

# The use of AFM to investigate the delignification process :

## Part I - AFM performance by differentiating pulping processes

D. E. D. PEREIRA<sup>1\*</sup>, D. CHERNOFF<sup>2</sup>, E. CLAUDIO-DA-SILVA, JR.<sup>1</sup> & B. J. DEMUNER<sup>1</sup>

### Summary

Atomic Force Microscopy has been used to follow delignification performance, focusing residual lignin over eucalypt pulp fibers. In part I of this paper, residual lignin from 7 delignification processes have been analyzed, by both chemical and microscopic methods. In Part II, both TCF (Total Chlorine Free) and ECF (Elemental Chlorine Free) bleaching processes have been focused. The impact of delignification performance has been also evaluated, by physical characteristics of brown pulp. COD from brown pulps and filtrates have been measured, as well as functional group content. AFM permitted the identification of residual lignin characteristics of pulps from different processes, and highlighted peculiarities of each sample. Residual lignin has been found to be related to low phase. More results were obtained and described on Part II of this paper.

### KEYWORDS

Delignification processes, Eucalypt, AFM, Atomic Force Microscopy, Superbatch, Enerbatch, ASAM, Organosolv, Milox, RDH.

### AUTHORS

1. Aracruz Celulose, Centro de Pesquisa e Tecnologia, 29197-000 Aracruz - ES, Brazil

2. Advanced Surface Microscopy, Inc., 6009 Knyghton Rd, Indianapolis, IN 46220-4955, USA

\* Current Address : International Paper CRC. 1422 Long Meadow Rd. Tuxedo, NY 10950 - USA

### Introduction

Lignin, as principle component of trees, is one of the most abundant material in the world (Sarkanen, K.V. et al. 1971). Despite of much research, the exact chemical structure of lignin is still unknown. Its basic structure is that of benzene rings, substituted with different functional groups, which are linked together in random fashion.

Although crucial to the sustainability of trees, lignin removed from wood during pulp and paper production can cause significant environmental impact. Extraction of lignin from wood has to be done by highly selective processes, which demand a lot of research before becoming commercially viable. In the Kraft pulp production process, for example, most of the lignin suffers from several structural changes, which increase its solubility, thereby permitting its removal from the pulp by washing. This lignin is usually burned in a recovery furnace to supply energy to the process.

A small part of lignin remains on the fiber surface after pulping, giving Kraft pulps their typical brown color. This color has to be removed in a subsequent bleaching process, with the help of strong oxidants, through nucleophilic or electrophilic reactions (Grazl, J. S. 1987). The chemicals and the machinery involved in the pulp bleaching are quite expensive and sometimes affect the pulp quality. Moreover, the effluent of these processes can significantly impact the



environment. A good method to determine the amount and reactivity of lignin in fibers is therefore crucial (Gellerstedt, G. et al. 1987).

The rapid adoption of changes on the industrial scale has increased the need to understand the fundamental properties of residual lignin derived from these new processes. Furthermore, a number of modifications in the pulping process, such as modified Kraft and isothermal cooking, combined with additional brownstock washing operations (e. g. hot alkali washing) have promoted interest in an adequate characterization of residual lignin (Dreyer, B. 1994).

The most "famous" delignification process can be divided in two groups : in the first group are the Kraft similar processes, which are already in commercial scale. Among them, Super Batch (Tikka, P. et al. 1994), Enerbatch and RDH – Rapid Displacement Heating (Shin, N. H. et al. 1994), which are detailed in the experimental. The second group involves non commercial processes, which are still in laboratories or pilot plant : ASAM (Anthraquinone Sulfide Alkali Methanol – Schubert, H. L. et al. 1993 and Patt, R. et al. 1986), Organosolv (Araujo, E. S. et al. 1995) and Milox (Pohjavesi, S. et al.), also further. They have been included in this experimental in order to provide good comparison. Every alternative delignification process, as well as every bleaching sequence provides different residual lignin to be handled, washed, bleached and therefore removed.

