Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 22 Sep 2010

To cite this article: P. Larsson-Brelid, M. E. P. Wålinder, M. Westin & Roger Rowell (2008): Ecobuild a Center for Development of Fully Biobased Material Systems and Furniture Applications, Molecular Crystals and Liquid Crystals, 484:1, 257/[623]-264/[630]

To link to this article: http://dx.doi.org/10.1080/15421400801904666

Mol. Cryst. Liq. Cryst., Vol. 484, pp. 257/[623]–264/[630], 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400801904666

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Ecobuild a Center for Development of Fully Biobased Material Systems and Furniture Applications

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There is a great incentive and motivation in the building and wood research communities as well as in the industry to develop more eco-efficient and durable wood-based products with better performances. In this context, eco-efficient products refer to "green" sustainable products where both economical and ecological aspects have to be balanced. This presentation will give the general strategies within the newly formed Swedish Institute Excellence Center, EcoBuild. The conceptual idea for this competence centre is a conversion of biomass into innovative, eco-efficient and durable wood based products. The vision is that EcoBuild will, through the formation of a university-institute-industry cooperation, act as an international leading innovation, research and technology development platform within the wood science and technology field. The research projects within the centre are guided by a group of about 30 industry partners and also by end-user demands (Fig. 1). Types of materials in focus are: modified solid wood such as heat treated, furfurylated and acetylated wood, biobased binders and coatings, and biocomposites. A top priority is to develop fully biobased products, i.e., all raw materials should preferably be biobased, including chemicals for modification, adhesives, and surface treatment. Aspects and initial results regarding some of the EcoBuild activities will also be presented. Examples of research projects already started are: 1) Novel bio-based board resins; 2) UV-resistant clear coatings for exterior use; 3) Highly durable WPCs for outdoor use based on modified wood particles; 4) Modification of hardwood for exterior applications; 5) Fundamental understanding of the mechanisms involved in the durability of modified wood.

Keywords: acetylation; adhesives; biobinders; bioresins; chemical modification; coatings; composite; ecology; economy; furniture

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INTRODUCTION

World-wide environmental concerns urge the need for a development of new biobased material systems and products. There is a great incentive and motivation in the building and wood research communities as well as in the industry to develop more *eco-efficient* and *durable* wood-based products with better performances, where *eco-efficient* should be a balance between both economical and ecological aspects.

The formation of the Institute Excellence Center, EcoBuild, will through its university-institute-industry cooperation act as a leading innovation, research and technology development platform within the wood science and technology field, with emphasis on eco-efficiency and durability. The conceptual idea is a conversion of biomass into innovative, eco-efficient and durable wood based products, Figure 2.

The EcoBuild vision is also to become an attractive and persistent arena for development and utilization of knowledge for all parties involved. The research projects within the center are guided by industry and end-user demands. The center is hosted by SP Trätek, located on the campus area of the Royal Institute of Technology (KTH) in Stockholm, and more than thirty companies are participating.

Driving forces for EcoBuild are the demand for a sustainable society with declining oil resources; the development of new valuable knowledge in the fields of "green chemistry" and biotechnology; conventional

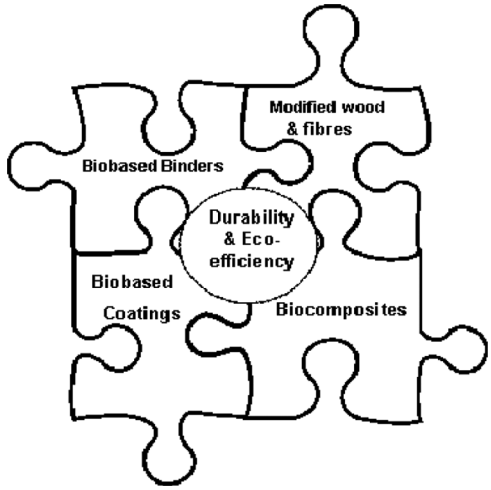

FIGURE 1 The integrated research areas within Institute Excellence Center, EcoBuild.

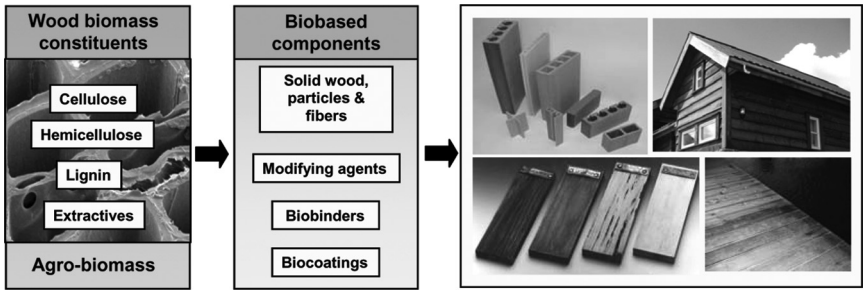

FIGURE 2 Basic idea of EcoBuild.

preservatives, coatings and binders tend to lack sustainability; and the starting points are mainly ideas and approaches that have been built up during years of research. The funding for the centre is 9 M∈ over a six year period (yearly turn-over of 1.5 M€) with 3.6 M€ from the Swedish government. Approximately 60% of the funding comes from industrial funds (33 companies) and other external partners and 50% of the industrial funding is "in kind" and 50% "in cash".

