Effects of Microfibrillated Cellulose Addition on the Coating Characteristics of Waterborne Paints Applied to Wood and Bamboo Substrates

(National Pingtung University of Science and Technology, TAIWAN)
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【Introduction】

As environmental regulations tighten, waterborne coatings with low VOC emissions have become the market standard; however, their mechanical strength and weathering resistance remain significant challenges. To address these limitations, this study employs microfibrillated cellulose (MFC)—characterized by its high specific surface area and exceptional strength—as an eco-friendly functional additive. Compared to costly inorganic nanomaterials, MFC offers distinct advantages within a circular economy framework. In this research, non-chemically modified MFC was incorporated into a one-component waterborne acrylic coating and applied across three different substrates. A systematic evaluation was conducted on key performance indicators, including pendulum and pencil hardness, abrasion and impact resistance, contact angle, and adhesion. The results aim to quantify the reinforcing effects of MFC, providing empirical evidence and a strategic pathway for optimizing the performance of waterborne wood coatings.

【Experiment】

(1) Coating preparation:

A commercially available water-based acrylic primer was formulated with MFC. MFC was added at concentrations of 0.01%, 0.05%, 0.20%, and 0.50% (w/w), respectively. The MFC was first manually pre-mixed with a defoaming agent, followed by the addition of the primer. The mixture was then homogenized using a mechanical stirrer at 700–800 rpm for 20 minutes. Coating properties, including viscosity, touch-dry time, drying time, pot life, and solid content, were determined in accordance with the CNS 15200 standard.

(2) Specimen coating and characterization:

The homogenized water-based acrylic/MFC mixtures were applied using a four-sided applicator onto the surfaces of Taiwania (*Taiwania cryptomerioides*, T), Big-leaf Mahogany (*Swietenia macrophylla*, S), Moso Bamboo (*Phyllostachys edulis*, P), and glass plates (dimensions: 152 × 78 × 7 (mm)). The wet film thickness was controlled at 200 μm. Following application and drying, non-destructive evaluations of the primer film, including pendulum hardness and gloss, were conducted. Subsequently, a topcoat was applied over the same film surfaces with a wet film thickness of 200 μm. After the topcoat dried, the comprehensive properties of the MFC-enhanced films were tested, including hardness, contact angle.

【Results and discussion】

Regarding mechanical performance, the hardness assessment of MFC-modified water-based acrylic primer systems (Figure 1) demonstrated modest yet consistent enhancements for both gymnosperm and angiosperm wood substrates with increasing MFC incorporation. This improvement is ascribed to the effective load transfer and microstructural reinforcement imparted by MFC within the polymer matrix. In contrast, a pronounced decline in hardness was observed for bamboo substrates. This deterioration is primarily attributed to excessive fiber loading, which disrupts film continuity and compromises coating consolidation during the curing process. Additionally, the intrinsically dense and highly lignified cellular architecture of bamboo acts as a physical constraint, hindering MFC penetration and interfacial interlocking, thereby substantially diminishing its reinforcing efficiency.

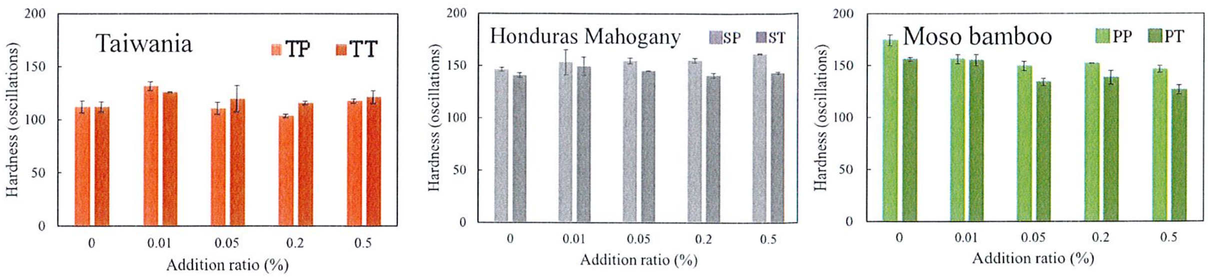

Figure 1 Evaluating the impact of varying MFC ratios on the pendulum hardness of wood and bamboo surface coatings.(TP, SP, PP : Primer ; TT, ST, PT : Primer and Topcoat)

Variations in MFC loading did not elicit statistically significant changes in either pencil hardness or contact angle (Figure 2). The limited influence of MFC on pencil hardness is ascribed to the predominance of surface scratch resistance in governing this parameter, rather than the intrinsic bulk mechanical integrity of the coating matrix. Even when MFC was incorporated into both primer and topcoat layers, the microscale reinforcement imparted by the fibers remained largely imperceptible in macroscopic pencil indentation tests, indicating that MFC primarily augments coating toughness and ductility rather than enhancing surface hardness.

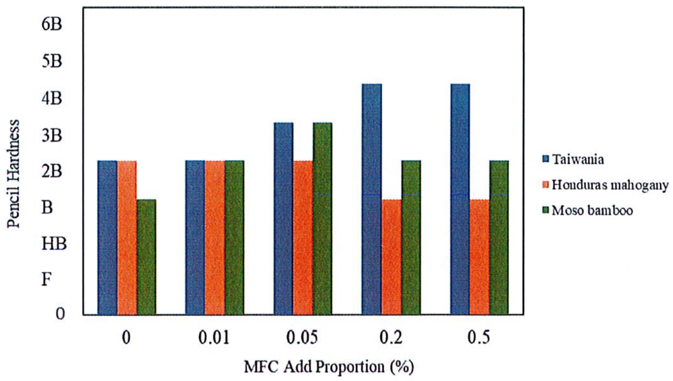

Figure 2 Evaluating the impact of varying MFC ratios on the pencil hardness of wood and bamboo surface coatings.

In a similar vein, MFC incorporation exerted negligible effects on surface wettability, as reflected by contact angle measurements (Figure 3). Although MFC in the primer effectively occludes the intrinsic porosity of wood and bamboo substrates, thereby improving surface planarity, the ultimate wettability is principally determined by the chemical composition and surface energy of the overlying transparent topcoat. Accordingly, the functional characteristics of MFC within the primer layer remain largely decoupled from the exterior surface, yielding minimal impact on contact angle behavior.

