Plasma Technology for Wood

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Outline

- Introduction
- Techniques and Materials
- First Results
- Conclusion and Perspectives

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- Introduction
  - CONTEXT
  - GLOBAL LONG TERM RESEARCH GOALS
  - PROJECT OBJECTIVES

- Techniques and Materials
- First Results
- Conclusion and Perspectives

Plasma Treatment and Wood – Why ?

The Quebec and Canadian wood industry currently is going through a serious crisis (competition from substitution products (PVC); emerging countries (Asia, South America), exchange parity with US dollar)

To stay competitive, the wood industry has to innovate and develop new products (nanotechnology, plasma, etc.)

Gobal Long Term Research Goals

Develop new protective systems for wood, parquets, kitchen cabinets, exterior siding in order to improve durability and facilitate maintenance

Functionalize wood to find new applications and markets (conductivity, interactive colors, energy generator, etc.)

Project Objectives

Assess the potential of plasma technology for the wood industry

Modify the wood surface energy with plasmas obtained from RF capacitive or inductive charge at low and high pressures (contact angle, wood/polymer adhesion, etc.)

Deposit organic or inorganic films (nano-layers) by magnetron cathodic sputtering (UV resistance, hardness, impact, hygroscopicity behavior, etc.)

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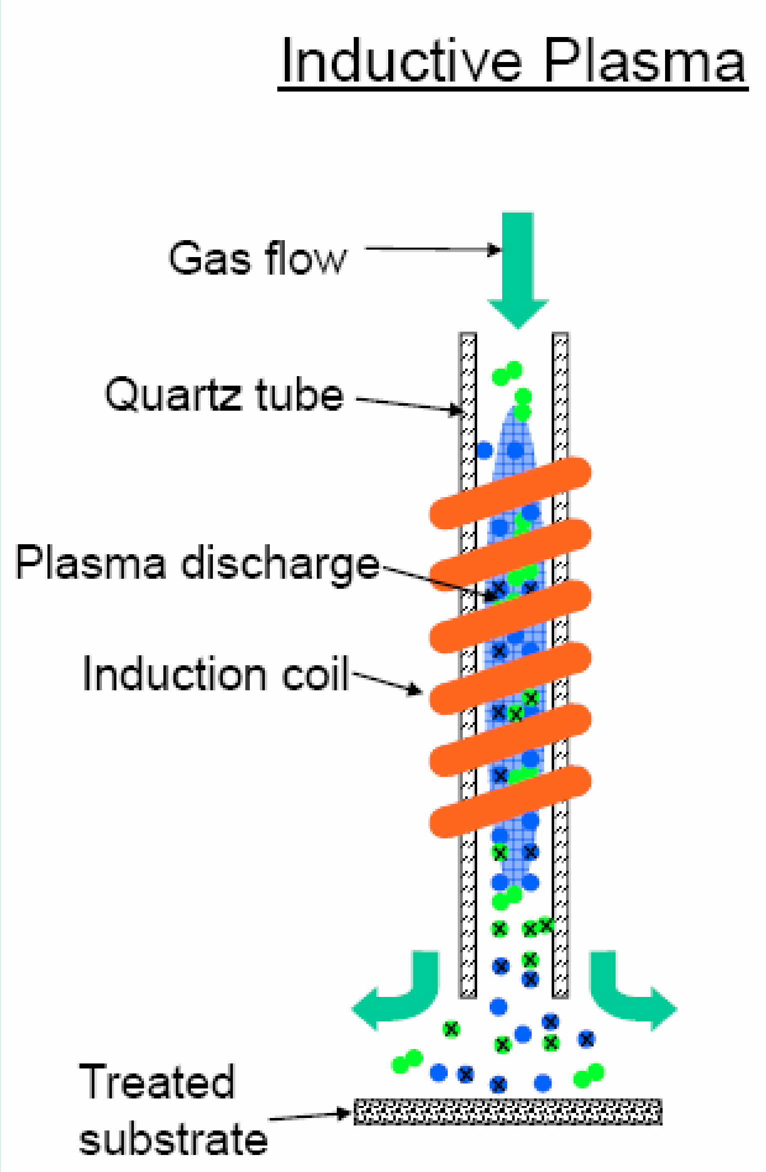
- Introduction
- Techniques and Materials
  - PLASMA APPROACHES
  - SURFACE CHARACTERIZATIONS
  - ADHESION PROPERTIES
- First Results
- Conclusion and Perspectives

