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### Pulp and Paper Research Conference

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**Woody Biomass Refinery by Thermochemical Conversion  
– Expected Role for the Pulp and Paper Industry –**

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Due to the global warming issue, CO<sub>2</sub> emissions from the use of fossil resources need to be reduced by substitution to renewable resources. In such a background, the use of woody biomass as chemicals and materials is drawing attention, because about 10% of petroleum is currently used for material production. Thermochemical conversion is one of the conversion technologies expected for that purpose. Renewable electricity has multiple options, including solar, wind and geothermal, but biomass is the only renewable carbon source. Therefore, it is important to develop an efficient thermochemical conversion technology that can replace the petrochemical industry. In this presentation, the issues of pyrolysis of woody biomass in the production of low-molecular-weight monomers will be presented from the viewpoint of the molecular mechanism of pyrolysis. Finally, the expected role of the pulp and paper industry in the future will be discussed.

**Miscibility between Cellulose Nanofiber and Polymer Emulsion:  
A Colloidal Science Perspective**

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Cellulose nanofiber (CNF) has unique characteristics as rheology modifiers, dispersants, and reinforcing fillers. Incorporation of the CNF into waterborne polymer emulsion is required to improve the rheological properties of the emulsion and mechanical properties of resulting polymer materials such as film and coating. Miscibility between the CNF aqueous dispersion and the polymer emulsion, however, depends on types of polymers, and the miscibility trends are unclear. Therefore, we systematically investigated the contributions of the chemical compositions of polymer onto phase separation behavior of CNF dispersion/polymer emulsion mixture. It was found that the chemical compositions of polymer significantly affected the miscibility; the increase in the amount of anionic functional groups led to agglomeration of CNFs and emulsion particles. The result was discussed based on the theories in colloid science and suggests that repulsive force induced by electric double layers and attractive force induced by depletion effect competitively affected the dispersed particles. The increase in the surface charge is likely to enhance the depletion effect rather than the repulsive force, resulting in particle agglomeration. The chemical modification of polymer emulsion was then carried out to improve miscibility with the CNF dispersion. Accordingly, changing the anionic functional groups to nonionic groups led to obtaining a homogenous mixture of CNF dispersion and polymer emulsion. These findings pave the way to expanding the application of CNFs to paint and coating fields.

**X-ray diffraction analysis of a trace amount of components in papers  
using the high speed detector**

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The X-ray diffraction has widely been used for identification and structural analysis of crystalline substances. Although the Scintillation detector(SC detector) is generally used for the X-ray diffraction analysis, the sensitivity is not enough for the qualitative analysis of a trace amount of components. Therefore, we investigated to apply the high speed detector to the X-ray diffraction analysis of a trace amount of components. The high speed detector detection unit with multiple semiconductor elements allows much shorter measurement time than the SC detector. Also the high speed detector has high sensitivity, and therefore is suitable for measurement of a trace amount of components. In this research, we report an example of analyzing trace substances in commercially available functional paper and red precipitate in the pipes with the high speed detector.

## **The effect of paper lint on misfeeding and its evaluation method**

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One of the general problems of the MFPs is misfeeding due to paper lint. Despite the generality of this problem, the detailed friction mechanism is not clear. Furthermore, in recent years there are so many paper brands in overseas markets and the development of a simple evaluation method about paper lint is a growing demand among major manufacturers of the MFPs. In this paper, we describe the mechanism of the decrease of friction between rubber roller and paper in association with paper lint. Because the mechanism depends on the relative size of the paper lint particle to surface roughness of paper, we should evaluate not only the paper lint amount on the paper, but also the effect of the relative size of the paper lint on the contact and friction. We conclude that the evaluation method JBMS-88 is one of the simple and low-cost methods as the friction-based evaluation method.

## **Wood-Based New Functional Materials "MinerPa®" -Development of Mineral Particles/Pulp Fibers Composites-**

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One of the useful approaches to functionalize paper is hybridizations of inorganic fillers and pulp fibers. By adopting a unique pulp-modification technology, Nippon Paper Industries have developed composites of mineral particles and pulp fibers, named as "MinerPa®", which are wood-based functional materials. Herein, we will report some practical examples of using MinerPa® which we have conducted; preparations and evaluations of papermaking adequacy and functionalities in sheet.

Each composite of calcium dioxide ( $\text{CaCO}_3$ ), Barium sulfate ( $\text{BaSO}_4$ ) or hydrotalcite was individually prepared by *in-situ* reaction under existence of pulp fibers in water. Scanning electron microscopy (SEM) observation showed that the surface of pulp fiber was densely covered with inorganic particles, which was observed at three composites. By using obtained composites as raw materials, a papermaking process was conducted to evaluate its practical usage by using a machine. A sheet of  $\text{BaSO}_4$ /pulp composite was continuously producible and made with remarkably high first-pass retention (97.0%) and first-pass ash retention (96.5%) despite of its high ash content (over 65%). Further investigation of a sheet of  $\text{BaSO}_4$ / or hydrotalcite/pulp composite was conducted to evaluate its functionality. Each composite sheet showed a characteristic function attributed to inorganic particles loaded on pulp fibers. A sheet of  $\text{BaSO}_4$ /pulp composite showed X-ray shielding properties, and a sheet of hydrotalcite/pulp composite revealed to have a high deodorant and anti-bacterial performance.

