Development of Functional and Scratch Resistant UV Curable Wood Coatings

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GENÇ Wood Coating Systems

Table of Contents

1

GENERAL INFORMATION ABOUT COATING SYSTEMS

Main Components and Purposes of Coatings

Kayalar AR-GE MERKEZİ

Protection of substrates	Functional properties	Coloring and decorative properties
		

Binders	Pigments	Solvents	Fillers	Additives
				

Automotive coatings

Aircraft coatings

Textile coatings

Architectural coatings

Metal coatings

Wood coatings

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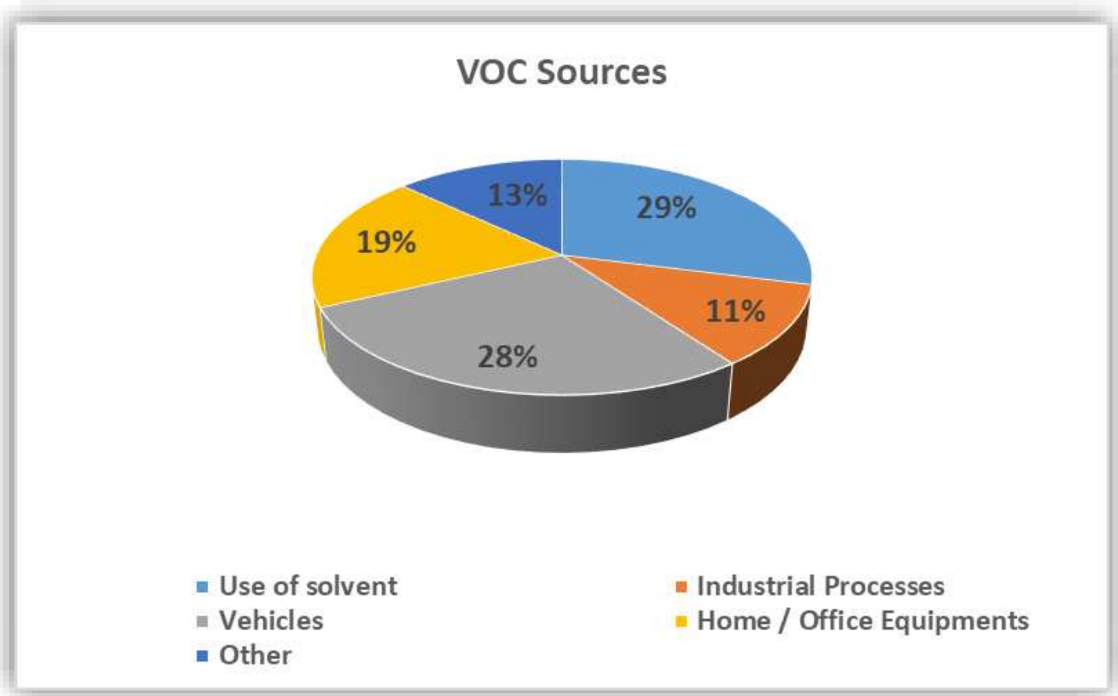
Wood Coatings Depending on the Binder Type

- Cellulosic coatings
- Acrylic coatings (1K ve 2K)
- Synthetic coatings
- Epoxy coatings
- Polyurethane coatings (1K ve 2K)
- Waterbased coatings (PUD and acrylic 1K, 2K)
- UV curable coatings
- Powder coatings
- Acid curable coatings

Disadvantages of Solventbased Systems and Alternatives



https://epa.gov

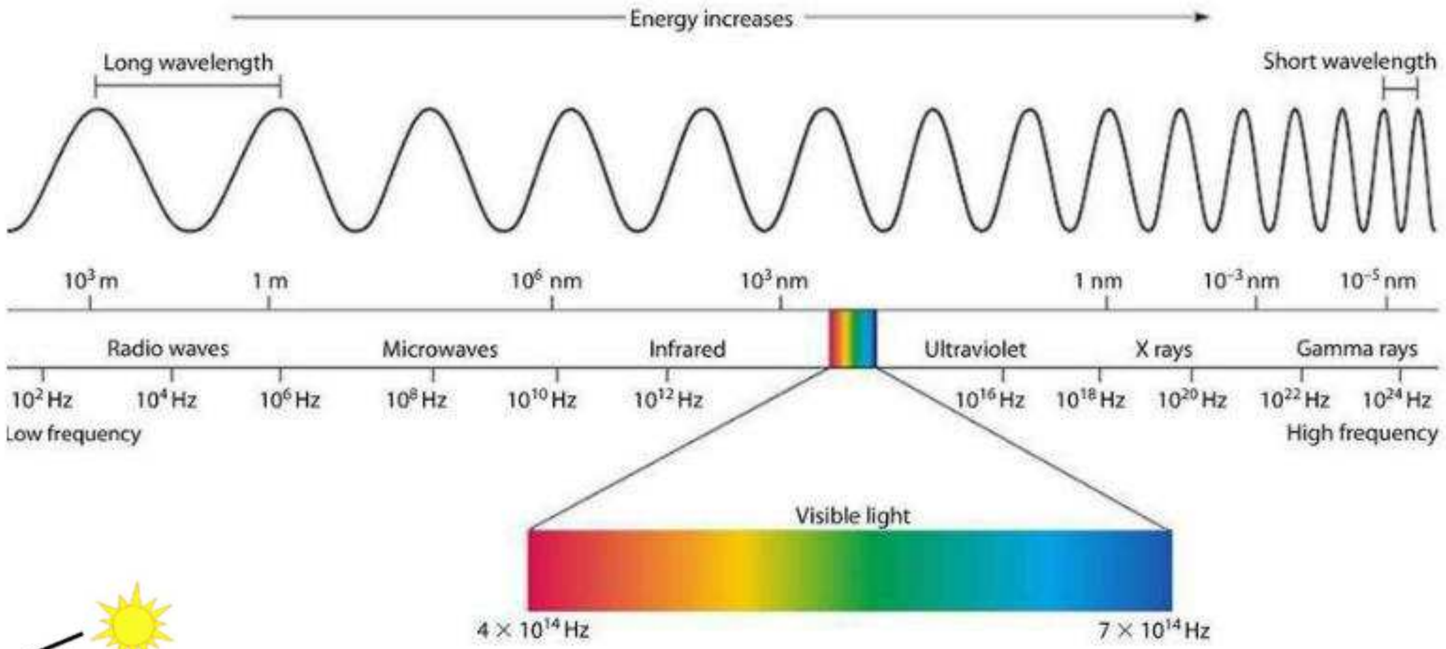
- UV curable systems
- Waterbased systems
- % 100 solid systems (Powder coatings)
- High solid systems
- Biobased systems