Lignin can be characterized by a large number of analytical chemical methods (SCAN, Sarkanen, K.V. et al. 1967, Adler, E. et al. 1959, and Himmel, M. E. et al. 1990). These methods are generally time consuming but can aid in elaborating forest improvement programs aimed at reducing lignin content. Unfortunately, problems related to extraction and modification of physical properties of residual lignins have traditionally limited our understanding of these structures. Such understanding is considered to be of fundamental importance for the optimization of pulping and bleaching in order to maximize pulp quality and minimize production cost. In this context, the inherent difficulties encountered in the isolation, extraction and analysis of residual lignin in wood pulp may be minimized through the use of novel techniques.

The amount of residual lignin, known as a non-homogeneous one, has been shown to be strongly influenced (decreased) by higher hydroxide ion concentration during Kraft cooking and is to some extent decreased by higher hydrosulphide ion concentration (Lindgreen, C. T. et al. 1996). The process temperature has no effect on the amount of residual lignin but the main influence of ionic forces in delignification is by the reagents activation and not by the solubility of lignin fragments.

The importance of developing new research tools for lignin analysis has moved us to adopt the Atomic Force Microscope (Binnig, G. et al. 1986). In this technique, a sharp probing tip is brought into close proximity with and scanned across the specimen surface. The probe is oscillated vertically near its mechanical resonance frequency (ca. 300 kHz). When the probe just touches the surface the amplitude of oscillation is reduced; the AFM uses this change in amplitude in order to track the surface topography.

In the pulp and paper industries, however, few works have been published in which this technique has been used to elucidate answers to fundamental questions (Pereira, D. E. D. et al. 1993, Hanley S. H. et al. 1992, Hanley, S. H. et al. 1994, Hanley, S. H. et al. 1995, Phillips, T. L. et al. 1992 and Pereira, D. E. D. et al. 1995). In 1993, the atomic images of a milled wood lignin grain, as well as the images of pulp from different bleaching processes were obtained (Pereira, D. E. D. et al. 1993) The main goal of that work was to look for a new way to understand the behavior of a specific chemical structure : the residual lignin.

In a further work (Pereira, D. E. D. et al. 1995) the use of atomic force microscopy associated with a chemical modification of the cantilever was investigated as a new method for characterize the chemical nature of residual lignin. The objective of that work was to find a way to distinguish the structure of lignin from that of cellulose using AFM. To this end three different methodologies has been applied: first, Tapping Mode<sup>TM</sup>, with a second channel, the phase contrast, which provides enhanced edge and material contrast and finally, the modification of surface chemistry of the probing tips, changing the oxide surface to a methyl – or amino terminated surface. Contact mode/friction images were acquired using a silicon nitride tip (oxide surface). The chemical modification of the probing tip (Methyl (-CH<sub>3</sub>) and amino (-NH<sub>2</sub>) surfaces) produced different amounts of phase contrast.

## Trioplan

toile de formation triple couche de

**CRISTINI** **FELTRI**  
**GC**

[cristini.france@feutres-cristini.com](mailto:cristini.france@feutres-cristini.com)



In the present work, the aim was to explore more profoundly lignin quality, using also the atomic force microscopy as a tool for its studies. Analysis and characterization of different lignin structures from different pulping processes have been done, comparing both chemical and microscopic methods. Residual lignin from cooking stages has been also analyzed here, by both classical and microscopic method. In Part II, oxygen delignification stage has been focused and also observed under AFM technique.

## Experimental

### Pulp samples

Wood eucalypt chips have been cooked in seven delignification processes, in order to compare its lignin reactivity. Wood characteristics are described on table I. Cookings were performed at different institutions, and in following conditions as listed below :

	amount
Lignin	30,1 %
Dichlormethane Extractives	0,16 %
Penthosane	16,4 %
Wood density	472 Kg/m <sup>3</sup>
Guaiacyl / Syringyl	0,88

Table I - Chemical Characterization of Eucalypt Wood

**Kraft** : production pulp of Aracruz Celulose, Brazil. This delignification process is the most common around the world. It has been therefore considered as a reference in this study.