Techniques and materials… plasma approaches

Plasma Treatment Approach – 1/4



RF inductive plasma at low pressure

Gas: Ar, Ar/N2, Ar/O2, N2, N2/O2, N2/H2
Substrate: Sugar Maple
Power: 150W

Aim: improve the coating/wood adhesion (surface energy)

Techniques and materials… plasma approaches

<u>Plasma Treatment Approach – 2/4</u>

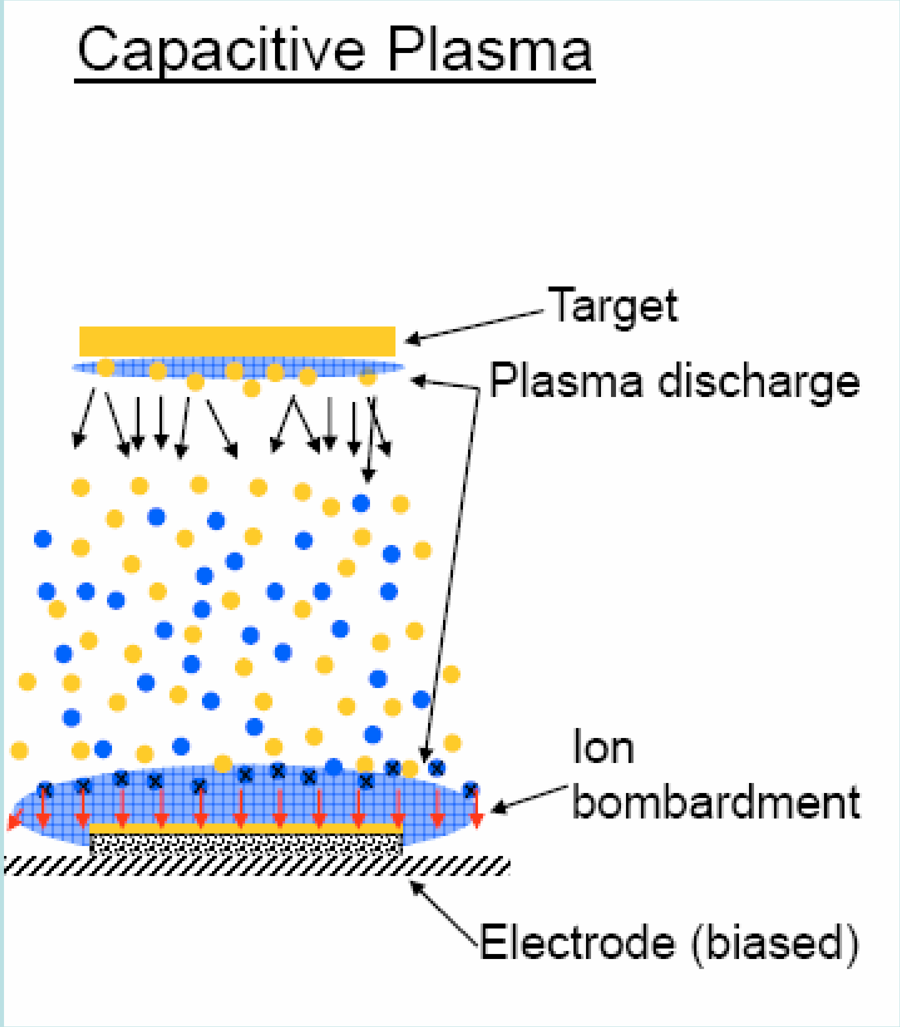
<u>RF capacitive plasma at atmospheric pressure</u>

<u>Gas</u>: Ar, Ar/N2, Ar/O2, N2, N2/O2, N2/H2
<u>Substrate</u>: Sugar Maple

<u>Aim</u>: improve the coating/wood adhesion (surface energy)

