

Organic-Inorganic Hybrid Materials as Protective Coatings on Plastic Sheets

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VI. Summary

Properties of Plastic Sheets

- ❖ Plastic sheets (PC, PMMA, PET) have several advantages over inorganic glasses.
 - High impact resistance
 - High optical transparency
 - Light weight
 - Well-established processing and shaping technology
- ❖ Applications
 - Automotive head light housing
 - Plastic lenses for eyeglasses
 - Non automotive vehicle windows



Hard Coatings on Plastic Sheets

- ❖ Major drawback of plastic sheets limiting their uses
 - Poor scratch resistance due to soft surface
 - It causes a faster decrease of the optical quality of the uncoated plastics
 - Hard coating is essential for the protection of soft plastic surface
- ❖ Ordinary hard coating materials for plastic sheets
 - Melamine, acrylic, urethane based materials have been used.
- ❖ **Inorganic-organic hybrid composites** as hard coating materials
 - show excellent advantages of both organic and inorganic precursors.
 - based on the use of metal alkoxide and organosilane via sol-gel method

Inorganic component

Colloidal silica
trimethoxysilane)
TEOS(tetraethylorthosilicate)
trimethoxysilane)
TMOS(tetramethylorthosilicate)
$$\begin{array}{c} \text{OCH}_3 \\ | \\ \text{H}_3\text{CO-Si-OCH}_3 \\ | \\ \text{OCH}_3 \end{array}$$

Organic component

GPTMS (3-glycidoxypropyl
MPTMS(methacryloxypropyl
VTES(vinyltriethoxysilane)
MTES(methyltriethoxysilane)

Plastic Sheets with High Refractive Index

❖ Rainbow effect

- When the refractive index of hard coating films does not match with that of plastic sheets, rainbow phenomena on the coating films happen due to the interference of lights
- Thus the refractive index of coating films should correspond with that of the plastic sheets

❖ Plastic sheets with high refractive index

- polythiourethane ($n_e=1.61$), polycarbonate ($n_e=1.59$), PMMA ($n_e=1.48$)
- Hard coating films based on silica showed low refractive index less than 1.50.
- Therefore, how to prepare hard coating films for plastic sheets with high refractive index has been a matter of both academic and practical interest.

❖ The aim of this research

- Preparation of hard coating films for plastic sheets with high refractive index to overcome the rainbow effect

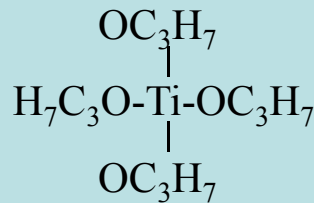
Hard Coating Solutions with High Refractive Index

Preparation of Organic–inorganic Hybrid Composites by the Sol–Gel Method

- ▶ Precursors: Titanium tetraisopropoxide (TTIP), 3-Glycidoxypropyl trimethoxysilane (GPTMS)

Inorganic component
component

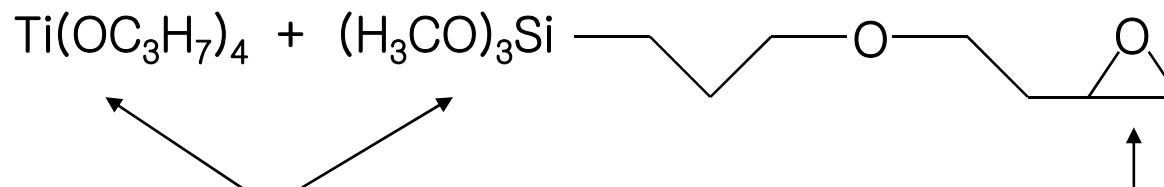
TTIP (titanium tetraisopropoxide)



Organic

GPTMS

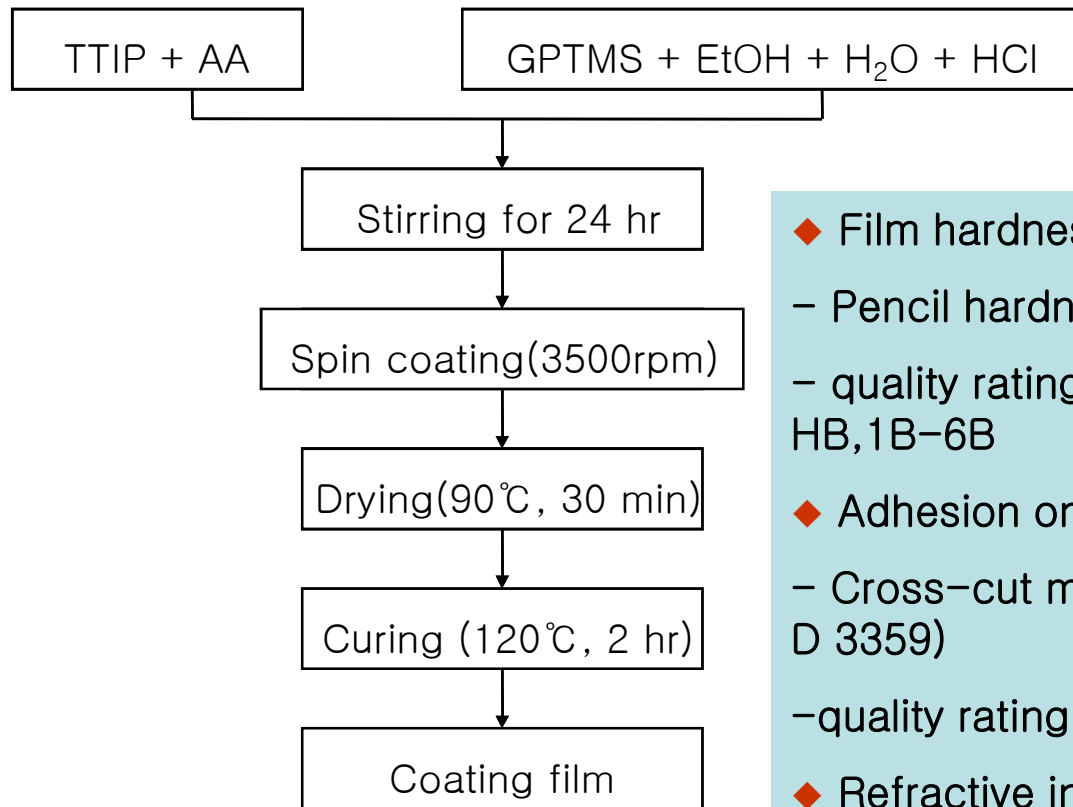
(3-glycidoxypropyltrimethoxysilane)