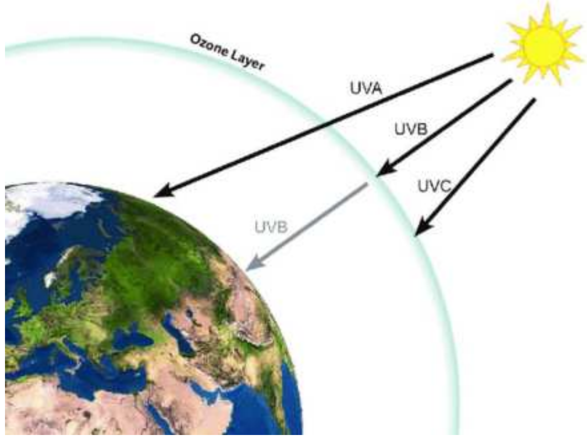
2

UV CURABLE SYSTEMS

Electromagnetic Sprectrum & UV Region

Kayalar AR-GE MERKEZİ





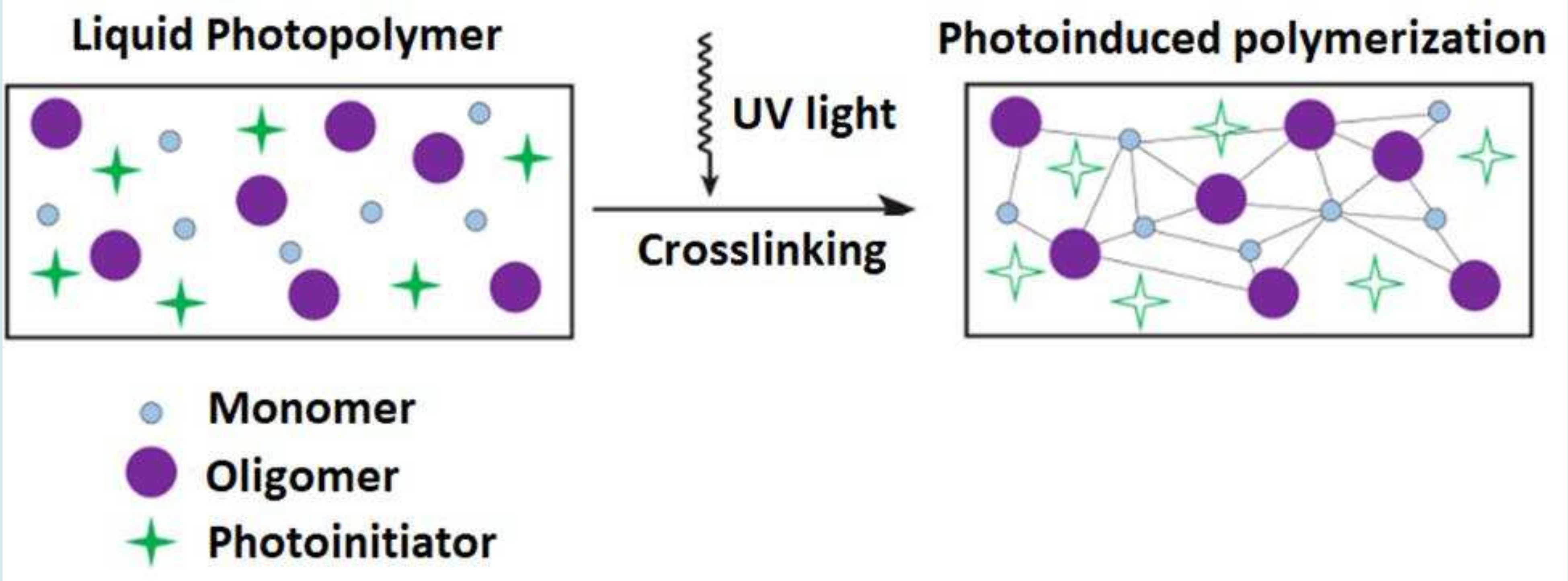
UV Region	Wavelength (nm)	Characteristic Properties	Application Area
Visible Region	780-380		Adhesives
UV-A	380-315	Deep Curing	Inks and Coatings
UV-B	315-280		Varnishes
UV-C	280-200	Surface Curing	Sterilization
UV-V	200-100	Absorption by Oxygen	Excimer Lamps

Components of UV Curable Systems

Kayalar AR-GE MERKEZİ

Oligomers	Monomers (Reactive diluents)	Photoinitiators	Additives
❑ High molecular weight compounds ❑ Reducing viscosity ❑ Participate in crosslinking reactions	❑ Low molecular weight compounds ❑ Reducing viscosity ❑ Participate in crosslinking reactions	❑ Initiation of the polymerization ❑ Can be different chemical structure	❑ Improving the performance of the coating ❑ Can be different type
✓ Epoxy acrylates ✓ Polyester acrylates ✓ Urethane acrylates ✓ Polyether acrylates	✓ TPGDA ✓ (Tripropylene glycol diacrylate ✓ DPGDA Dipropylene glycol diacrylate ✓ HDDA (Hexandiol diacrylate) ✓ LA (Lauryl acrylate) ✓ IBOA (Isobornyl acrylate)	✓ Type- 1 PI ✓ Type-2 PI ✓ One Component Type-2 PI ✓ Polymeric PI	✓ Dispersing agents ✓ Defoamers ✓ Rheology modifiers ✓ Matting agents ✓ Fillers ✓ Anti-sagging agents ✓ Matlaştırıcılar ✓ UV Stabilizers ✓ Adhesion promoters

Principles of UV Curable Systems



Free Radical Polymerization Mechanism

Kayalar AR-GE MERKEZİ

Initiation

$$\text{Photoinitiator} + h\nu \rightarrow 2R^{*}$$

$$R^{*} + M \rightarrow RM^{*}$$

Propagation

$$RM^{*} + M_n \rightarrow RM^{*}_{n+1}$$

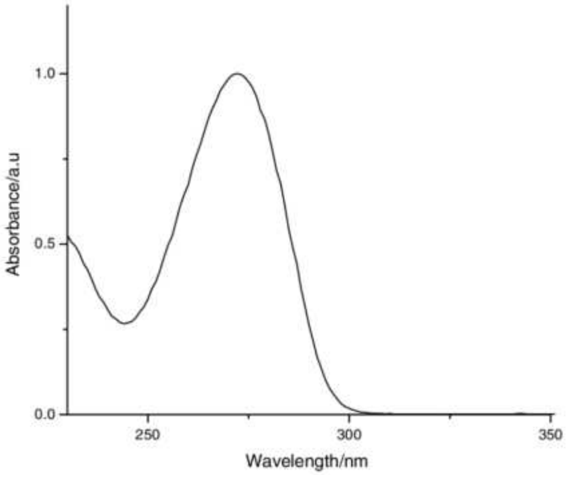
Termination

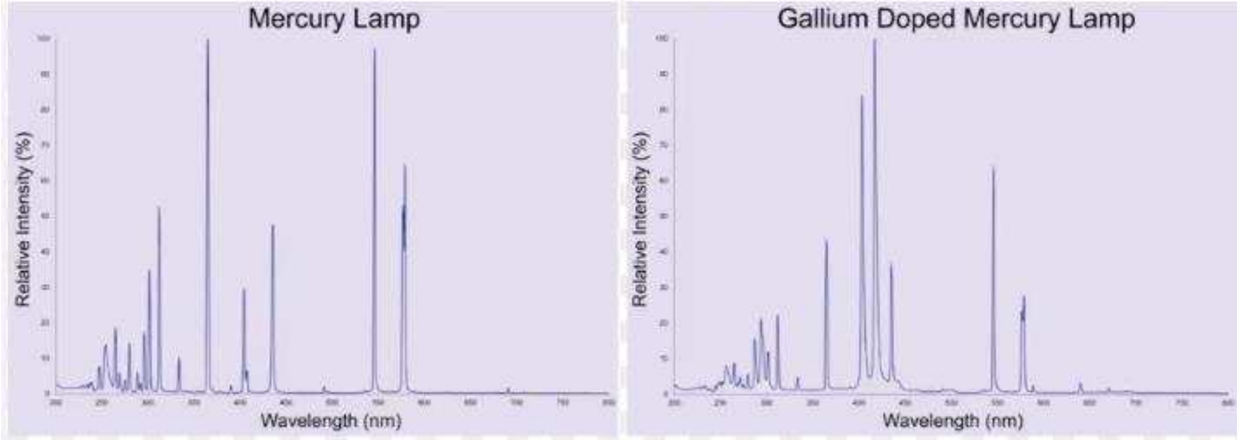
by combination

$$RM^{*}_n + M^{*}_m R \rightarrow RM_n M_m R$$

by disproportionation

$$RM_n - CH_2 - CH_2^{*} + RM_m - CH_2 - CH_2^{*} \rightarrow RM_n - CH = CH_2 + RM_m - CH_2 - CH_3$$





Advantages of UV Curable Systems

Kayalar AR-GE MERKEZİ

Environmental

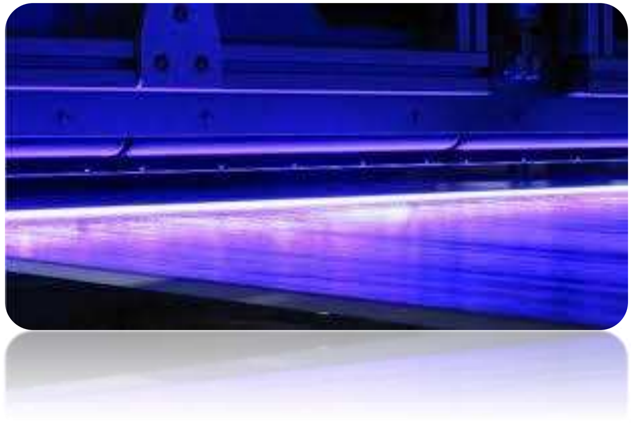
- ✓ Very low VOC emissions
- ✓ Minimum waste
- ✓ More sustainable