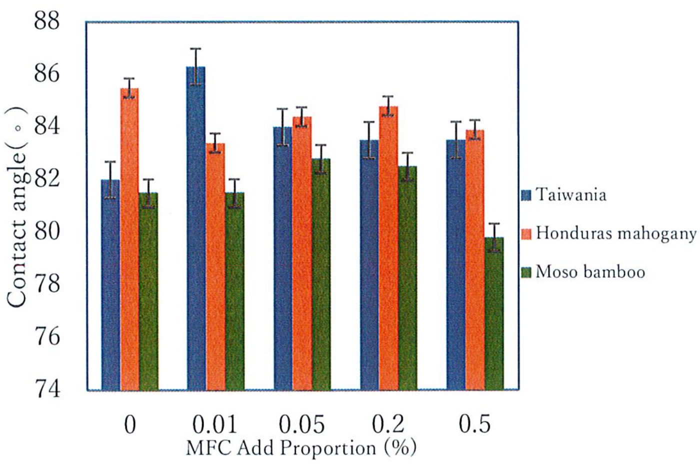

Figure 3 Evaluating the impact of varying MFC ratios on the contact angle of wood and bamboo surface coatings.

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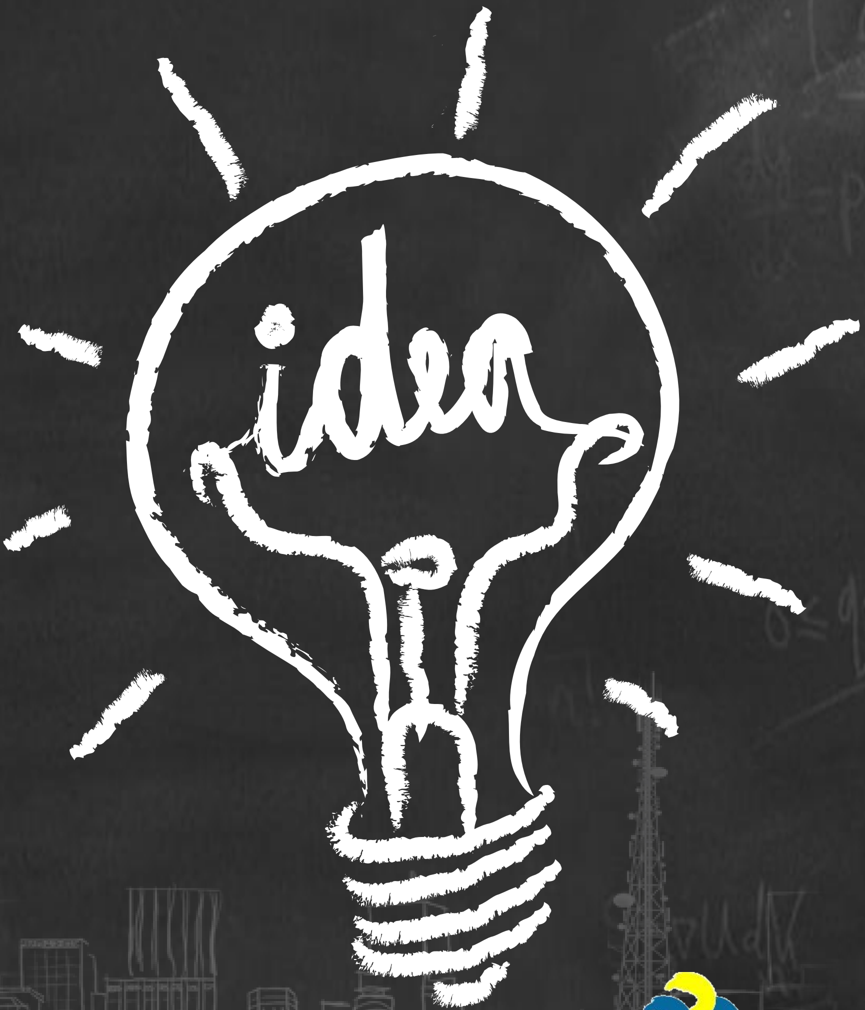

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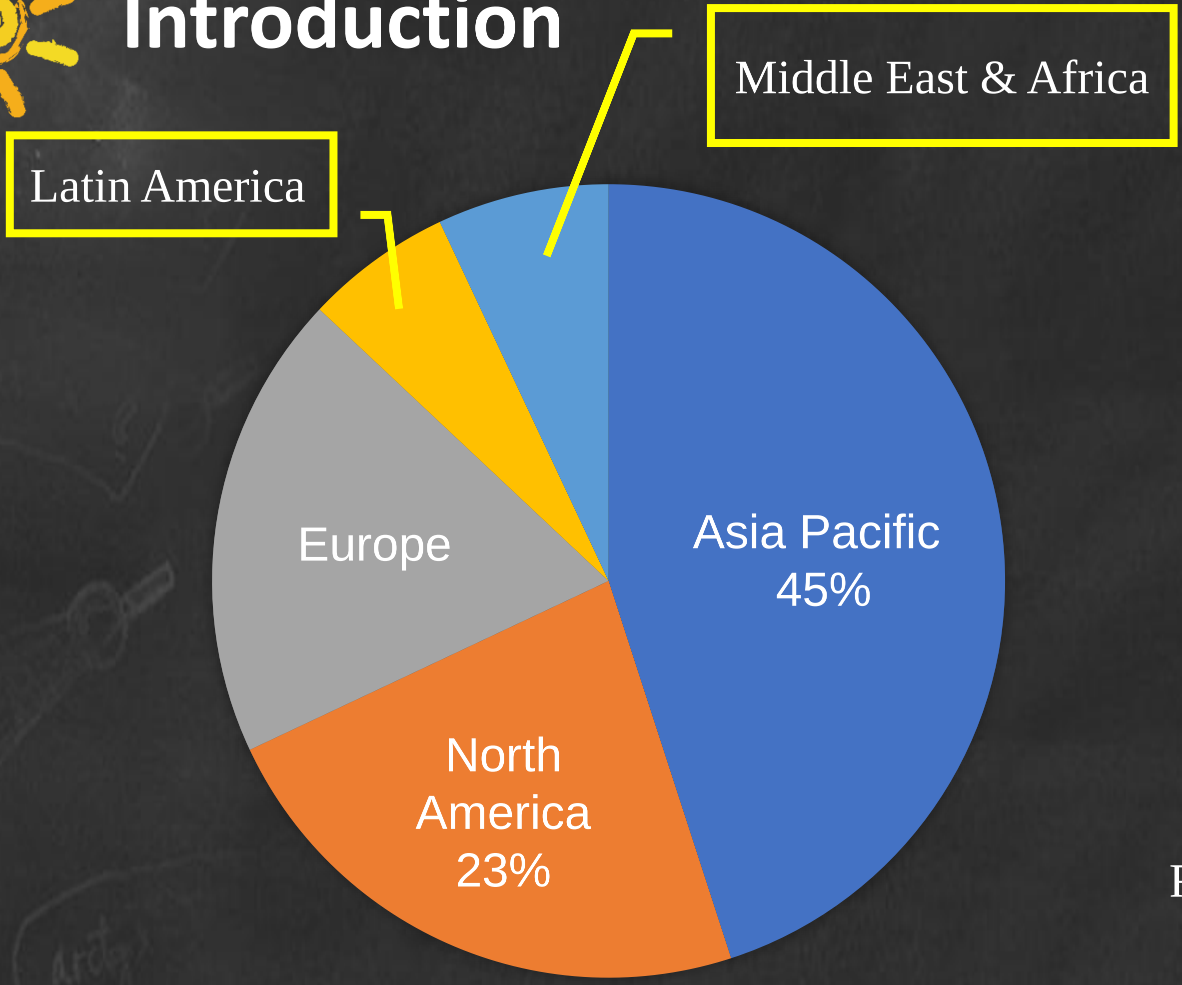
Outline