**Enerbatch** : performed at IMPCO - Austria in a similar way to Kraft process. The chips have been pre impregnated in a pressurized stage, together with black liquor, at the beginning of cooking and white liquor, further. Cooking temperature : 165°C. After liquor removal, pulp is piped to a blow tank and washed.

**Super Batch** : also in a similar way to Kraft process. The chips were twice pre impregnated in a double vessel. The treatment with black liquor contributes to a high sulphidity at the beginning of the cooking process, thus preserving the fiber properties. Black liquor is also taken off several times during the pulping. Cooking in three different kappa numbers were performed at SUNDS - Sweden (intermediated by Oy Lännen Laboratoriot - Finland).

**RDH - Rapid Displacement Heating** : also considered among the group of Kraft similar processes, very similar to Super batch but with little variations in liquor displacement. Cookings have been performed at Beloit - USA, at the following chemical concentrations : NaOH : 17 %, Na<sub>2</sub>S : 30 %.

**ASAM : Alkali Sulfur Anthraquinone Methanol** : its name demonstrates all chemicals used in this delignification processes. Cookings were performed at the University of Hamburg - Germany, which retains process patent. This process is not in commercial scale but its big potential attracts for comparison purposes. Cooking was performed in a rotative autoclave, 30 liters capacity. Partially dried chips were impregnated with vapor, at 105°C, during 30 minutes. All chemicals were introduced together, at the beginning of cooking, maintaining a liquor : wood relationship like 1:1. The chemicals were applied in the following percentage : Sodium Hydroxide : 7,5 %, Sodium Sulfide : 17,5 %, Anthraquinone : 0,1 % and Methanol : 15 %. Cooking time was 90 minutes, temperature 175°C and pH 10,6. After cooking chips were washed, disintegrated and milled at 0,15 mm.

**ORGANOSOLV** : this delignification process utilizes one organic solvent, in this case, ethanol, to lignin removal. Cooking has been done at USP - University of São Paulo, in São Carlos, Brazil. Cooking has been performed in a 7 liters capacity digester. Air-dried woodchips were first impregnated with vapor at 105°C, during 30 minutes. The wood/liquor ratio was 1:1 in ethanol : water. Cooking time was 90 minutes at 175°C and a 10,6 pH.

**MILOX** : acid formic has been the delignification agent in this process. The cooking has been performed in three different stages : in the first one, 6 liters of acid formic 85 % + 1 % H<sub>2</sub>O<sub>2</sub>, during 2 hours at a temperature of 80°C. After drainage and at a subsequent stage, 7,5 liters of formic acid were introduced to in the digester, during 3 hours, at 107°C. Thereafter a defibration has been performed, as well as a weak formic acid washing and in a third stage, again acid formic + peroxide has been used during 2 hours, at 80°C. The pulp was washed 24 hours after the third stage in order to neutralize formic acid. The cooking has been performed at KCL, Research Institute of Pulp and Paper in Finland and is still not in commercial scale available.

### Chemical analysis

The methods utilized for Wood Density, Lignin amount in wood and pulp, extractives in Dichlormethane, Kappa,



Active Alkali, Sulphidity, Yield, Pulp Viscosity, Pentosane and can be found in Scan Norms (SCAN). The Methoxyl Contents and Guaiacyl/Syringyl ratio have been estimated according to Hames, et. al. 1991. COD in pulps and filtrates have been analyzed as described in Standard Methods. Phenolic Hydroxyl has been analyzed as described by Masson et al. 1983. Bleachability is the brightness gain of a sample, when a determined amount of bleaching chemical is applied. Bleachability has been determined by a "home-made" method, still not published. It includes a short TCF bleaching sequence, together with a previous stage of intense chelation, without oxygen delignification.

**Physical analysis**

All Pulps have been analyzed by physical tests described in Scan Norms.