Production & Application

- ✓ Very fast curing at room temperature
- ✓ Need little space for applications
- ✓ High production capacity with automation

Product Performance

- ✓ Ease of stacking of products
- ✓ Excellent strength, chemical resistance
- ✓ High scratch resistance



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Usage Areas of UV Curable Systems

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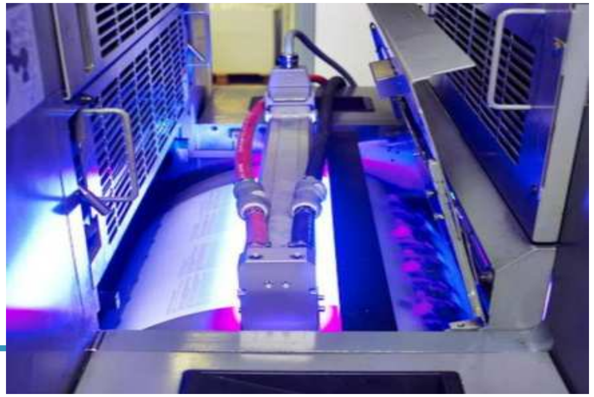

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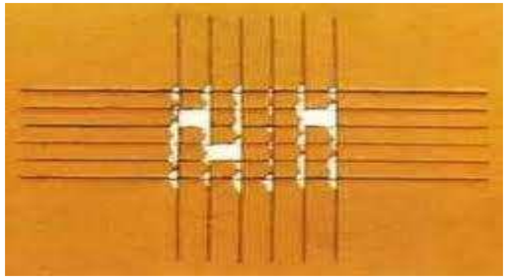
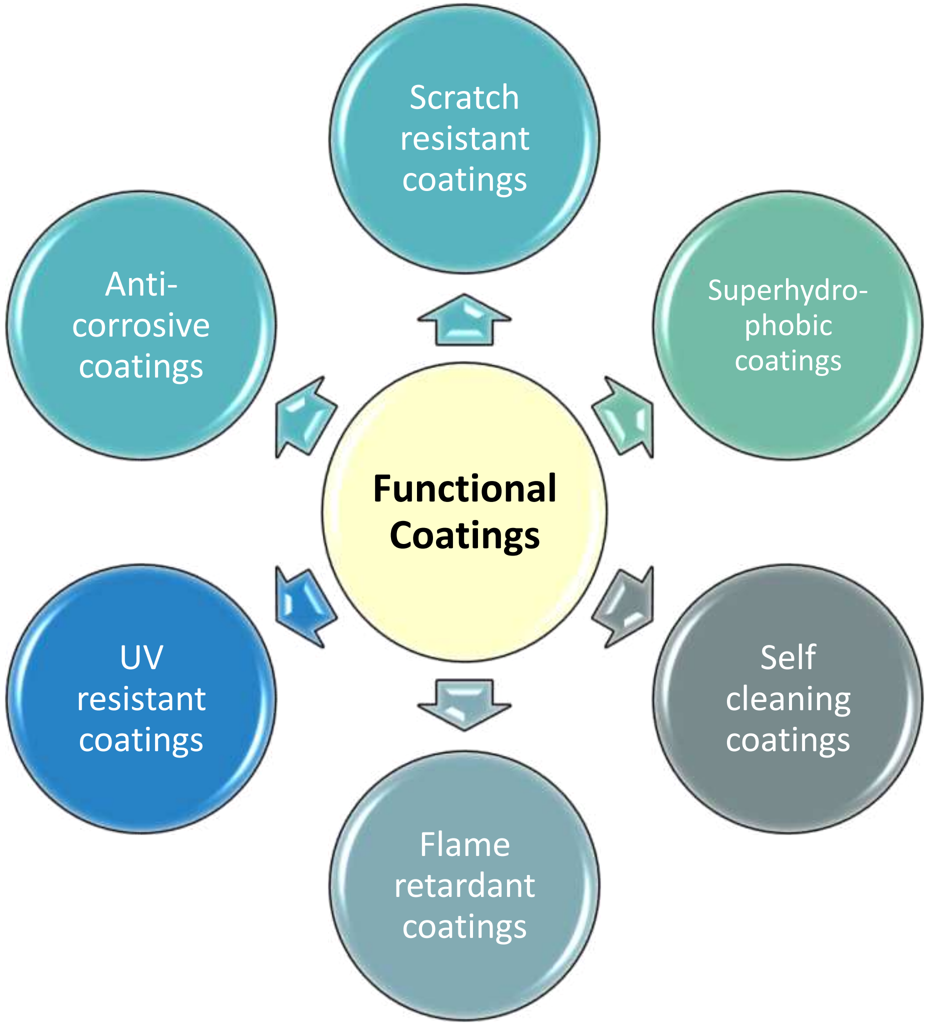
3

FUNCTIONAL COATINGS & NANOPARTICLES

Kayalar
AR-GE MERKEZİ





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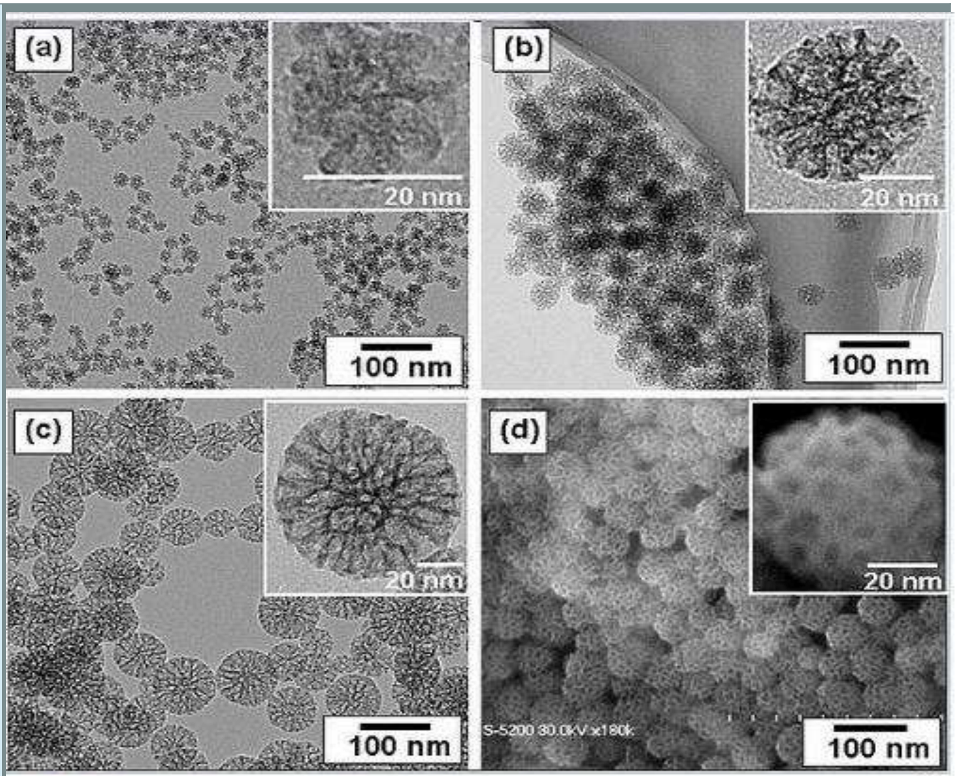
Nanoparticles

- "**N**anoparticles" refers to solid particles with a size between 1 and 100 nm, often as a solid powder or dispersed in a liquid solvent.
- Must be separated by a specific distance, thus avoiding their agglomeration
- A coating is described as "nanocoating" if it contains a nanocomponent.