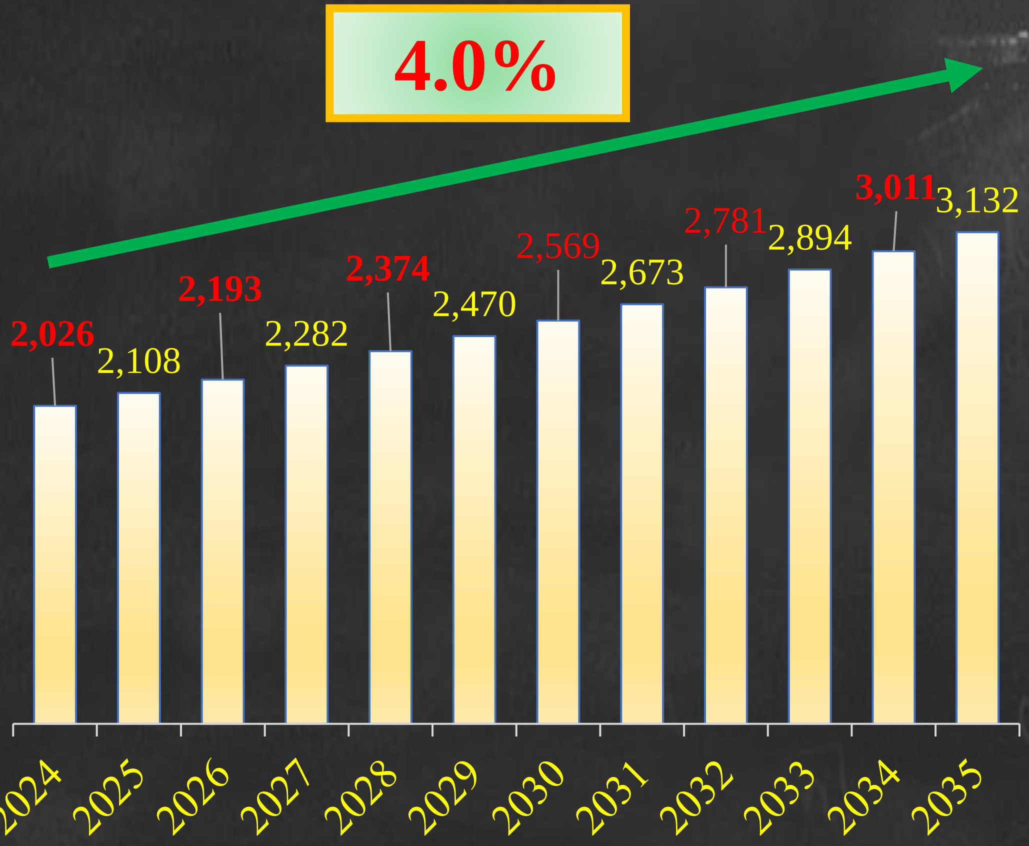
PART ONE

Introduction

Introduction

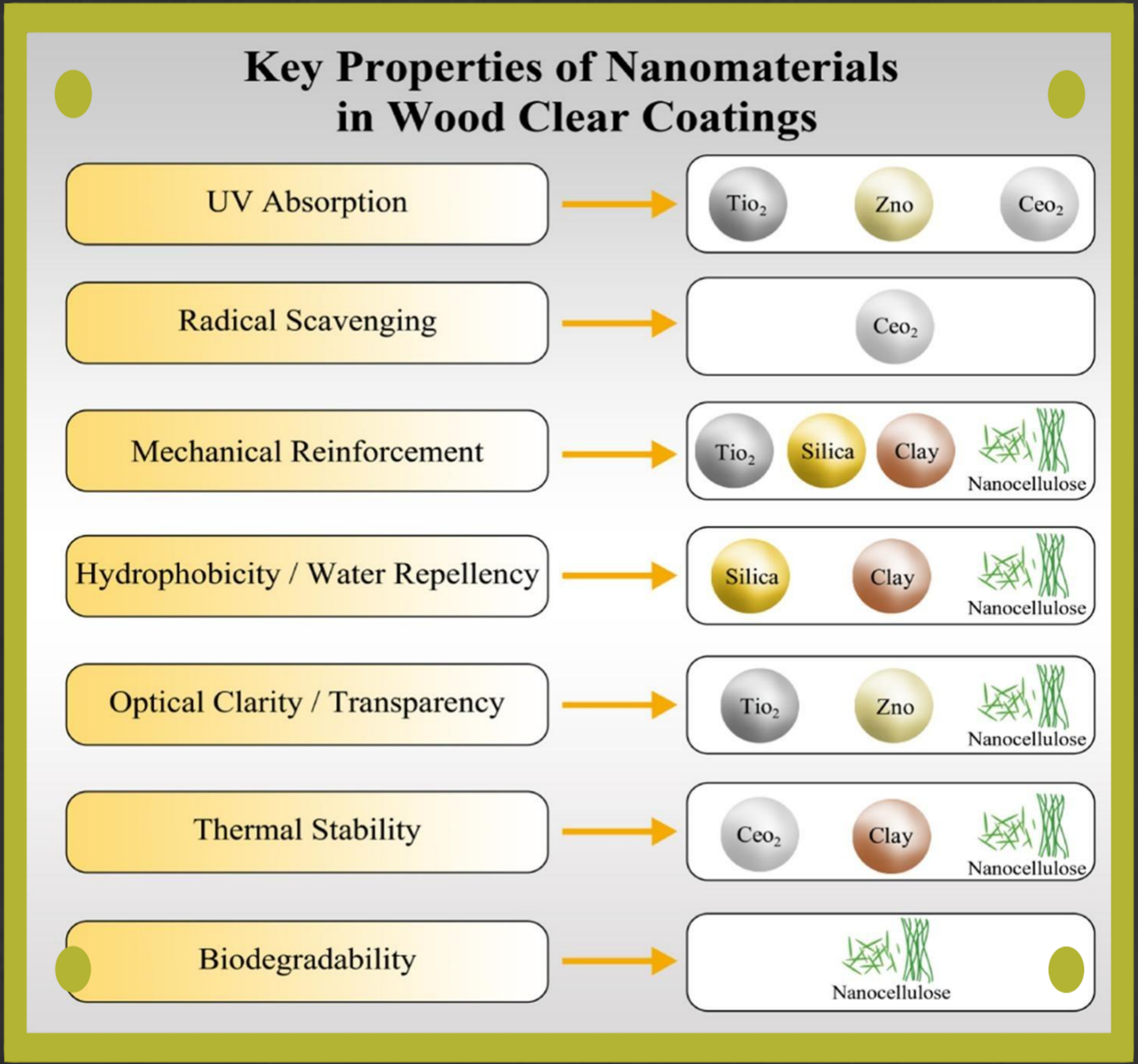


Global Paint and Coatings Market Share Analysis 2024
(Source:Transparency market research,2025)



Revenue Growth of the Global Paints and Coatings Market
(2024-2035)
(Source:Transparency market research,2025)