**AFM analysis**

The AFM analysis has been performed at the Advanced Surface Microscopy, in Indianapolis - IN - USA (Chernoff, D. 1995). Wood pulp fibers were handled dry, without milling. Samples were mounted on small metal plates, using Tempfix polymer adhesive. The pulps were examined at room temperature in ambient air using Digital Instruments Nanoscope III/Scanning Probe Microscope System, fitted with Nanoscope III controller, with Phase Extender Module and Dimension 3000 large sample AFM with G scanner. The AFM has been calibrated every 3 months during this work. Each half of the pictures consists of 512 x 512 pixels. Images were flattened (by subtracting the line mean elevation and slope from each scan line) to eliminate low frequency noise and / or plane-fitted to eliminate tilt. Tapping ModeTM AFM have been used to capture height and phase data types for fields ranging from 1 to 10 m.

For each sample, we typically captured a set of images at a total of 4 spots on 3 or 4 different fibers, so that the fiber axis was parallel to the Y-axis of the image. Each image set typically consisted of a 10 m view, two 3 m views within that area and two 1 m views within the 3 m areas. All images were done in air. Probes for Tapping ModeTM were standard silicon tips, produced by Nanosensors with typical resonant frequency of about 300 kHz. The standard drive frequency was 0,25 kHz below resonance. The data in Table 4 summarize the general parameters of AFM analysis. Since no test methods (e. g. ASTM, DIN, etc.) have been established for AFM, the methods and procedures described here have been used. These procedures gave us confidence that can yield characteristic information about the sample and is not affected by variations of the operation conditions.

**Results and discussion**

The data in Table 1 describe wood characterization. Standard methods SCAN have been used. The data in Table 2 summarize the chemical characterizations of pulp samples. Cooking performance has been evaluated in two distinct blocks, the first one comparing commercial scale processes and the second one comparing alternative processes.

In terms of pulps similar to Kraft processes, the Super Batch, with the same kappa number as Kraft pulp, had little advantage in sulphidity, with the same alkali consumption, same viscosity and bigger yield. In the other hand, their COD values were higher than Kraft process.

Parameter	Commercial Scale Processes (similar to kraft)				Alternative Processes		
	Kraft	Super Batch	RDH	Enerbatch	Milox	Organo-solv	ASAM
Kappa	14.8	14.3	10	12.8	25	40	12
Active alkali, % as NaOH	15	14.8	17	25			7.5
Sulphidity, %	33	18.5	30	28			17.5
Yield, %	50	51	52	51.1	47.1	60	51
Pulp Viscosity, dm <sup>2</sup> /Kg	1012	1046	755	840	1099	915	1198
Extractives in DCM, %	0.16	0.15	0.20	0.14	0.13	0.16	0.18
Filtrate COD, mg O <sub>2</sub> /L	261	580	452	126	333	600	304
Pulp COD, Kg O <sub>2</sub> /ton 90	7.5	26.6	17.3	4.7	13.1	24.0	11.6

Obs: Organosolv: Ethanol:H<sub>2</sub>O = 1:1 ; ASAM: 0,1 % AQ, 15 % MeOH, 17,5 % Na<sub>2</sub>SO<sub>3</sub> ; Milox: formic acid: 85 % + 1 % H<sub>2</sub>O<sub>2</sub>

Table 2 - **Chemical Characterization of Eucalypt Pulps from Different Pulping Processes**

As RDH pulp had a different kappa number, it cannot be easily compared with Kraft, unless in a subjective way. Apparently it would have the same behavior as the Kraft pulp, but also with higher COD values, in pulp and filtrate. Enerbatch process has been analyzed in a subjective way, although it's similarity to Kraft. Enerbatch pulp had higher yield and lower kappa number, therefore presenting higher bleachability. The lower COD values highlighted the process as the best potential for Minimum Impact Mill projects.

Among the non-commercial processes, ASAM has presented the higher yield and pulp viscosity and similar COD values if compared to Kraft process.