Techniques and materials… plasma approaches

Plasma Treatment Approach – 3/4



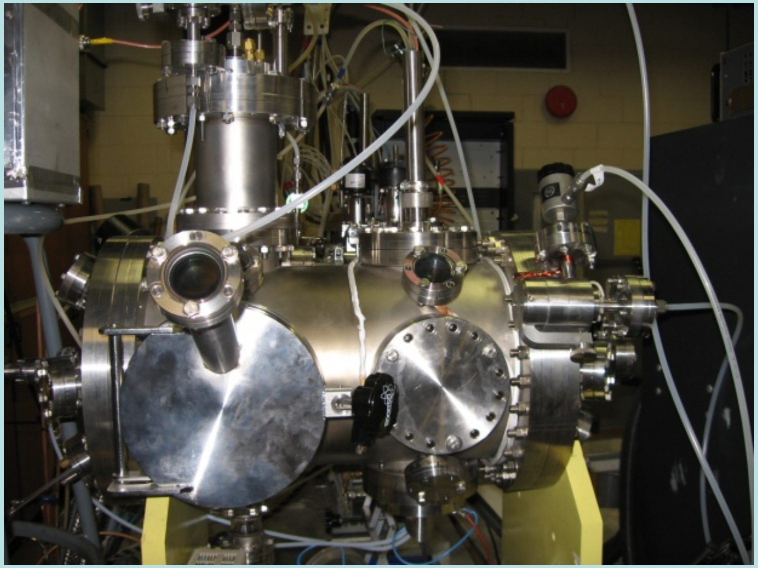
RF capacitive plasma at low pressure

Gas: Ar, N2
Substrate: Sugar Maple
Power: 150W

Aim: improve the coating/wood adhesion (surface energy)

Techniques and materials… plasma approaches

Plasma Treatment Approach – 4/4



Thin film deposition by magnetron sputtering plasma

Targets: Zn, Si, Teflon
Vector gas: Ar
Pressure: 1torr

Aim: UV, H_2O resistance, Hardness

Techniques and materials
SURFACE CHARACTERIZATION

The **nature of surface atoms** after treatment is obtained by X-rays Photoemission Spectroscopy

The surface **roughness** and nano-layers **thickness** is studied by Atomic Force Microscopy
also we do contact angle measurements

Techniques and materials- adhesion

<u>Wood/coating adhesion</u>

Waterborne coating based on polyurethane/polyacrylate are applied on Sugar Maple samples immediately after plasma treatments (60 μm)

Adhesion is next measured in accordance with ASTM D4541

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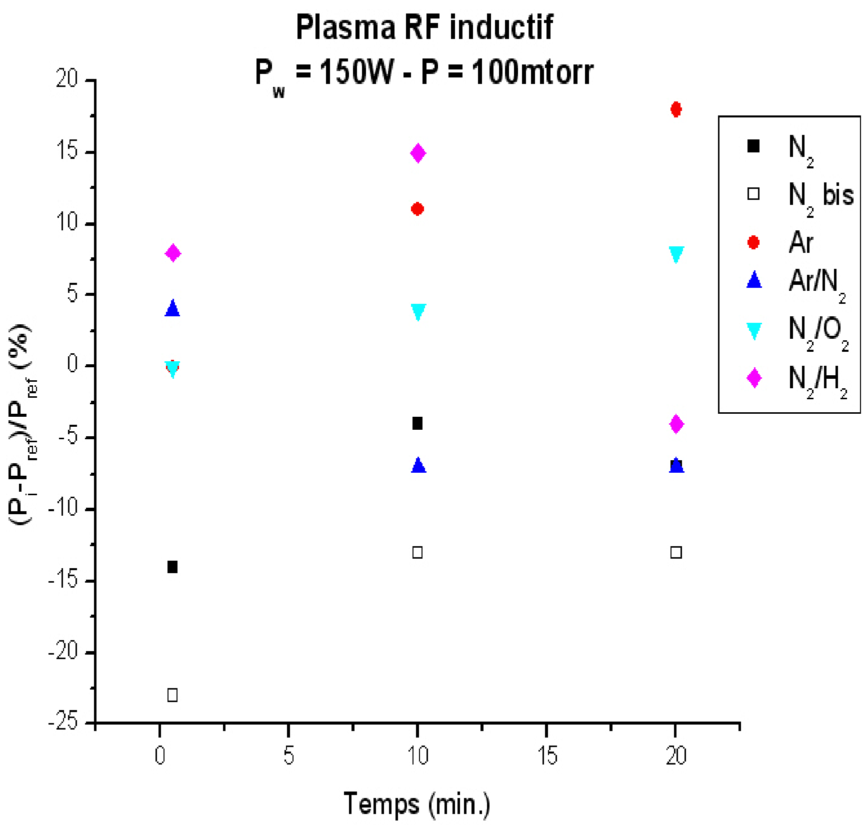
- First Results
  - METHODOLOGY
  - PLASMA TREATMENTS
  - THIN FILM DEPOSITIONS
- Conclusion and Perspectives