TEM (a, b, and c) images of prepared mesoporous silica nanoparticles with mean outer diameter: (a) 20nm, (b) 45nm, and (c) 80nm. SEM (d) image corresponding to (b). The insets are a high magnification of mesoporous silica particle.

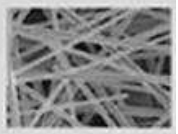
https://en.wikipedia.org/wiki/Nanoparticle

Classification of Nanomaterials

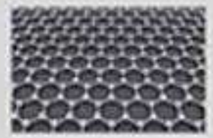
Kayalar AR-GE MERKEZİ

According to chemical nature

Organic	Inorganic	Nanocomposites
• Dendrimers • Liposome • Polymeric nanoparticles • Capsules	• Nanowires • Nanoparticles (metal or metal oxide) • Nano-sheets • Nano-crystals • Quantum dots • Nanoshell • Carbon based structures (Fullerene, carbon nanotubes)	• Inorganic • Organic


Nanowire


Nanoparticle

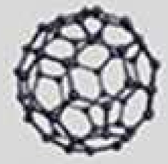

Nanosheets

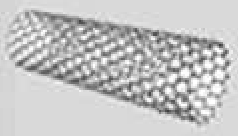

Nanoshell


Dendrimer

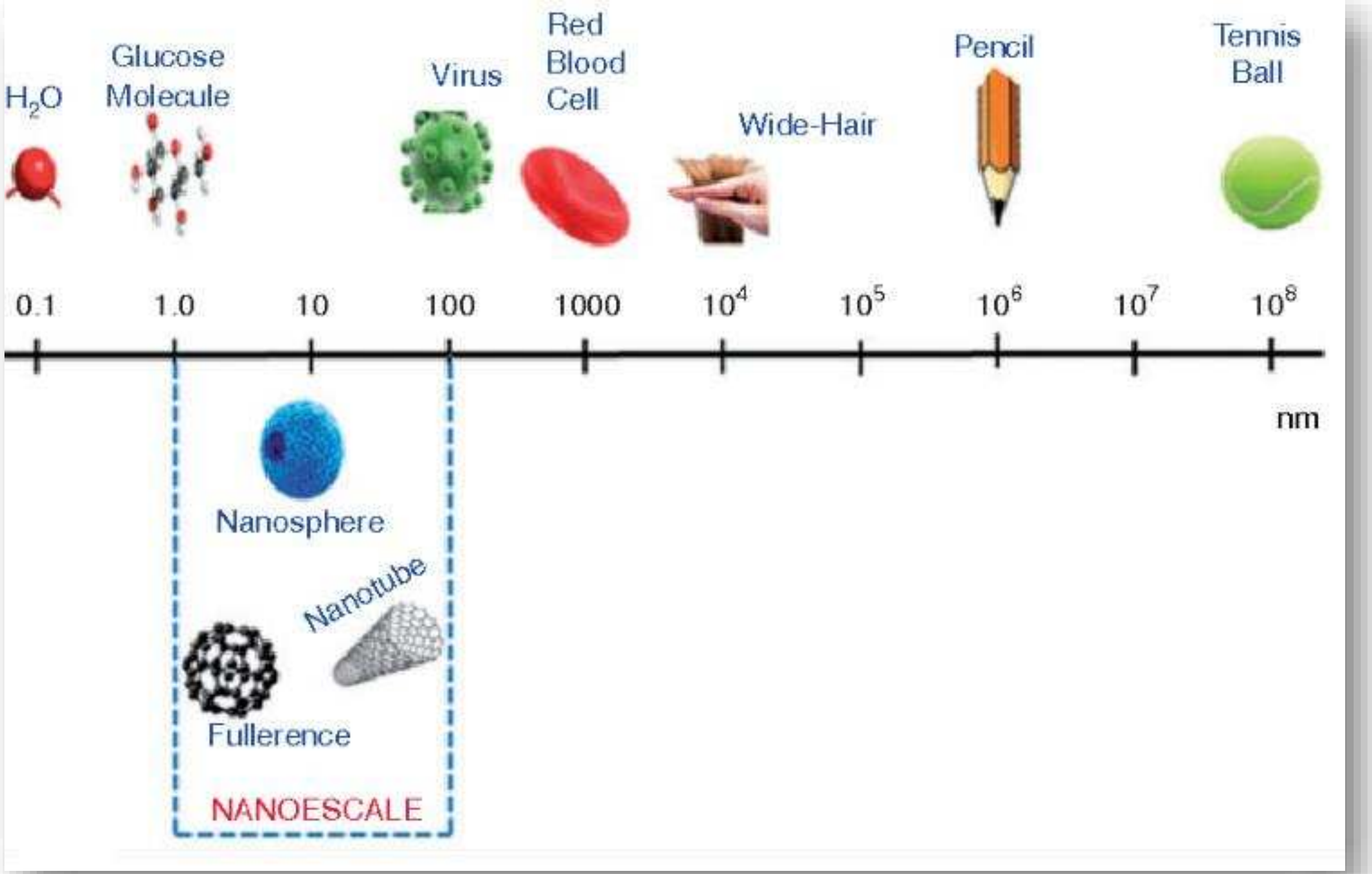
According to shape

Nanoparticles
- Zero dimensional
- One dimensional
- Two dimensional
- Three dimensional

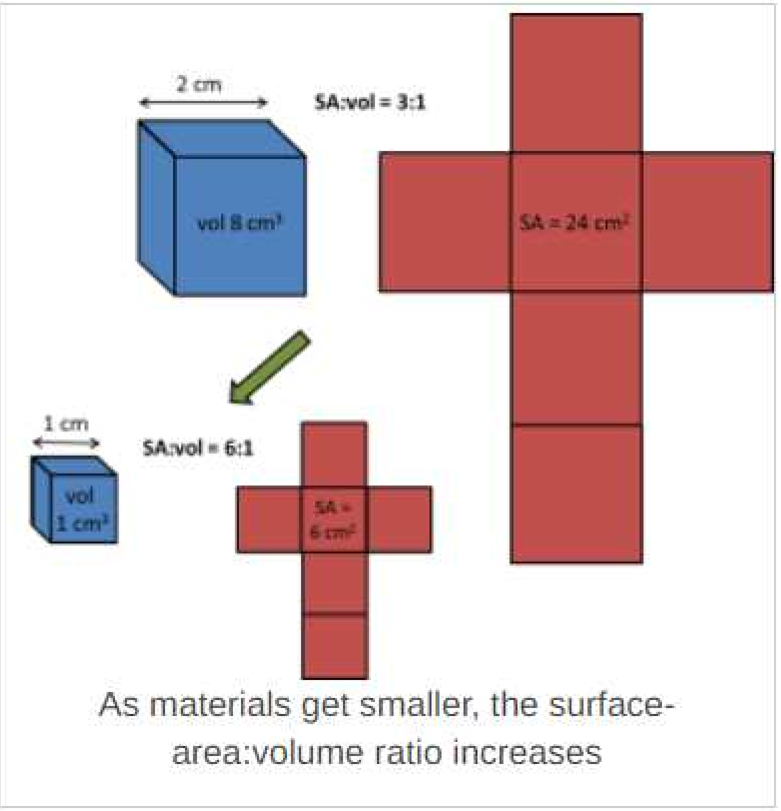

Fullerene


Carbon Nanotube

Nanoparticles



- ✓ **High surface area/volume ratio that** leads to thinner films, using less paint for a specific surface area