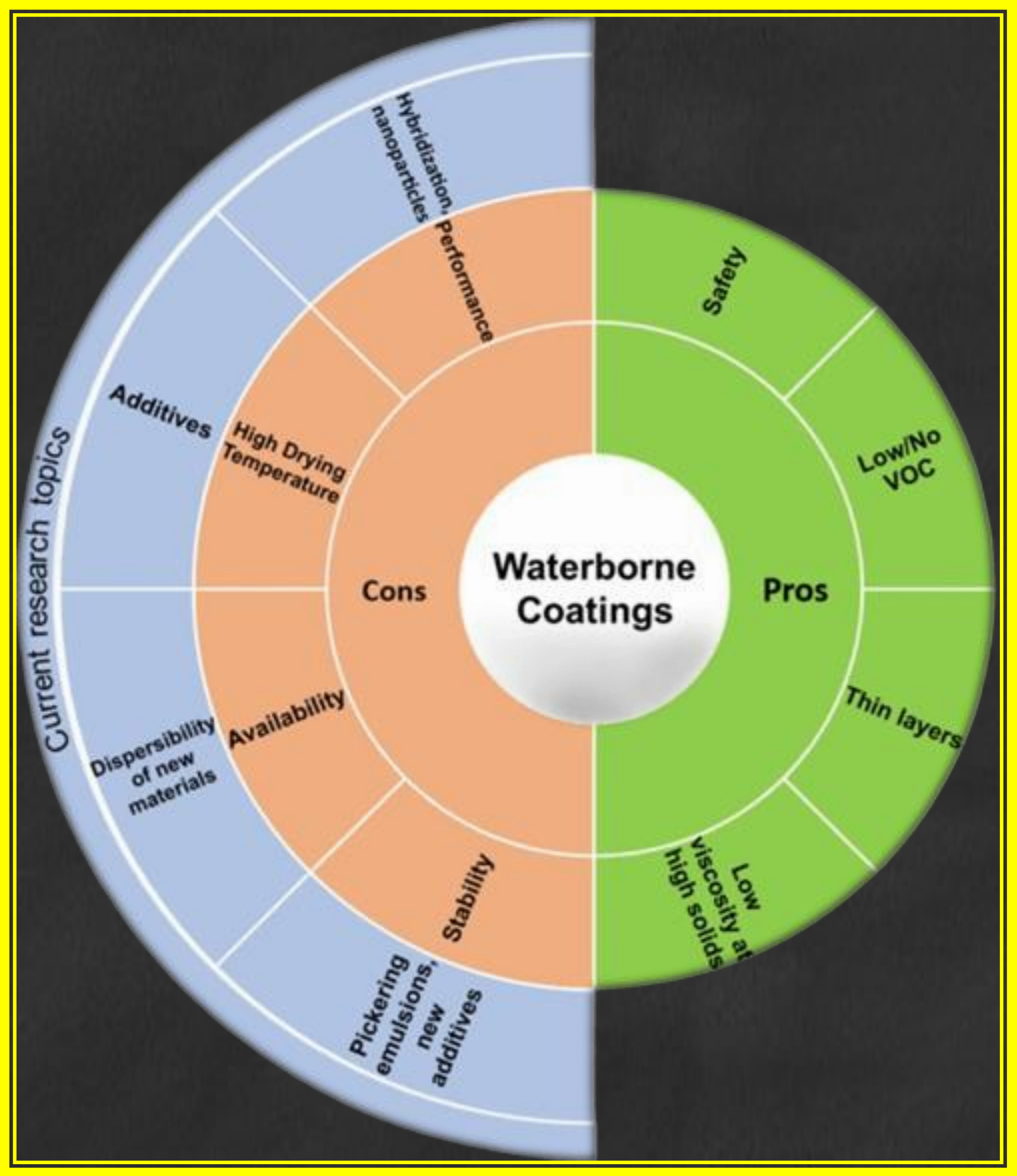
Introduction



Illustrates the key properties of nanomaterials in wood clear coatings (Categorized by nanomaterial type).

Introduction

drawbacks



Benefits

Benefits and drawbacks to waterborne coating systems compared to existing alternatives.