The academic partners for EcoBuild include the Royal Institute of Technology, Stockholm, Sweden, Chalmers University of Technology, Göteborg, Sweden, Lund University of Technology, Lund, Sweden and the University of Life Sciences, Ås, Norway. Institute partners include the Norwegian Forest and Landscape Institute, Ås, Norway, the Institute of Fiber and Polymer Technology, Göteborg, Sweden and the Institute of Environmental Sciences, Stockholm, Sweden.

RESEARCH IN THE CENTER

The research program is focused on the development of innovative, eco-efficient and durable wood-based materials and products for building and furniture applications, and the research and technology development within the EcoBuild Centre will be structured into five integrated projects: 1) Biobased binders; 2) Biobased coatings; 3) Biocomposites; 4) Modified wood and fibres; and 5) Durability and eco-efficiency. Examples of sub-project among 23 projects, already started within the above integrated projects are: 1) Novel protein-based board resins, 2) UV-resistant clear coatings for exterior use. 3) Highly durable WPCs for outdoor use based on modified wood particles. 4) Modification of hardwood for exterior applications. 5) Fundamental understanding of the mechanisms involved in the durability of modified wood.

Types of materials of primary interest are: modified solid wood, such as, heat treated, furfurylated and acetylated wood, biobased binders and coatings, wood polymer composites (WPCs), panels & boards, and engineered wood products (EWP).

BioBinders

This area will be divided into two sub-areas:

A) The thermoset resins are intended as biobased alternative to the current, fossil based binders for panels & boards (particle boards, fiberboards, plywood, oriented strand board, etc.), and Engineered Wood Products (Laminated Veneer Lumber, Parallel Strand Lumber, GluLam, etc.). Examples of such fossil-based binders are MUF (Melamine Urea Formaldehyde) and PF (Phenol Formaldehyde) resins. The novel biobased resins are intended to be low-emission products based on lignins (e.g., LPF resins), furan compounds, plant proteins, bark and nutshell liquids with technically viable performance and cost.

B) The thermoplastic binders are intended as bioderived alternatives to the current fossil-based matrix polymer, e.g. polyolefins and poly vinyl chloride, used in WPC (Wood Plastic Composite) products of today. The bioderived thermoplastics should be durable, compatible with modified wood, have proper melt wetting characteristics and physical properties. The focus will be on cellulose esters, with development work in collaboration with e.g., Eastman Chemicals and AWL Scandinavia.

BioCoatings

This area will be divided into four sub-areas, A) UV resistant clear coatings and B) Water-borne tall oil based alkyd-acrylic hybrids, C) High performance niche products by sol-gel with nano-particles, D) primers specifically developed for modified wood products. In all sub-areas surfaces, interphases and extracts of coating films will be analysed with MRI (Magnetic Resonance Imaging of moisture profiles), UV/Vis, FTIR and GC-MS spectroscopy. Accelerated aging and field testing will also be important issues.

Modified Wood and Fibers

EcoBuild center will initially focus on three wood modification concepts: acetylation; furfurylation and thermal modification. These methods are now commercially available. Furthermore, new environmentally friendly water-repellent wood products are already produced

by impregnating wood with tall oil derivatives and promising progress has been made to improve such products by grafting the tall oil to the wood polymers.

Conventional heating in wood modification processes is time-consuming due to slow heat transfer, and when treating wood of lumber dimensions it leads to uneven heating and consequently uneven quality of the product. However, microwave energy leads to rapid heating of the whole volume, but also a very efficient removal of residual chemicals after reaction. SP has a unique pilot plant for modification of wood, using microwave technology. The pilot plant allows modifying wood in lumber dimensions. Electrical components like pumps, level guards and measuring instrument are flame proof. The process has a very flexible computer control. Other EcoBuild partners have full scale production facilities that will be used within the center. A continuous full scale fiber modification plant (DanAcell in Denmark) is also available for EcoBuild activities.

Biocomposites

There is a demand for wood based materials with enhanced properties and in this technology area, the focus will be on a new generation of eco-efficient and durable wood based materials for the use in out-door applications. The conceptual idea is based on wood modification technologies, which provide a more water resistant wood-polymer bonding and a higher resistance towards biological degradation. Examples of potential wood modification routes are acetylation, furfurylation and heat treatment. Biocomposites, such as, wood plastic composites (WPC), can be produced from modified fibers or residuals from modified wood. The WPC of interest in this project is manufactured from wood particles or sawdust.

Wood-polymer adhesion mechanisms, moisture sorption behavior, interface and interphase morphology as well as biological resistance will be emphasized in this technology area.