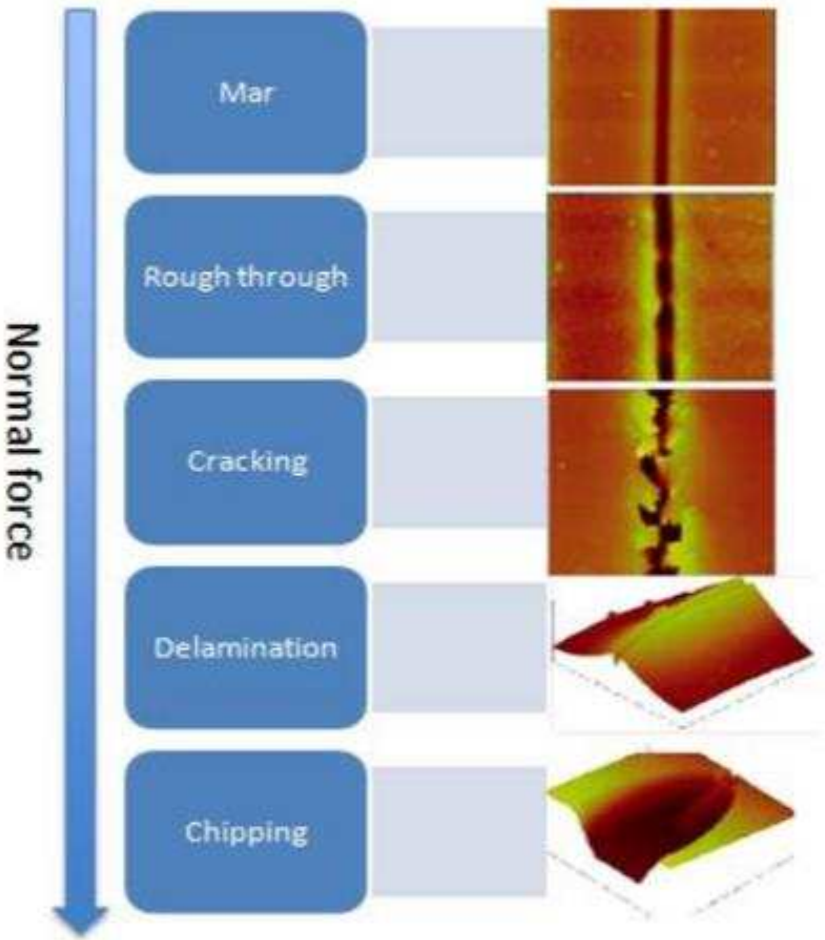


https://chembam.com/definitions/nanotechnology/

4

EXPERIMENTAL PART

Scratch Resistant Wood Coatings



Higher cost
Difficult dispersion
Stability problem

Scratch Resistant Coatings

Nanoparticles for mechanical properties and scratch resistance

Improve the scratch resistance performance instead of adding nanoparticles to the formulations, we use an alternative approach to achieve the desired improvements

Preparing Steps of UV Curable Formulations

Kayalar AR-GE MERKEZİ

Determination of inorganic additives (IA-1, IA-2)

Determination of concentration of inorganic additives

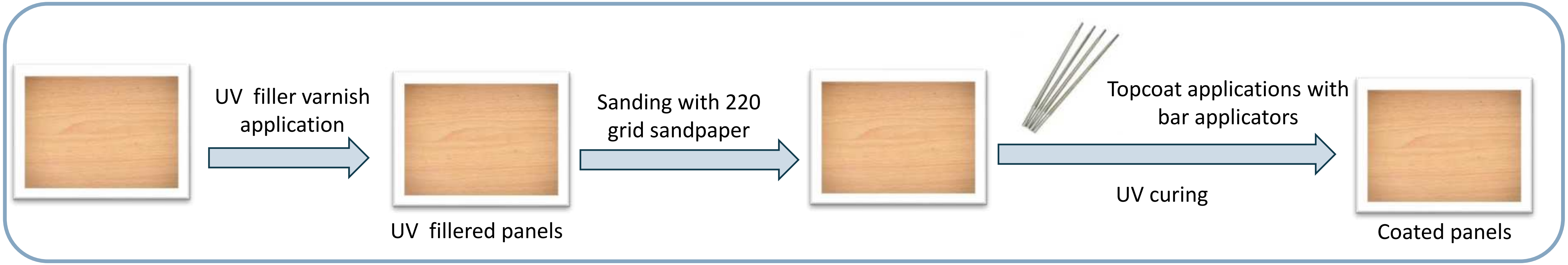
Preparation of UV Acrylic Matt Varnish Topcoat (Roller) formulations

Tests & Analysis

Application Procedure of UV Formulations

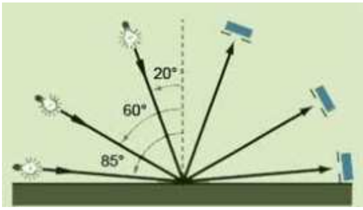
UV Curing Experimental Parameters for Topcoat Applications

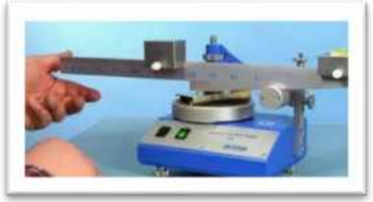
UV lamps (100 W)	Hg	Hg + Ga	-
Band speed of UV device	4 m/min	10 m/min	-
Wet film thickness (with bar applicator)	12 µm	24 µm	40 µm



Targeted Values (wet formulations & coated panels)

	Targeted values for wet formulation
Solid Content (%) TS 6035 EN ISO 3251	80-95
Density (g/cm³) ASTM D 1475-98)	1,07-1,13
Viscosity (DIN6, 20°C, sec) TS EN ISO 2431, DIN 53211)	40-45
Grinding (TS 2620 EN ISO 1524, ASTM D-1210)	6-8
Stock Stability (TS 4324)	Stable, no sagging
	Targeted values for coated panels
Adhesion (cross-cut, DIN EN ISO 2409) (0 is the best, 5 is the worst)	0
Scratch Resistance (Erichsen Scratch Tester 413, N)	min 5
Gloss (Glossmeter, ASTM D 523, 60⁰)	16-24





5

RESULTS AND DISCUSSIONS

First Trials & Applications

UV Matt Topcoat Varnish (Roller coater)

Formulation	Inorganic Additive	UV Curing (Passes) (Hg lamp, 10 m/min)	Surface
Formulation-1	IA-1	1	Good
Formulation-2	IA-2	1	Bad
(with 40 µm bar applicator)			

Some additional trials with IA-2

First Trials & Applications

Kayalar AR-GE MERKEZİ

Additive Trials

Formulation	Inorganic Additive	UV Curing (Passes) (Hg lamp, 10 m/min)	Surface
Formulation-3	IA-2 + Additive-1	1	Bad
Formulation-4	IA-2 + Additive-1 Additive-2	1	Good

(with 40 µm bar applicator)

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First Trials & Applications

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Concentration Trials of IA-2

Formulation	Inorganic Additive	Concentration of Inorganic Additive	UV Curing (Passes) (Hg lamp, 10 m/min)	Surface
Formulation-5	IA-2 + Additive-1 Additive-2	Higher	1	Good
Formulation-6	IA-2 + Additive-1 Additive-2	Lower	1	Better

(with 40 µm bar applicator)

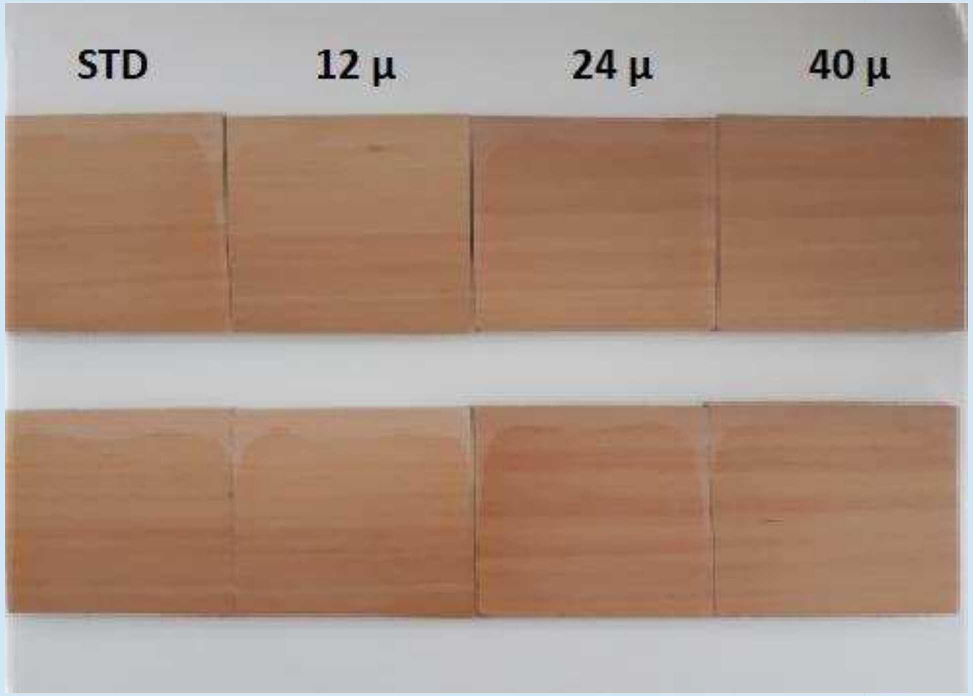
Wet Film Thickness Trials (Formulation-6)