PART TWO

Methods and materials

Methods and materials

MFC-0.01、0.05、0.2、0.5

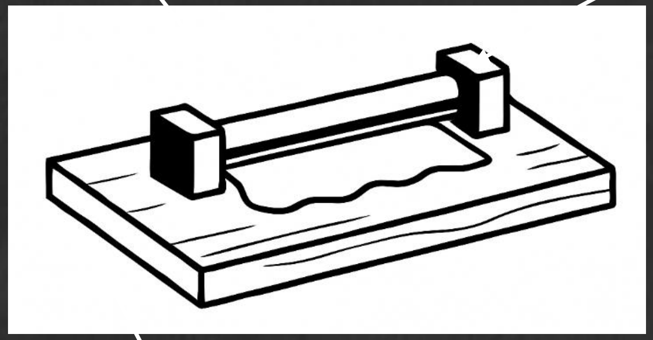
Waterborne Acrylic Coating

700-800rpm
Mixing 20-30min

Film Thickness： 200 μm.

Taiwania

Moso Bamboo



Big-leaf Mahogany

Methods and materials

Measurement of Coating Properties

Properties of Liquid Coatings

- Viscosity
- Set-to-touch
- Drying time
- Pot life

Properties of Coating Films

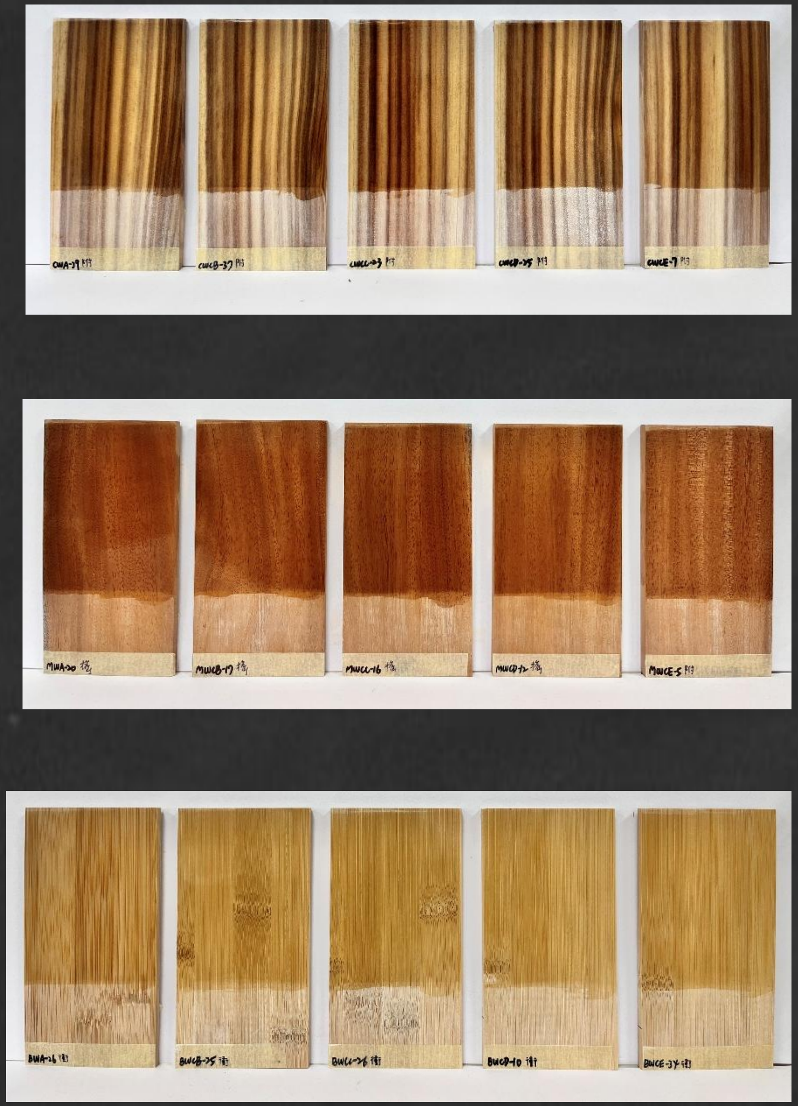
- Hardness(pendulum 、Pencil)
- Contact angle
- Gloss

PART THREE

Results & Discussion

Results & Discussion

0 0.01 0.05 0.20 0.50 (%)



Taiwania

Big-leaf Mahogany

Moso Bamboo

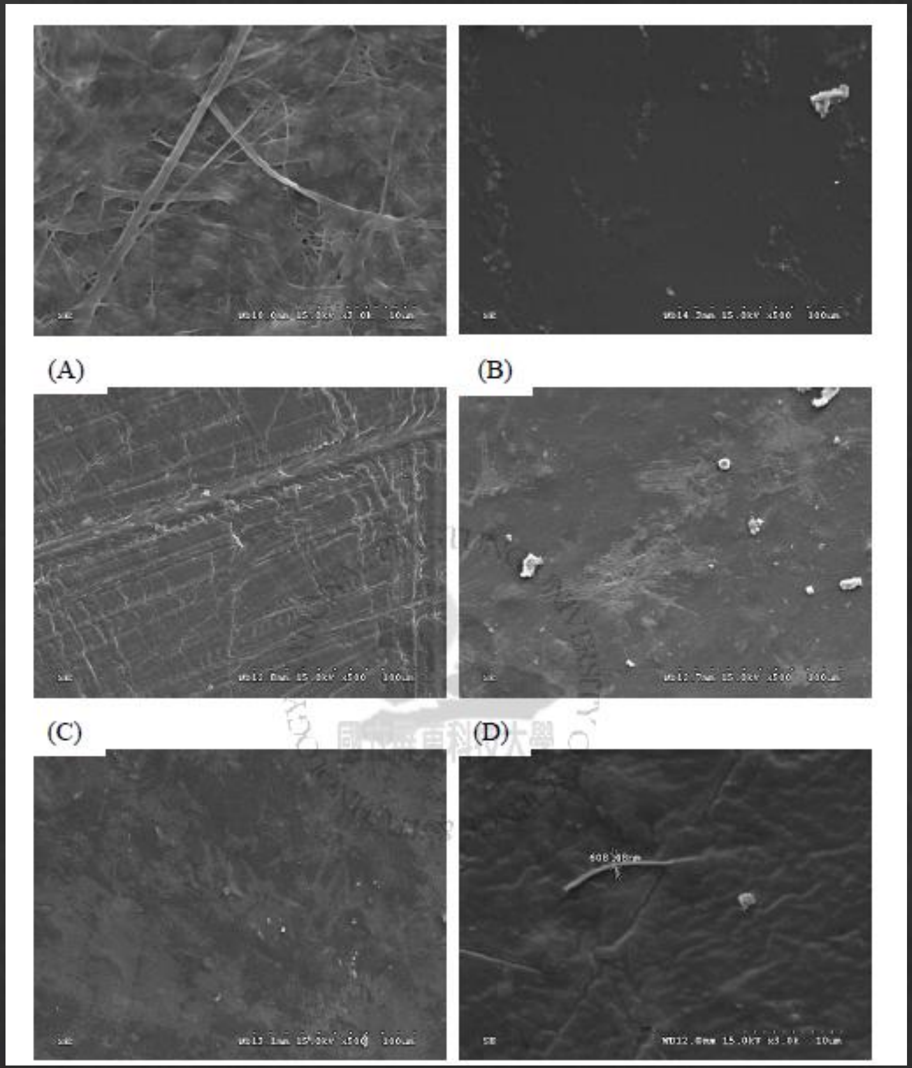
Visual appearance of coatings on three substrates at various MFC concentrations.