Parameter	Kraft	Super Batch	RDH	Ener-batch	Milox	Organo-solv	ASAM
Methoxyl / C9	1.89	1.48	1.82	1.78	1.85	1.81	1.21
Phenolic Hydroxyl, mmol/g	1.24	1.24	1.26	1.45	1.11	1.05	1.00
Initial Brightness, % ISO	37.4	40.8	40.4	35.1	21.3	17.7	46.5
Final Brightness, % ISO	63.8	62.2	63.4	61.8	30.3	20.5	65.4
Bleachability, % ISO	26.4	21.4	23.0	26.7	9.0	2.8	18.9

Table 3 - **Methoxyl and Phenolic Hydroxyl content and bleaching performance of pulps**

The methoxyl and phenolic hydroxyl content of the lignin as well as the ISO brightness of the pulps are described on Table 3. The different methoxyl contents can predict differences in lignin structure. The amount of phenolic -OH radicals is also very coherent with the lignin amount and with the role of each bleaching chemical. Super Batch and ASAM processes showed less lignin condensation, related to the lower amount of methoxyl groups. Theoretically these pulps should be easily bleached than the others, as showed in practice, according to bleachability data.

Figures 1 - 9 can reveal that, at the same PFI level, there are strong differences of quality observed, if compared Kraft versus alternative processes. It is important to highlight that the observed differences obtained are related only to the processes, since the wood has been the same for all evaluations.

Results on Figures 1 to 3 reveal that ASAM pulp has higher values for Shopper Riegler, Dynamic Drainage Time and Retention Water Index, indicating that this delignification process can facilitate flexibilization and fibrillation of fibers, thus contributing to a lower refining energy requirement.

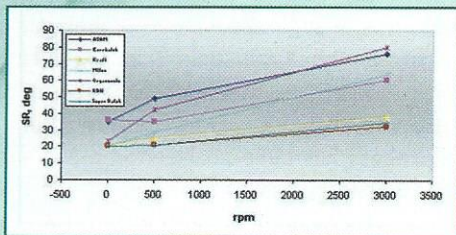


Figure 1

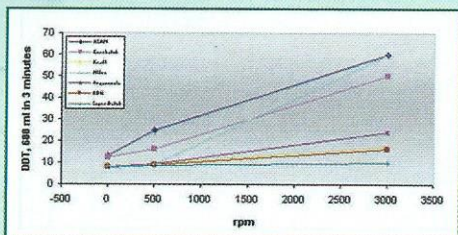


Figure 2

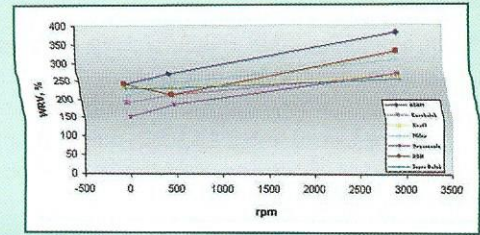


Figure 3

Figures 4 to 6 distinguish two groups, according to the mechanical resistance (tensile and tear) and stiffness. At one side, pulps like Milox and Organosolv showed lower value for resistance properties. At the other side, the remaining pulps from this group showed significantly higher mechanical resistance and stiffness.

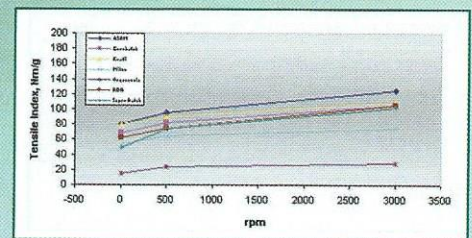


Figure 4

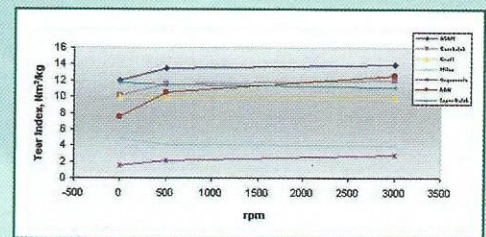


Figure 5

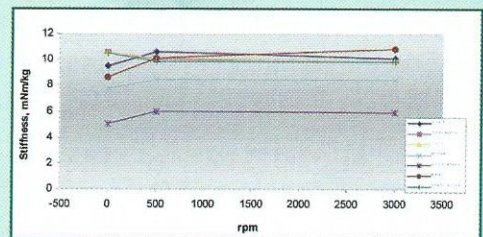


Figure 6

Results on Figures 7 to 9 show the Organosolv pulp as the one, which presented lower values for elongation and apparent density, indicative of rigid fibers, with low binding capacity. Milox pulp presented the highest values for these properties.