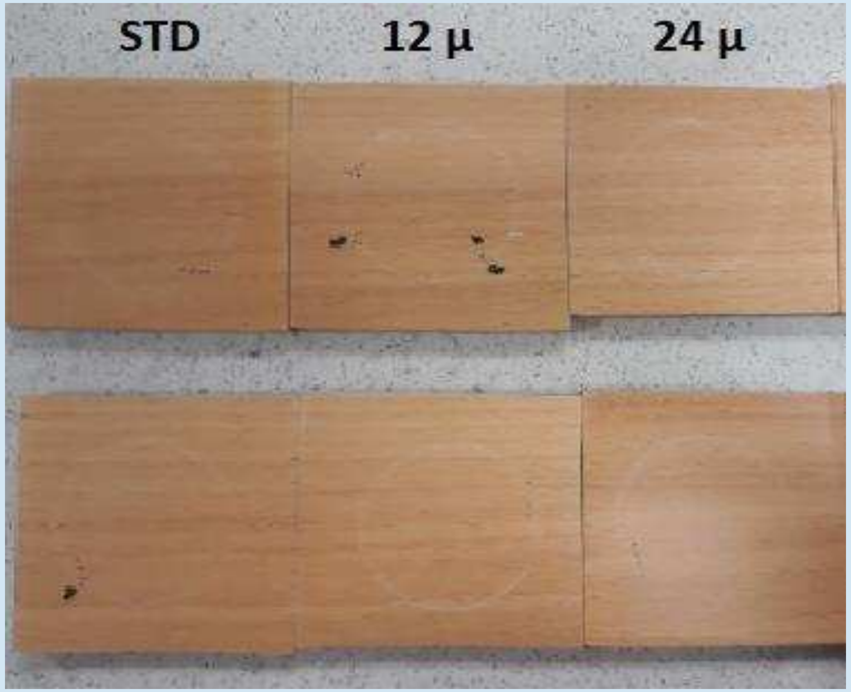
Kayalar AR-GE MERKEZİ

		STD	Formulation-6 (IA-2)
Wet film thickness 12 µm (bar applicator) Hg + Ga		4 m/min 1 Pass	4 m/min 1 Pass
	Scratch resistance (Erichsen, N)	4 N	3 N
		STD	Formulation-6 (IA-2)
		4 m/min 2 Passes	4 m/min 2 Passes
	Scratch resistance (Erichsen, N)	4 N	3 N
		STD	Formulation-6 (IA-2)
Wet film thickness 24 µm (bar applicator) Hg + Ga		4 m/min 1 Pass	4 m/min 1 Pass
	Scratch resistance (Erichsen, N)	4 N	3-4 N
		STD	Formulation-6 (IA-2)
	Scratch resistance (Erichsen, N)	4 m/min 2 Passes	4 m/min 2 Passes
		4 N	3-4 N
		STD	Formulation-6 (IA-2)
Wet film thickness 40 µm (bar applicator) Hg + Ga		4 m/min 1 Pass	4 m/min 1 Pass
	Scratch resistance (Erichsen, N)	4 N	The surface is bad, drying problem
		STD	Formulation-6 (IA-2)
	Scratch resistance (Erichsen, N)	4 m/min 2 Passes	4 m/min 2 Passes
		4 N	The surface is bad, drying problem

Scratch Test Results

Before Scratch Test	After Scratch Test



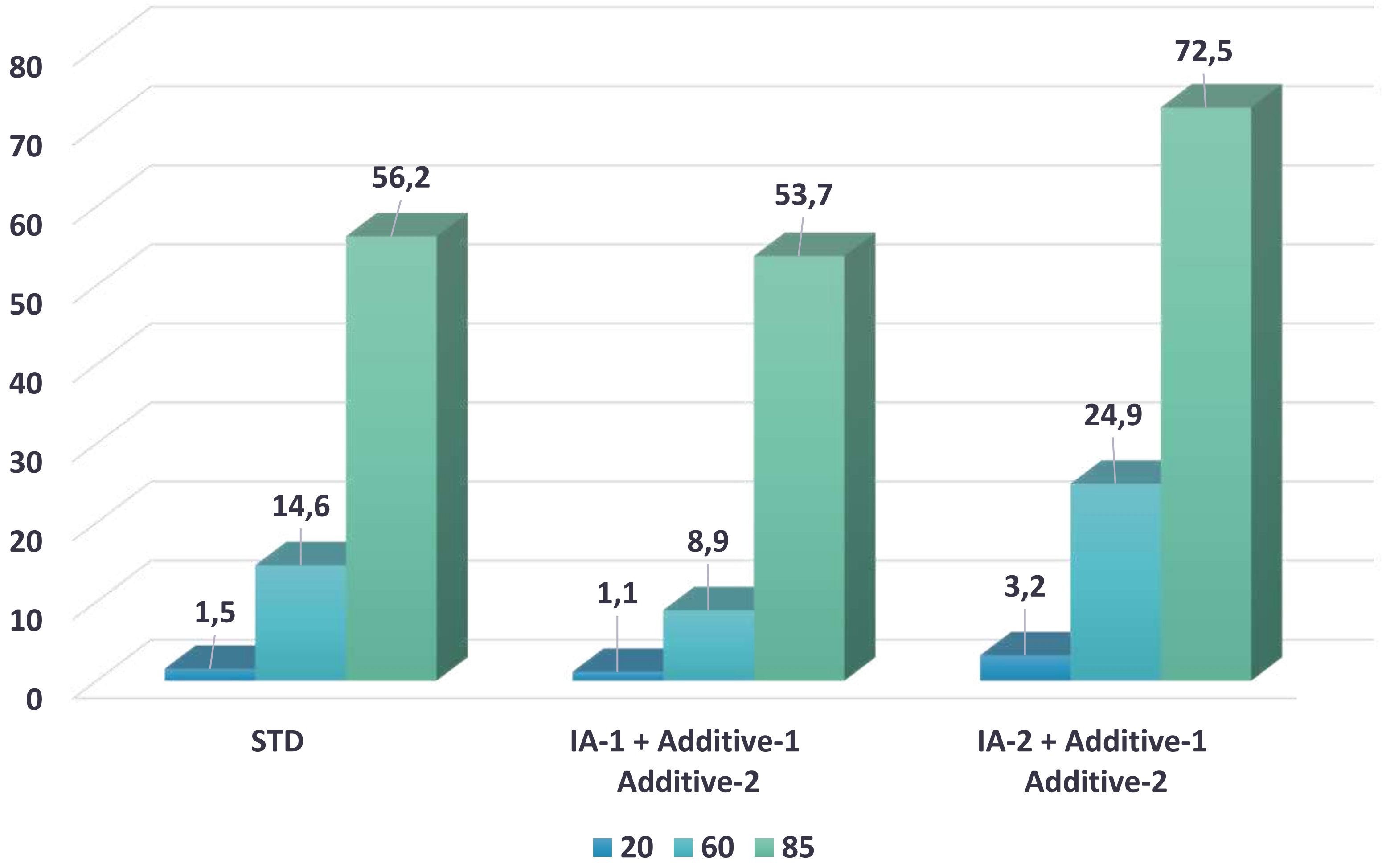


Trials with (IA-1) and (IA-2) at Lower Concentration

Wet film thickness - 24 µm (bar applicator)