Results & Discussion

Properties of Liquid Coatings

Sample type	Addition ratio (%)	Viscosity (mPa.s)	Surface drying time (min)	Drying time (min)	Pot life (day)
水性壓克力塗料	0.00	340.0±0.0	15±5	30±5	3
	0.01	305.8±2.0	15±5	30±5	3
	0.05	294.0±2.2	15±5	30±5	3
	0.20	270.4±0.9	15±5	30±5	3
	0.50	320.0±2.5	15±5	30±5	3

Results & Discussion：SEM



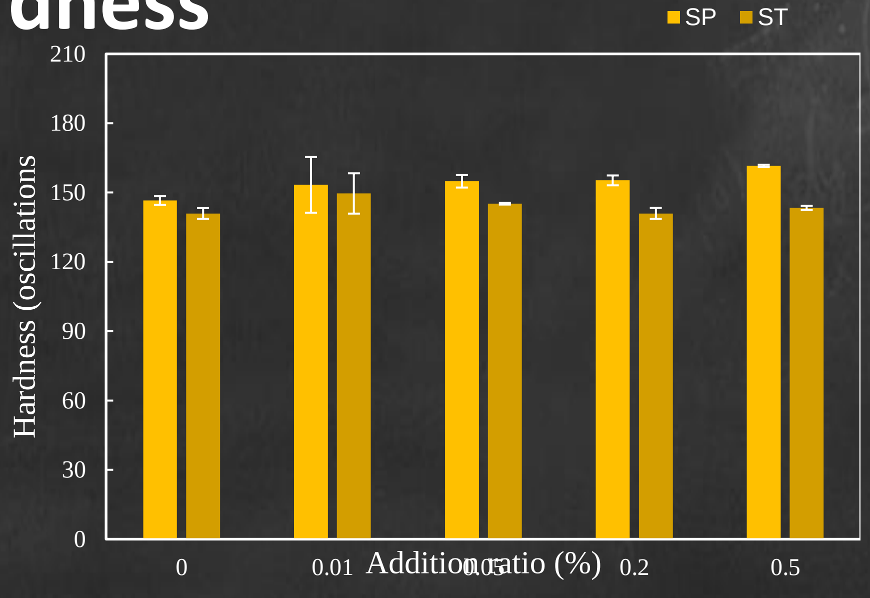
（A）MFC、（B）0.00%、

（C）0.01%、（D）0.05%、

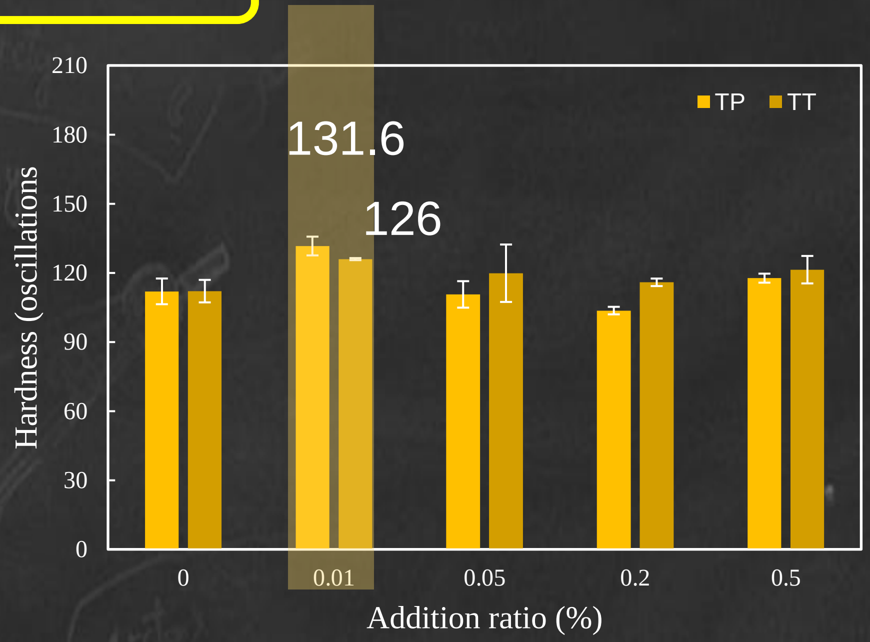
（E）0.20%及（F）0.50%

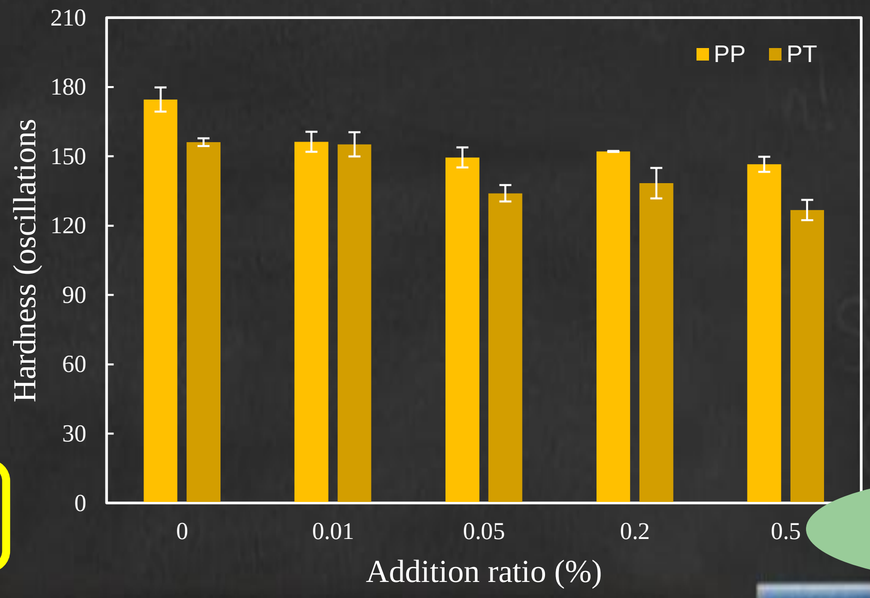
Results & Discussion：pendulum hardness

Big-leaf Mahogany



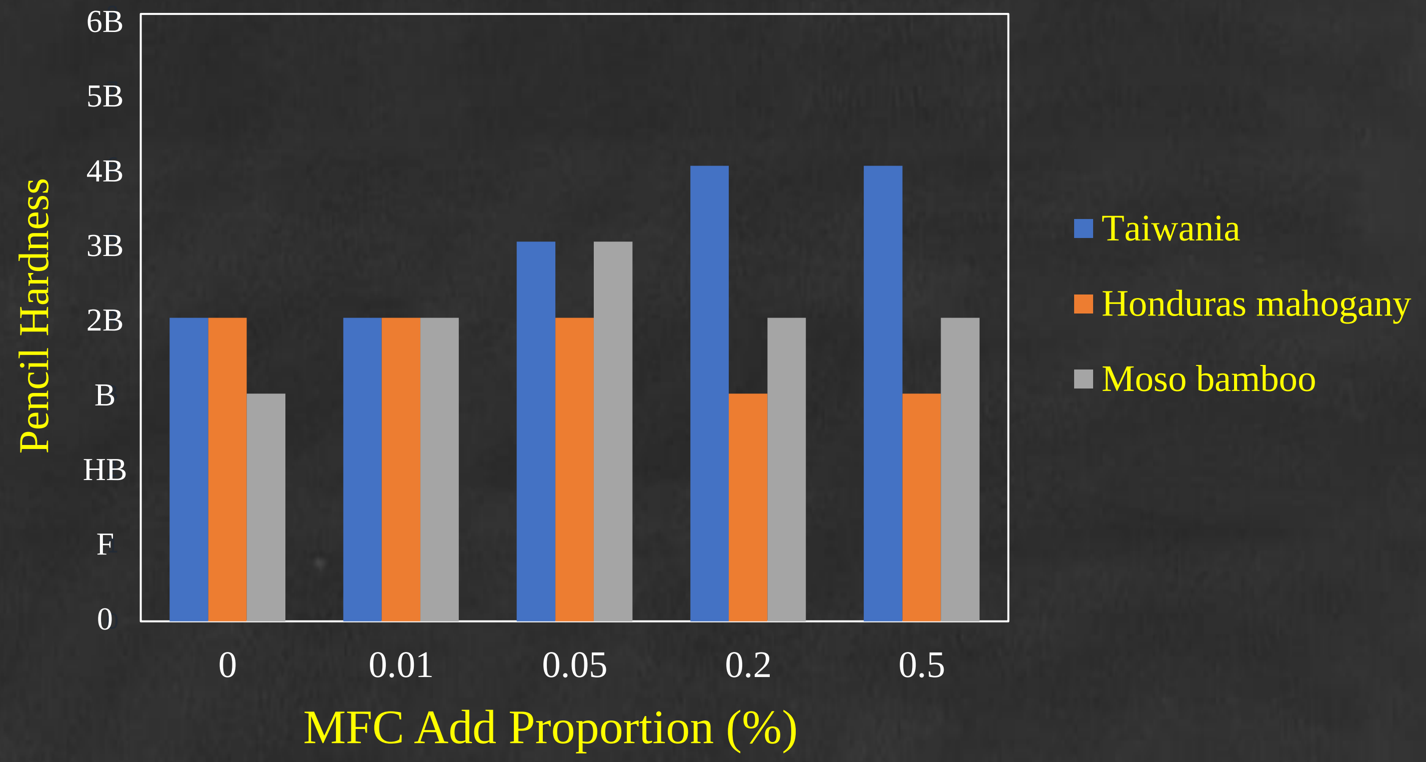
Taiwania



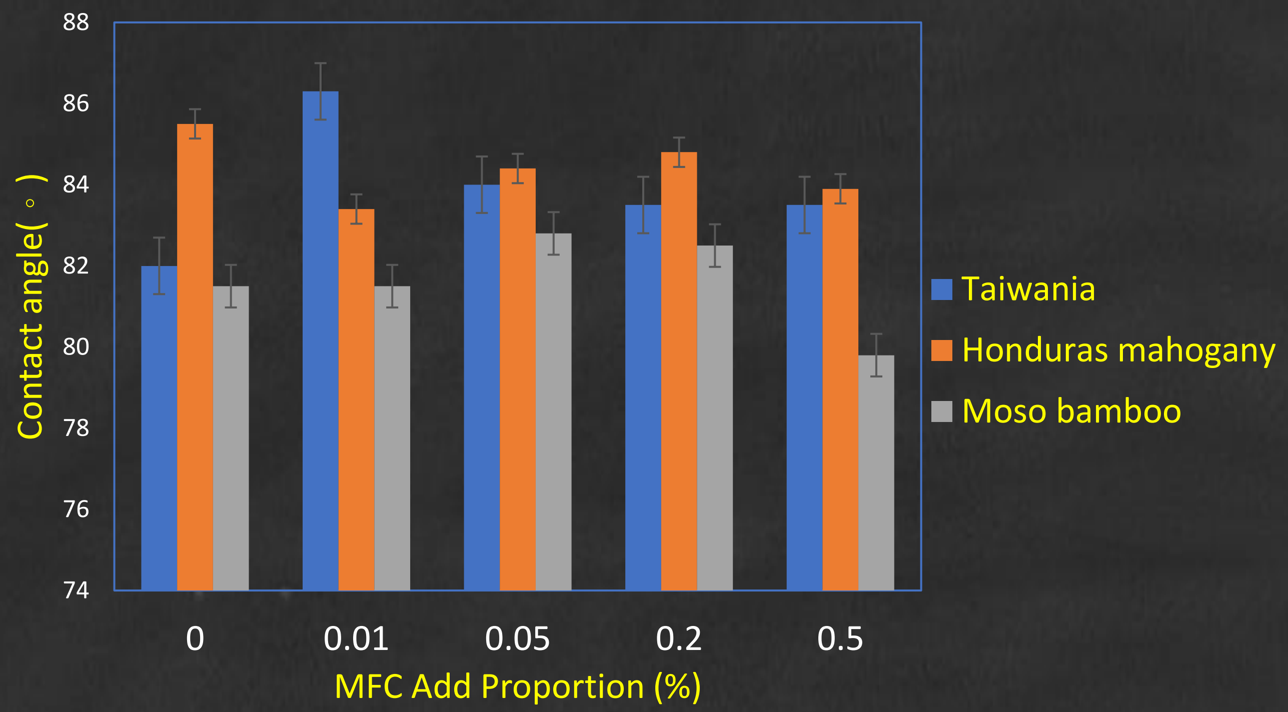


Moso Bamboo