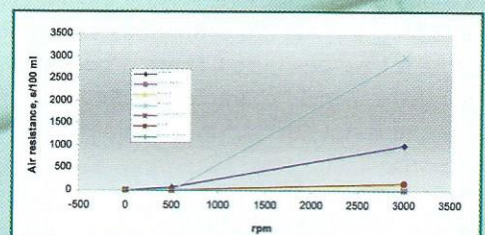


Figure 7



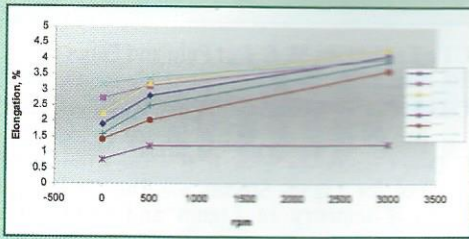


Figure 8

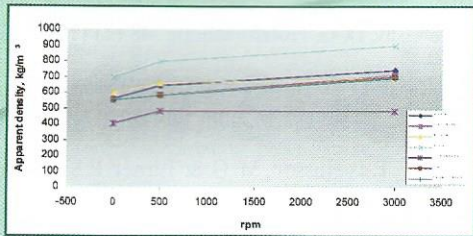


Figure 9

Atomic Force Microscopy pictures are shown in Figure 10, with 3 mm phase data images of seven samples. Fibrils of about 500 nm wide and 250 nm high were found on all specimens. The microfibrils had very small radii of curvature, probably less than 5 nm. In addition to cantilever amplitude, used to track the surface topography (left side pictures), the probe motion was characterized by its phase (right side pictures) relative to the driving oscillator.

Figure 10 reveals aspects of residual lignin in brown pulps from different delignification processes. Kraft pulp presented low phase contrast, as well as amorphous regions spread in fibrillar regions.

Super Batch showed also low phase contrast, and fibrillar regions covered by amorphous bumps. RDH pulp showed all possible contrasts (high, medium or low), and organized fibers also covered by amorphous bumps. Enerbatch pulp had alternate regions of low and high phase contrast, low phase contrast dominating the fibrillar regions.

Milox pulp had high phase contrast, showing islands of amorphous regions covering fibril surfaces. Organosolv had also high phase contrast with partially damaged fibrillar regions. ASAM had also high phase contrast, with much bumpy regions. As one can observe, all pulps, which showed high phase contrast, had a poor performance in bleaching process, due to lower activation of its residual lignin.

The results obtained in this work motivated us to continue exploring AFM as a tool for residual lignin studies. In Part II the oxygen delignification of the same pulps has been focused. We believe this instrument can be used for many other purposes for the pulp and paper industry and can boost the search of highest challenges related to it.