These results suggest that MinerPa® would provide a new functional material based on wood-based resources, which will be considered to contribute to protect global environment or ecosystem and facilitate using sustainable resources.

## **ANDRITZ Cutting-edge digital technology for Stable and Safe Recovery Boiler Operation**

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Digital technology, such as IT, IOT, and AI has been rapidly progressing and is pervading into people's lives, supporting them and enriching their lives. These digital technologies are creating a new added value for the pulp and paper industry as well. ANDRITZ has developed "Recovery Smart Business" for Evaporator, Recovery boiler, White liquor plant and Power boiler. The Recovery Smart Business is a technology solution that combines cutting-edge digital technology and ANDRITZ's process know-how. Its state-of-the-art digital technology is divided into six sub-technology groups such as Smart sensor, Robot solution, Digital Twin, Process optimization system, Digital advisor and Advanced visual analysis. One of the Recovery Smart Business using these cutting-edge technologies has already been put into a practical use in the Recovery boiler process as "Smart Recovery Boiler", and not only stable operation but also the safety of the equipment and the operator has been improved. The Smart Recovery Boiler can be installed for the recovery boiler whether it is new or existing.

## **Revolutions in the history of civilization induced by paper**

### **Part 10: Developments in Europe**

Kiyooki Iida

Islam got paper in hands in the 8th century. Abbasid Caliphate not only used it for administration but also copied precedent civilizations on paper and evolved its own culture, which increased paper consumption exponentially. Cairo had prosperous paper industry and book market.

On the other hands, Europe, after the collapse of the Roman Empire (372-410), suffered from troubles like invasions by different ethnic tribes, reduction of population, decline of trade and business, and increased immigrants. However, things turned around in the 13th century. The population and the economy grew significantly, and science and philosophy restored. At that age, Europe began to use paper. In the 1000s, paper was manufactured in Islamic Spain and Sicily. Between 1000 and 1300, the examples of paper use were recorded and found in several places in Europe. In the late 1300s, a paper mill started operation in Italy, the technology of which was transferred to Germany and later advanced to England.

In those days, Europe was superior to Islam in mining and metal engineering, which helped Italian to develop mold with metallic wire and stamper covered with iron. These developments and their original gelatin immersion reduced the cost of paper production, and Italian exported their paper to Islam as an exchange for pepper and silk. In the 18th century, Cairo became just a despot to Arab business and lost its book market.

In Europe, the economy grew steadily and civilization was restored, paper consumption increased and more numbers of copies were wanted. Then, the metallic movable type printing system was invented, which, cooperative with paper, helped to induced historical social revolutions.

Their paper making process is briefly reviewed.

**Safety assessment of cellulose nanofibers obtained from soda cooking bamboo pulp:  
bacterial reverse mutation test, mouse lymphoma thymidine kinase assay, micronucleus test,  
and repeated dose 90-day oral toxicity study in rats**

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Bamboo plants, especially Moso bamboo (*Phyllostachys edulis*), grow rapidly and are suitable resources for reuse loop. With the aim of utilizing Moso bamboo for future application in food materials, cellulose nanofibers (CNFs) were prepared from bamboo pulp via alkaline cooking with wet milling after an enzymatic pretreatment. The certification test revealed that bamboo CNFs were more nano-sized than microfibrinous cellulose which is a recognized food additive. Accordingly, the CNFs cannot be classified into the microfibrinous cellulose category. Therefore, we conducted bacterial reverse mutation test, *in vitro* mouse lymphoma TK (thymidine kinase) assay, and *in vitro* cell micronucleus test on the Chinese hamster lung cell line and confirmed that the bamboo CNFs exhibited no mutagenicity. Furthermore, a repeated dose 90-day oral toxicity study was conducted on rats using 1 wt% bamboo CNFs suspension, which revealed no abnormality on long-term ingestion. No deaths were observed in any of the administration groups throughout the test period and no effects of the test substance were observed on rats under general conditions, urinalysis, and ophthalmologic examination. In addition, hematological examinations, blood biochemical examinations, organ weight measurements, necropsy findings, and histopathological examinations performed after the administration period showed no effects of the test substance on the rats. Since no toxicity due to the test substance was observed in either the male or female administration group, the no observed adverse effect level (NOAEL) under the test conditions was determined to be 200 mg/kg/day or more for both males and females.