Results & Discussion：pencil hardness



Results & Discussion ： contact angle

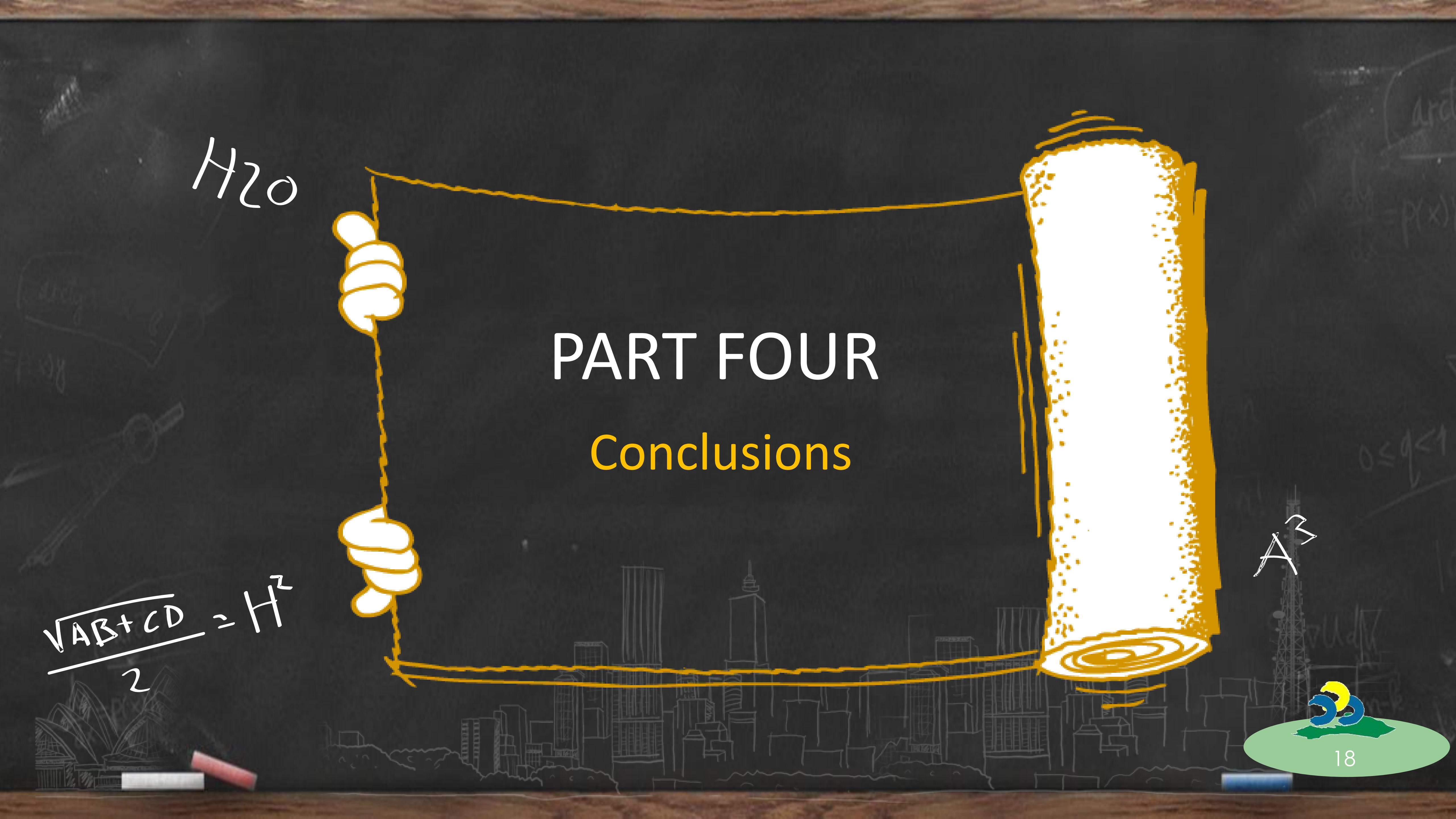


Results & Discussion ： Gloss

Sample type	Addition ratio （%）	Gloss （GU）
TP	0.00	9.9±1.6
	0.01	9.3±2.0
	0.05	9.8±2.4
	0.20	7.6±2.2
	0.50	6.1±1.5
TT	0.00	78.7±5.3
	0.01	81.3±5.4
	0.05	82.4±3.5
	0.20	84.1±4.3
	0.50	84.3±4.3

Sample type	Addition ratio （%）	Gloss （GU）
SP	0	9.9±1.6
	0.01	9.3±2.0
	0.05	9.8±2.4
	0.20	7.6±2.2
	0.50	6.1±1.5
ST	0	78.7±5.3
	0.01	81.3±5.4
	0.05	82.4±3.5
	0.20	84.1±4.3
	0.50	84.3±4.3

Sample type	Addition ratio （%）	Gloss （GU）
PP	0	3.1±1.7
	0.01	10.2±2.3
	0.05	6.0±1.8
	0.20	7.2±1.7
	0.50	6.3±1.6
PT	0	76.2±6.7
	0.01	88.1±1.5
	0.05	88.1±3.7
	0.20	90.2±0.6
	0.50	87.2±2.4



PART FOUR
Conclusions

Conclusions

Reinforcement Effects:

•**Softwoods:** The primary application value of MFC lies in enhancing **film hardness**.

•**Hardwoods and Bamboo:** The benefits are mainly reflected in a significant improvement in **gloss**.

Key Influencing Factors:

•MFC is more effective at increasing hardness on porous **softwood** substrates. On denser substrates, however, it may slightly reduce hardness by interfering with the **film-forming process**.

Practical Recommendations:

The MFC dosage should be dynamically adjusted based on specific substrate characteristics (e.g., domestic vs. imported, wood vs. bamboo) and the desired performance objectives.

Thanks For Your Attention