## Conclusions

AFM permitted to complement the identification of lignin

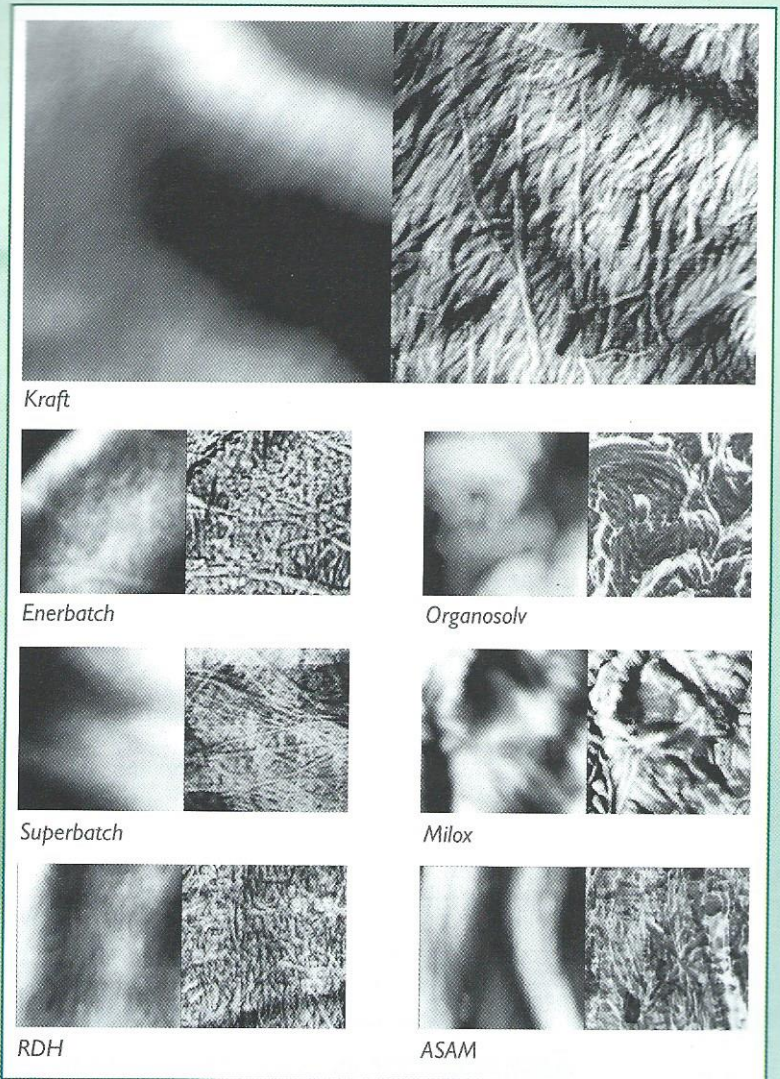


Figure 10 - 1  $\mu$ m AFM images of residual lignin from different delignification processes. White patches refer to lignin. Left side pictures refer to topographic image. Right side : phase image.

characteristics from different pulping and oxygen delignification processes, and highlighted peculiarities of each sample. The information given by AFM among the different delignification processes, have increased our interest in understanding the nature of residual lignin.

## Acknowledgment

The authors are thankful to Mr. Panu Tikka (Oy Lännen Laboratoriot - Rauma, Finland), Dr. Othar Kordsachia (Institut für Holzchemie - Hamburg, Germany), Prof. Antônio Aprigeo Curvelo (University of São Paulo - São Carlos, Brazil), Dr. Nan Hee Shin (Beloit Corporation - Jamaica, USA), Dr. Michael Sinner (Voest Alpine - Austria) and Kristiina Poppius-Levlin (KCL - Finland) to perform cooking procedures, as well as some routine analysis of the resulting pulps. Dr. Yuan - Zong Lai (ESPRI - Syracuse, USA) is also recognized for his help by analyzing phenolic hydroxyls.