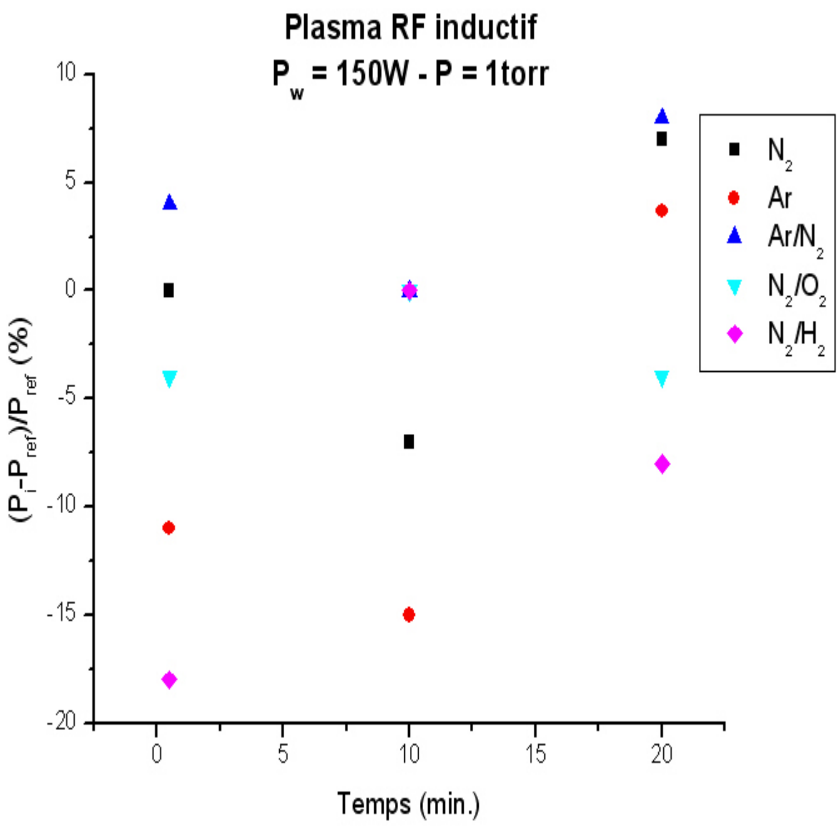
First Results - methodology

1. Selection and preparation of specimens
2. Vacuum treatment (0.1/1/5 torr)
3. Surface plasma treatment (0.5/10/20 min.)
4. XPS/AFM characterizations
5. Application and drying of coatings
6. Coating/wood adhesion characterization