Formulations (1 Pass, 4 m/min Hg + Ga)	Concentration of Inorganic Additive	Scratch Resistance (Erichsen, N)	Evaluation of Surface
STD	-	4	Slightly mar marks
IA-1 + Additive-1 Additive-2	Lower	5	Surface touch is very close to STD
IA-2 + Additive-1 Additive-2	Lower	3-4	Slightly mar marks

Gloss Measurements of Trials with (IA-1) and (IA-2) at Lower Concentration



Panels After Scratch Test

STD	IA-1 + Additive-1 Additive-2	IA-2 + Additive-1 Additive-2
		

Tests and Analysis (Laboratory Trials)

UV curable matt varnish formulations (for roller applications) were prepared

IA-1 + Additive-1
Additive-2

Analysis for wet formulation	Targeted Values	Results
Solid Content (%) (TS 6035 EN ISO 3251)	80-95	85-95
Density (g/cm^3) (ASTM D 1475-98)	1,07-1,13	1,09-1,12
Viscosity (DIN6, 20°C, sec) (TS EN ISO 2431, DIN 53211)	40-45	42-45
Grinding (TS 2620 EN ISO 1524, ASTM D-1210)	6-8	6-7
Stock Stability (TS 4324)	Stable, no sagging	Stable, no sagging

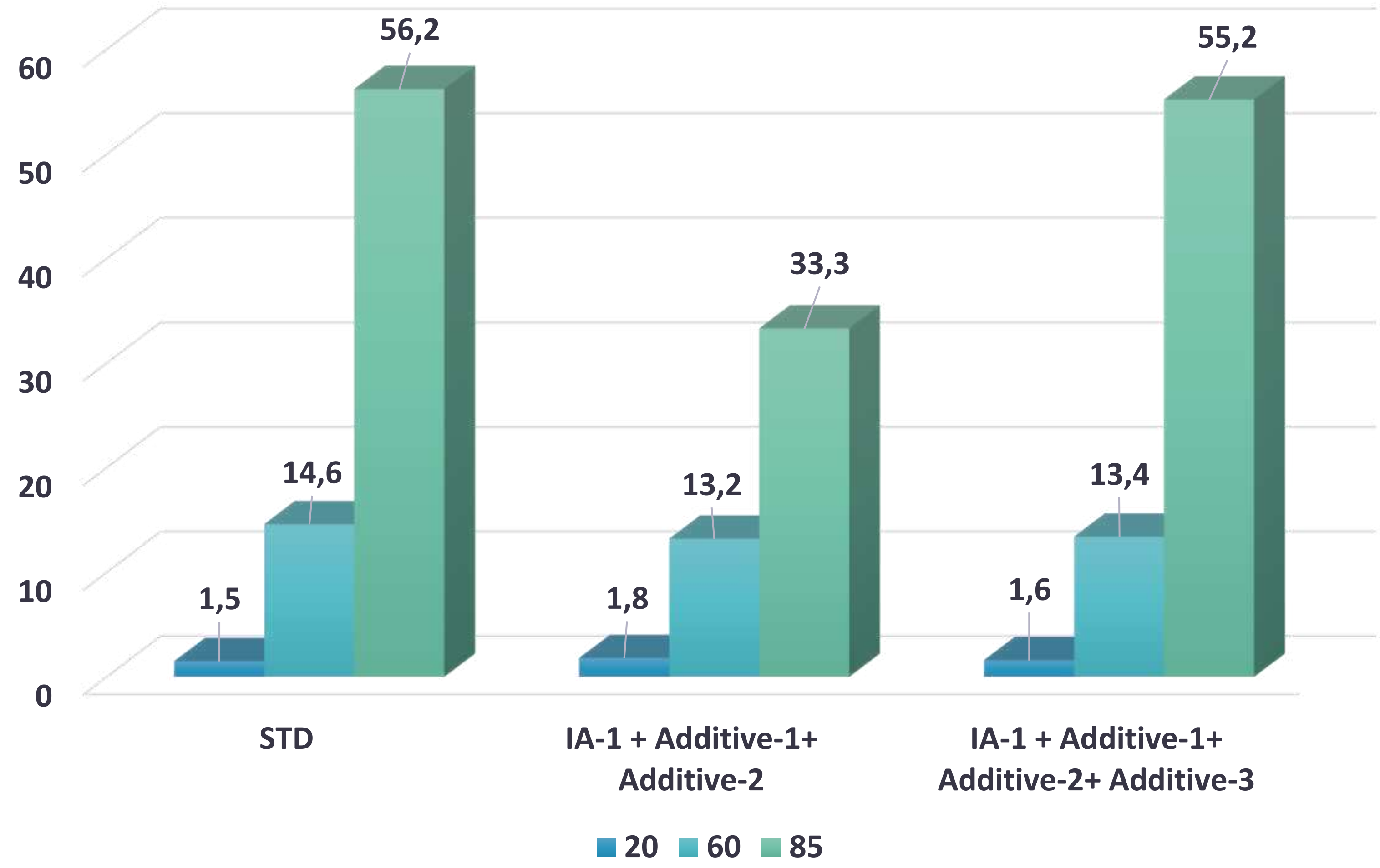
Coated Panel Tests (Laboratory Trials)

Wet film thickness - 24 µm (bar applicator)		
Formulations (1 Pass, 4 m/min Hg + Ga)	**Adhesion**	**Scratch Resistance (Erichsen, N)**
STD	0	4
IA-1 + Additive-1+ Additive-2	0	5
IA-1 + Additive-1+ Additive-2+ Additive-3	1	4

Gloss Measurements of Coated Panels (IA-1)

Kayalar AR-GE MERKEZİ

Wet film thickness - 24 µm (bar applicator)



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Coated Panel Tests (Laboratory Trials)

Wet film thickness - 24 µm (bar applicator)

