complex to understand and replicate. If cellulose assembly is driven by fundamental physical processes, they may be simpler to understand and replicate in the development of new self-assembly processes at the nanometre scale. There is an opportunity to rethink research in order to understand better the fundamental interaction of physical and biological systems. The work requires multidisciplinary collaboration between biology, physics, materials science, systems engineering, micro and nanotechnologies and modelling and simulation.

The chemistry and technology of biomass is experiencing a modern renaissance. The mounting pressures in our society to rely on benign resources and eco-efficient technologies have made the European forest based sector a focal point of activity and interest. The UK research community needs to get on board, this process has started but a lot more needs to be done. It is imperative to adopt schemes of creative information exchange, promoting collaboration and the development of new science and scientists.

The prize could be the development of a whole new platform for the manufacture of new high value materials based on Europe's most abundant, sustainable resource; "its forests".

Research into new materials development offers exciting new opportunities. However, even greater potential economic impact lies in supporting the development of new applications for these materials in industries as diverse as automotive, sports equipment, wind turbine, defence and aerospace. Strategic investment could lead to the creation of a new, high value, sustainable manufacturing base of small, medium and large companies within the UK.