First results - Plasma treatment

Inductive Plasma Results – film/wood adhesion

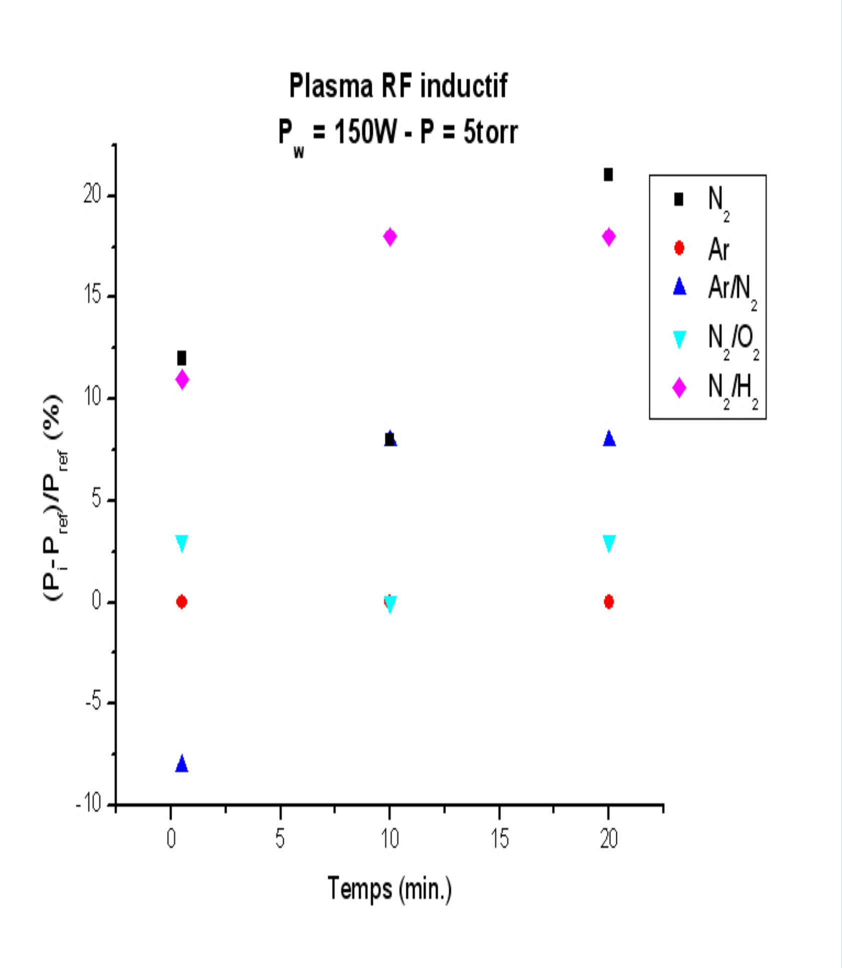




At 100 mtorr λ is greater => better surface treatment
What is the role of extractives (10^{-2} bar) on adhesion?

First results - Plasma treatments

<u>Inductive Plasma Results – film/wood adhesion</u>



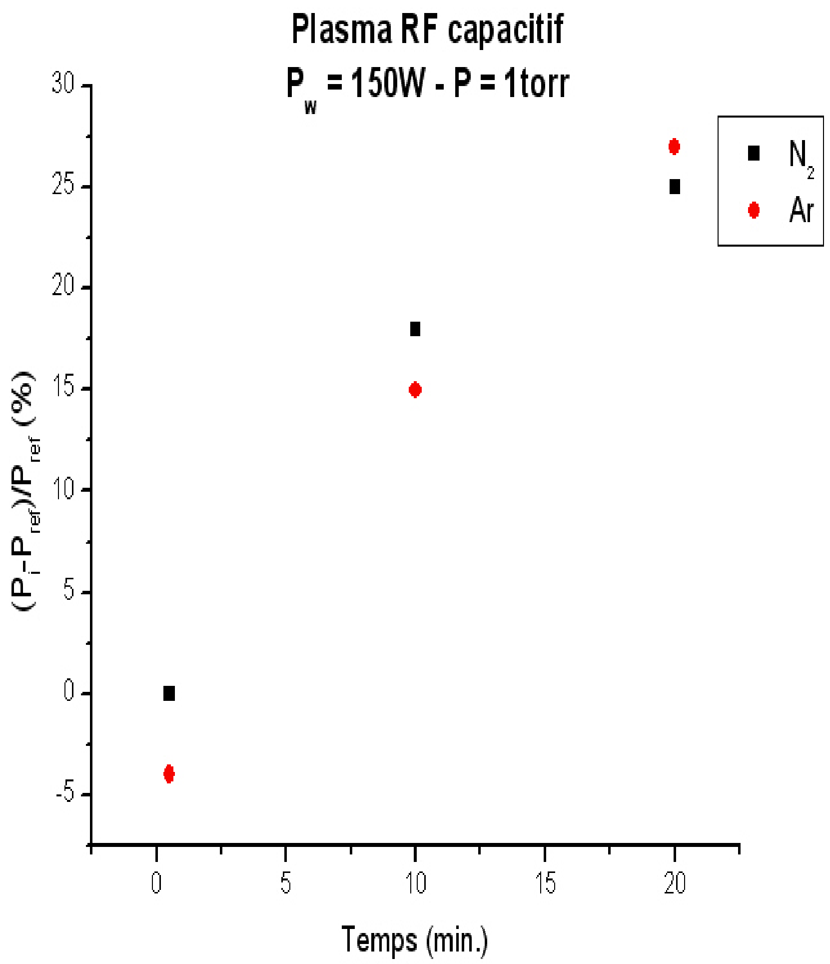
When flow rate is higher, treatment seems more effective