STD	IA-1 + Additive-1 + Additive-2	IA-1 + Additive-1 + Additive-2+ Additive-3
		

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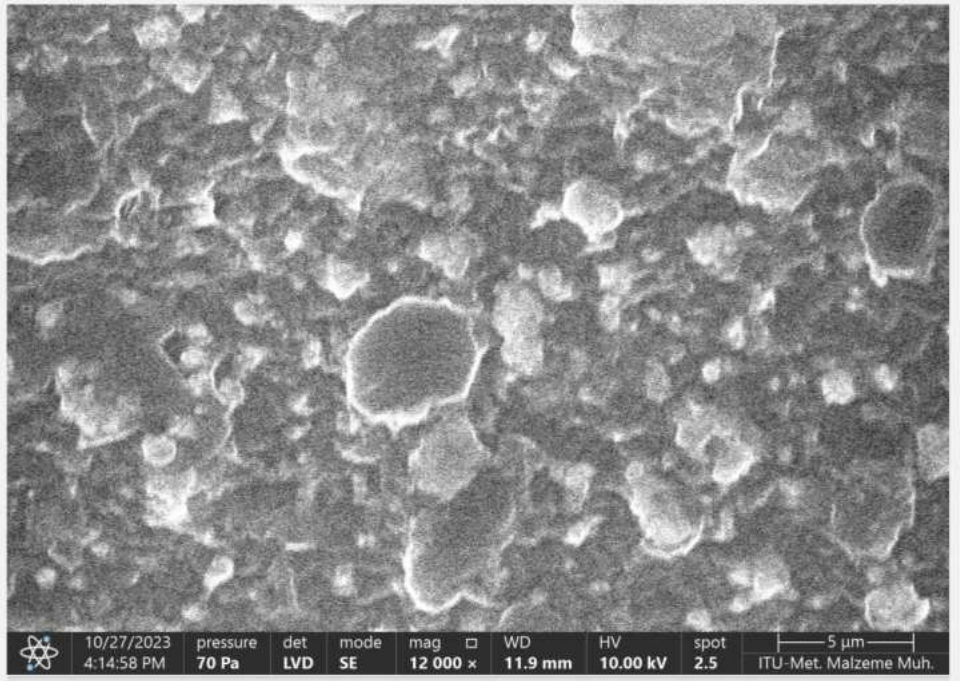
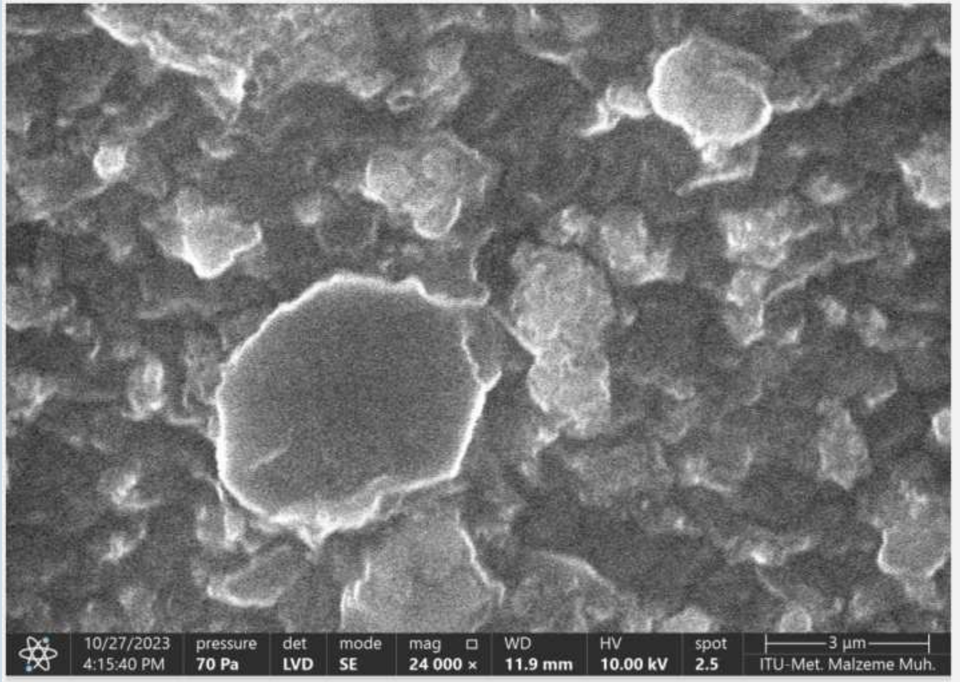
SEM Analysis Results

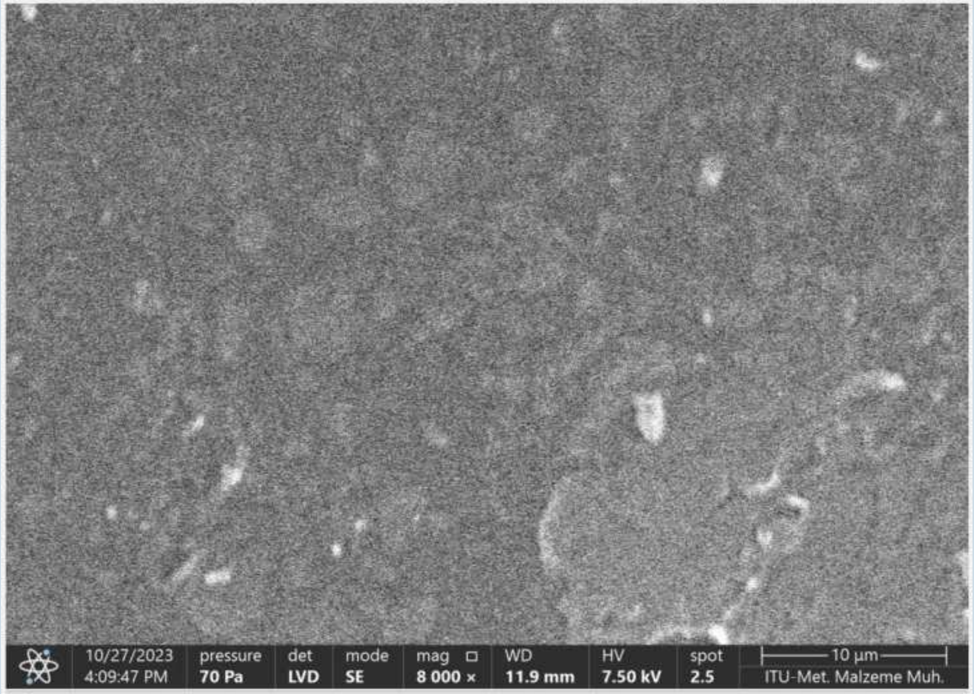
UV Curable Coatings with IA-1

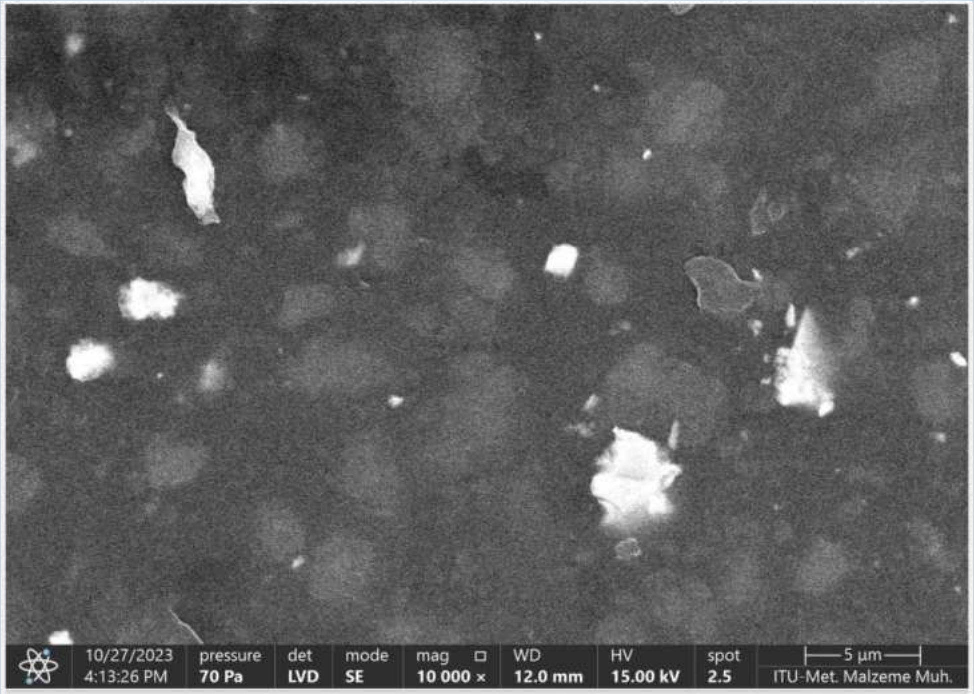




SEM Analysis Results

UV Curable Coatings with IA-2





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6

CONCLUSIONS

Conclusions

- To improve the scratch resistance performance instead of adding nanoparticles to the formulations an alternative approach was tried
- UV Acrylic Matt Varnish Topcoat formulations were prepared with different inorganic additives
- Effects of different factors (band speed, wet film thickness, concentration of inorganic additives) on UV curable product properties were investigated
- All wet formulation and coated panel tests were performed and compared to STD formulation
- Surface analysis of coated panels were investigated with SEM analysis

Conclusions

Kayalar AR-GE MERKEZİ

	STD	IA-1 + Additive-1+ Additive-2	IA-1 + Additive-1+ Additive-2+ Additive-3
Surface properties	Fully cured and smooth	Fully cured and smooth	Fully cured and smooth
Adhesion (cross-cut, DIN EN ISO 2409)	0	0	1
Gloss (Glossmeter, ASTM D 523, 60^0)	14,6	13,2	13,4
Scratch Resistance (Erichsen Scratch Tester 413, N)	4	5	4

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- NARSU Research Group
- Ebru ERGÜVEN – Deniz ER -Kayalar Kimya R&D Center
- Kayalar Kimya R&D and Application & Simulation Team
- All participants of congress and all listeners

THANK YOU FOR YOUR ATTENTION…