## REFERENCES

1. Sarkanen, K. V. & Ludwig, C. H. « *Lignins - Occurrence, Formation, Structure and Reactions* ». Eds., Wiley Interscience, New York, USA, 1971.
2. Grazi, J. S. *Das Papier* 3 (1987), 120 - 30.
3. Gellerstedt, G. & Lindfors, E. L. *Tappi Journal*, June (1987) 119 - 122.
4. Dreyer, B « Die Bleicharbeit von konventionellen und modifizierten kraftzellstoffen aus *E. grandis* unter Berücksichtigung der Restligninstrukturen ». Diplomarbeit University of Hamburg, Germany, Aug 1994.
5. Tikka, P. & Kovasin, K. « Laboratory Simulation of Modified Kraft Cooking System : a new cooking system enables independent temperature and liquor transfer programs ». *Tappi Pulping Conference*, Nov. 6/10, San Diego - CA, 1994.
6. Shin, N. H. & Mera, F. «The impact of RDH Extended Delignification on Bleaching» *Proceedings of the 1st. Latin American Delignification Conference - 08/12 Aug, 1994, Vitória - ES, Brazil.*
7. Schubert, H. L., Fuchs, K. Patt, R., Kordsachia, O. & Bobik, M. *Das Papier* 47 (1993) 10 A, S. V6 - V 15.
8. Patt, R. & Kordsachia, O. *Das Papier* 40 (1986) 10A, S. V1 - V8
9. Araújo, E. S. & Curvelo, A.A.S. « Cinética da Deslignificação Organossolve » - *Dissertação de Mestrado*, IQSC - USP, 1995.
10. Pohjavesi, S., Saari, K., Poppius-Levlin, K. & Sundquist, J. « Technical and Economic Feasibility Study of the Milox Process : *Proceedings of The 8th Intl. Symp. on Wood and Pulping Chemistry - 06/09 June, 1995, Helsinki - Finland (vol. II Page 231).*
11. SCAN - Scandinavian Pulp, Paper and Board
12. Sarkanen, K.V. et alii . *Tappi* 50 (12) : 587 - 590, 1967
13. Adler, E. et alii . *J. Acta Chem Scand.* 13 : 75 - 90, 1959
14. Himmel, M. E. et alii . *J. of Chromatography* 498 : 93 - 104, 1990
15. Lindgreen, C.T e Lindstrom, M. E. *J. of Pulp and Paper Science*, 22 (8) J290 - J295, Aug. 1996.
16. Binnig, G., Quate, C. F. & Gerber, Ch. *Phys. Rev. Lett.* 56, 930 (1986).
17. Pereira, D. E. D. & Claudio-da-Silva, Jr. E. « The Atomic Force Microscopy as a Tool for Lignin Studies » - *The III Brazilian Symposium on the Chemistry of Lignin and Other Wood Components - 1993 - Proceedings*
18. Hanley, S. H., Giasson, J., Revol, J - F & Gray, D. G. *Polymer* 33 (21) (1992) 4639 - 42.
19. Hanley, S. H. & Gray, D. G. *Holzforschung* 48 (1) (1994) 29 - 34.
20. Hanley, S. H. & Gray, D. G. *Surface Anal. Pap.* (1995) 301 - 24 Eds. Conners, Terrance E., Banerjee, Sujit. Publisher: CRC Boca Raton, Fla.
21. Phillips, T. L., Horr, T. J., Husson, M. G. & Turner, P. S. *Polymer* 33 (21) (1992) 4639 - 42.
22. Pereira, D. E. D & Claudio-da-Silva, Jr., E. « Improvement of AFM as an analytical instrument for Residual Lignin Characterization » in : *Proceedings International Symposium on Wood and Pulping Chemistry, Helsinki, Finland, June 1995.*
23. SCAN C 26: 76: paper preparation for physical tests.
24. Hames, B. R., Black, S., Abglevor, F., Evans, R., Johnson, D. K. & Chum, H. L. « Measurement of the Functional Group Contents of Lignins using FTIR and Partial Least Squares Regression », *Proceedings of the APPITA General Conference, Melbourne, Australia, April, 1991*
25. Standard Methods, 5210 B 17a. ed.
26. Masson, P. *Holzforschung* 37, 143 - 146, 1983.
27. Chernoff, D. « High resolution chemical mapping using tapping mode AFM with phase contrast, in ». *Proceedings Microscopy and Microanalysis 1995, 12 (1995) 888 - 89.* Publishers G. W. Bailey et. Al. Eds. Jones & Begell, New York.

# TECHNOJET

Votre spécialiste de l'égouttage

## Services

- Contrôle des éléments d'égouttage
- Trouble Shooting
- Retifications des éléments d'égouttage en céramique
- Unité mobile dans votre usine
- Montage

## Mesures

- Mesure laser et réglage des éléments d'égouttage
- Mesure rectiligne
- Mesure d'alignement d'axes
- Mesure de rugosité

## Ventes

- Segment céramique pour des réparations
- Outils diamants pour travaux d'amélioration
- Disques diamants pour rectification de cylindres

### Egger Technojet Ges.m.b.H

A-8833 Teufenbach 69  
Austria  
Tél. +43(0)3582/8253-0  
Fax +43(0)3582/8253-4  
e-mail : office@technojet.at

### Votre partenaire en France :

Ets HERZOG sarl  
9, rue des Sorbiers - 68370 ORBEY  
Tél. 03 89 71 34 02  
Fax 03 89 71 30 88  
e-mail : ets.herzog@wanadoo.fr