Active particles (ions, electrons) collide more with substrate

At high pressure, the number of active particles in plasma is likely higher

First Results - Plasma Treatments

Capacitive Plasma Results – film/wood adhesion



Results clearly show a significant improvement on adhesion after capacitive plasma treatment

In this case, substrate is directly in contact with plasma

First results – Plasma treatment

XPS Characterization

	Plain Wood	Ar 5 torr inductive	N_2 5 torr inductive	Ar/N_2 5 torr inductive	Ar 1 torr capacitive	N_2 1 torr capacitive
C %	75.4	78.8	44.5	54.1	75.4	76.7
O %	23.8	21.2	20.3	16.1	19.5	16
N %	0.89	0	34	29.4	0	3.6
Oth. %	0	0	0.2	0.4	5.1	4.3

Plasma allows cleaning and activating of wood surfaces

Nitrogen is grafted after inductive plasma but very little amount is found after capacitive one => what is NH_2 rate?

First results – Plasma Treatment

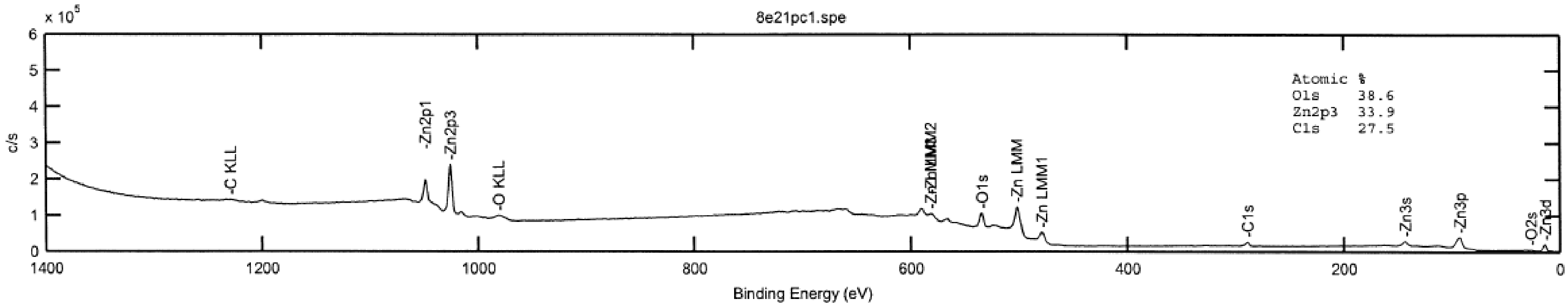
Wettability after treaments

Treatment (20 min.)	**Contact angle**	**Adhesion improvement**
Wood before treatment	81°	0 %
N_2 – 1 torr – capacitive	31°	27 %
Ar – 1 torr – capacitive	67°	25 %
Ar/N_2 – 1 torr – capacitive	51°	N/C
Ar – 5 torr – inductive	76°	0 %
N_2 – 5 torr – inductive	51°	21 %
N_2/H_2 – 5 torr – inductive	38°	18 %
Ar/N_2 – 5 torr – inductive	75°	8 %