Durability and Eco-efficiency

This technology area will involve all other areas in a matrix fashion, since the overall goal of EcoBuild is to develop eco-efficient and durable materials and products. The durability of the materials and products developed within the other technology areas will be evaluated in many different respects, Resistance to: A) decay by microbes (fungi and bacteria) and attack by insects and marine borers, B) Fire, C) Weathering (UV and moisture) and D) Chemical stress. The durability will be

evaluated in accelerated laboratory set-ups and field tests combined with, mechanical testing, microscopic analysis and chemical analysis. Properties of moisture sorption and wood-polymer interface will be evaluated before and after cyclic climatic aging. Emissions to air, soil and water from the different materials and products will be analyzed. Eco-toxicological testing will be done on leaching waters (with aquatic organisms, e.g. marine bacteria, algae and crustaceans) and soils (growth rate of seedlings). From the data achieved service life prediction (PSL) and Life Cycle Assessment can be made.

Examples of four sub-projects out of the 23 projects already started:

(1) Novel Agro-protein Based Board Resins

Objectives. The key objective is to develop and test at the pilot industrial scale, binder systems derived from natural, biological and renewable raw materials.

These binders are intended for both bulk and niche wood-based panel products industrial sectors. For the bulk sectors (panel products–particleboard, MDF, OSB), the major requirements are adequate resin performance with relatively fast cure rates as high throughputs are required in these industries. For the less volume-sensitive niche areas (higher performance composites, laminates), there are more stringent requirements on absolute resin performance. These requirements have been noted and are specific targets of subsections of this project.

A major aim of the project is to produce resin products that can directly enter the current product market in that they are tailored to be used on existing industrial plants. This means that developed binders must be of comparable viscosity, curing potential (speed), moisture content (liquid resins) tack and pot life, to presently used systems. This aspect will be a major focus of the project from the early phases. The partnership is aware that "blue sky research" on "natural binders" will not necessarily produce industrially viable systems. Hence, the focus from early in the project will be on the end use application and the research approach will be both fundamental and pragmatic.

A further objective of the project is to identify possible bottlenecks and technical barriers to the larger scale production and application of developed adhesive systems. This will be achieved via a series of carefully planned pilot and semi-industrial scale-up stages with final testing of resins on full or large pilot scale panel product, laminate or composite production facilities. It is also expected that the results of the project will create a heightened demand for a number of under-utilized agricultural by-product materials such as wheat gluten and rape protein. Life cycle assessment studies will be performed in

order to verify the benefits to society and nature. From the panel product manufacturers' perspective there would be the added advantage that the new adhesives could be used in existing facilities.

The expected achievements of this project are industrially viable protein derived adhesive formulations through development and scale-up to the pilot production phase. So-called "green products" are anticipated and the resultant product(s) will be renewable, sustainable and contribute to improved health standards.

(2) Highly UV-resistant Clear Biobased Coatings for Exterior Joinery and Garden Wood Products

Objectives. The key objective is to develop transparent coating systems derived from renewable resources for exterior wood products. The coatings should be highly weathering resistant, i.e., with considerably extended maintenance intervals in outdoor use.

A global trend for external wood joinery (windows and doors) and garden wood (garden furniture, playground equipment, public benches, decking and railing) is that the wood should be visible. What is currently restraining this trend, is the rather poor UV resistance of conventional transparent coating systems for exterior use leading to short maintenance intervals.

(3) Highly Durable WPCs for Outdoor Use Based on Modified Wood Particles and/or Bio-derived Matrices

Objectives. The objective of this project is to develop a new generation of eco-efficient and knowledge-based wood polymer composites (WPCs) for the use as both furniture and in outdoor building and joinery applications. The conceptual idea is based on application of new efficient wood modification technology which has the potential to create a water resistant wood-polymer bonding. This also involves the need for a better understanding of the mechanisms governing the wood-polymer interaction, especially in presence of moisture. In addition, new concepts for an optimal wood particle or fiber preparation regarding e.g., shape, porosity aspect ratio, and so-called micro-cellular foaming will be incorporated. So-called bio-derived polymer, such as cellulose esters, will be incorporated as matrix material.

(4) Modification of Hardwood for External Joinery, Decking, Garden Furniture, Play-ground Equipment, Marina Jettings etc.

Objectives. The overall objective of the project is to develop dimensionally stable and highly durable eco-efficient wood products from Swedish hardwoods. The species selected will be birch, aspen and

alder. Target application areas will be exterior joinery, cladding, garden furniture, decking, playground equipment, jetties and other outdoor products.

New durable products from modified wood have emerged on the market during the last few years for two main reasons. The restricted use of toxic preservatives due to an increased environmental concern and a need for reduced maintenance that causes unnecessary environmental impact. Wood with low natural durability can in this way be given durability as good as or better than the natural durability tropical woods. Examples of wood modification technologies are acetylation, furfurylation and thermal modification. These chemical modification routes are also known to reduce dimensional movements caused by varying moisture conditions.

CONCLUSIONS

We have high expectations for the achievements of EcoBuild over the next six years because of: long-time experience in this field of research, competences from different disciplines, strong interaction with industry, and formation of an international network of researchers. The collaboration between the partners should provide a sound basis for the development of a lasting platform for research and exchange of experience between science and industry in the area of value-added and eco-efficient products for the building and furniture industry.