Plasma treatments improve wettability => better coating/wood adhesion

First results film deposition

Thin ZnO film deposition

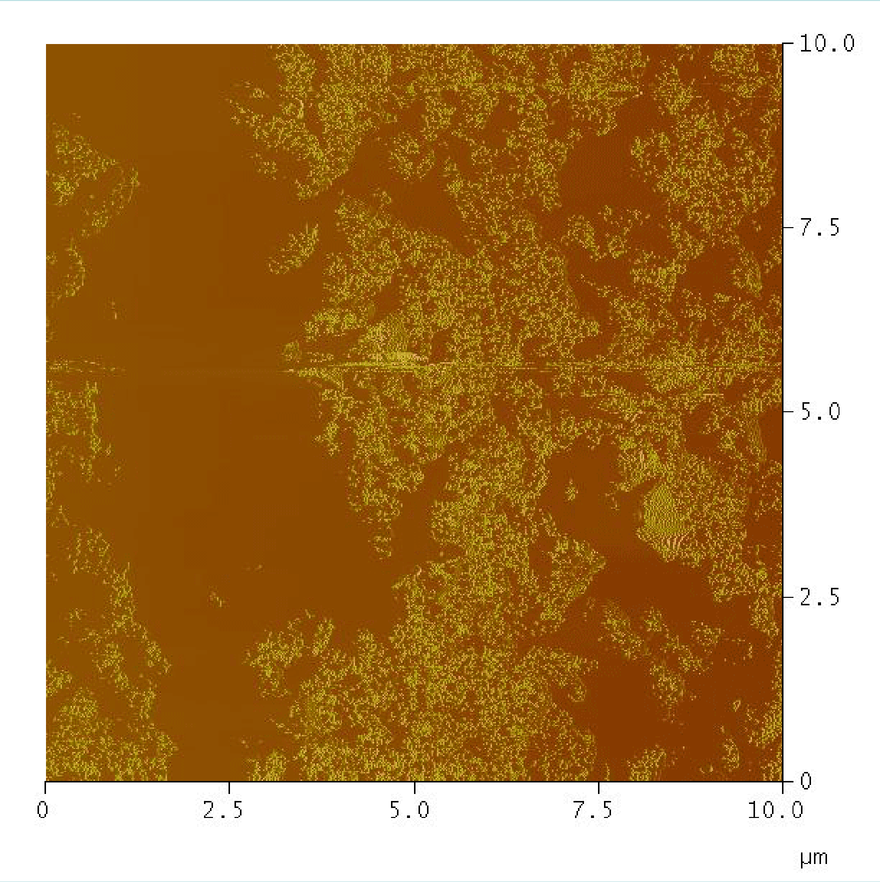


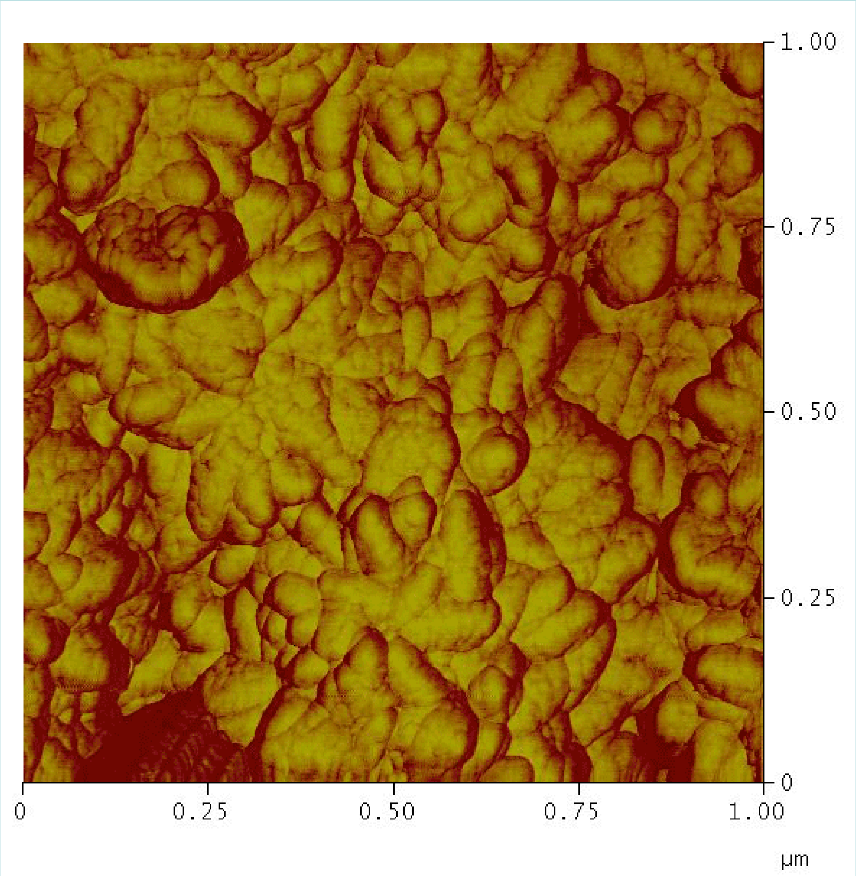
Color is not Modified

	Atomic %
C	27.5
Zn	33.9
O	38.6

First Results - Film deposition

Thin ZnO film deposition



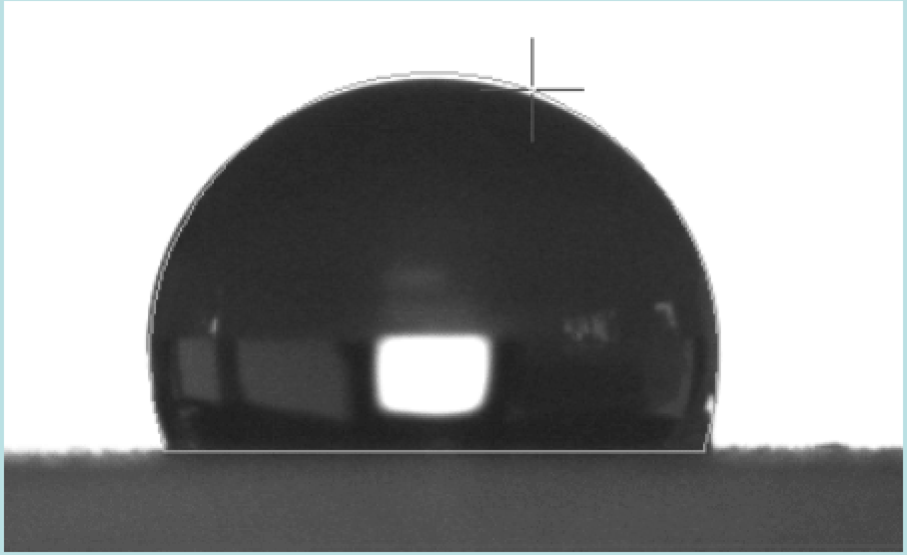


Film deposition is not homogenous

Shape is made up of random outgrowths

First Results - film deposition

Thin ZnO film deposition



ZnO deposition	Contact angle
Plain Wood	81°
Wood with deposition	110°

The wood surface becomes hydrophobic after ZnO deposition (contact angle = 110°)

ZnO thin film deposition might play the role of water barrier and improve the wood UV resistance

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Conclusions

Preliminary tests demonstrated plasma treatment could enhance some wood properties (adhesion, wettability, ,etc.)

Thin film deposition could allow creating new properties and functions for wood products (energy storage, mechanical properties, light source, etc.)

However, several questions stay opened: extractives role? treatment rate? chemical functions? Effect of heat/vacuum, Etc.

Perspectives

- Continue capacitive plasma treatments with N_2/Ar, N_2/O_2 and N_2/H_2 (completed)
- Repeat the best inductive plasma treatments (completed)
- Investigate the influence of power to decrease exposure time for technology transfer (in progress)
- Start atmospheric plasma treatments
- Continue thin film depositions to obtain multi-layer systems with different attributes (UV resistance, impact resistance, water barrier, etc.)

Acknowledgements

Advancing Plasma-Based Technologies
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nano technologies
pour le BOIS
for WOOD

CRSNG
NSERC

nano
québec
l'avenir des nanos est ici
nanotech's future is here

FPInnovations
Créer des solutions pour le secteur forestier

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