*Highly crosslinked inorganic network
upon hydrolysis/condensation*

*Organic network upon thermally
Induced polymerization*

Experimental Procedure for Hard Coating Films



- ◆ Film hardness
 - Pencil hardness tester
 - quality rating: 9H-1H, F, HB, 1B-6B
- ◆ Adhesion on PC sheets
 - Cross-cut method (ASTM D 3359)
 - quality rating: 0B-5B
- ◆ Refractive index
 - Ellipsometer (546 nm)

코팅 박리 정도	ASTM 등급
적자상이 깨끗함	6B
5% 미만	4B
5~15%	3B
15~35%	2B
35~65%	1B
65% 초과	0B

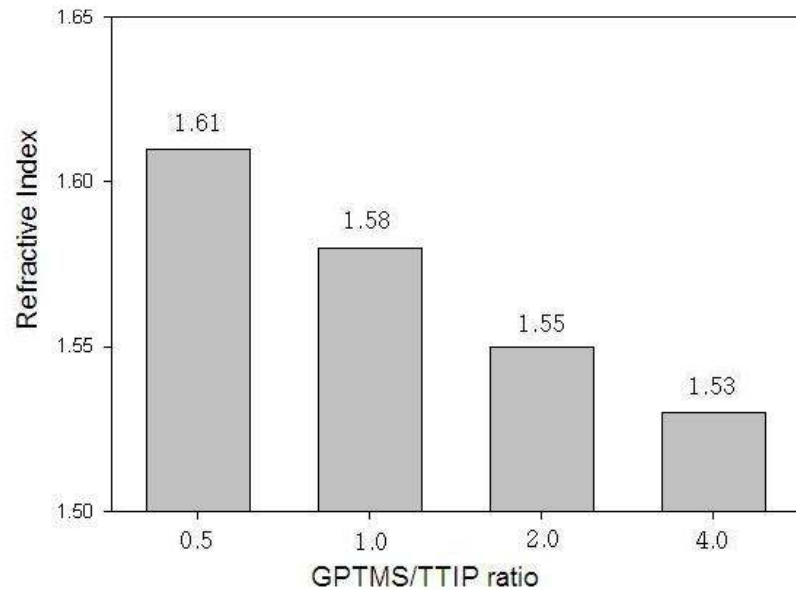
Use of GPTMS only as a Silane Coupling Agent

Effect of GPTMS content

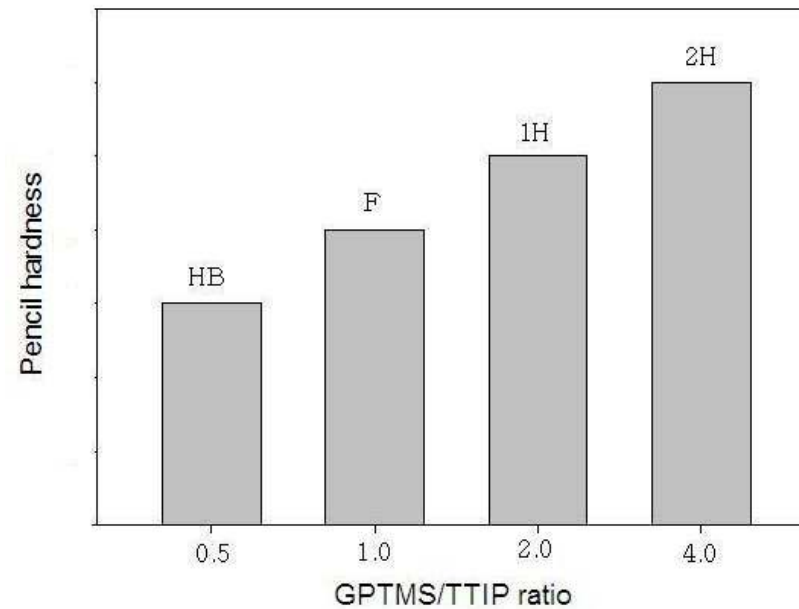
TTIP:GPTMS:AA:H₂O:EtOH:HCl = 1:variables:4:4:4:0.01



Refractive Index of Coating Films



Pencil Hardness of Coating Film

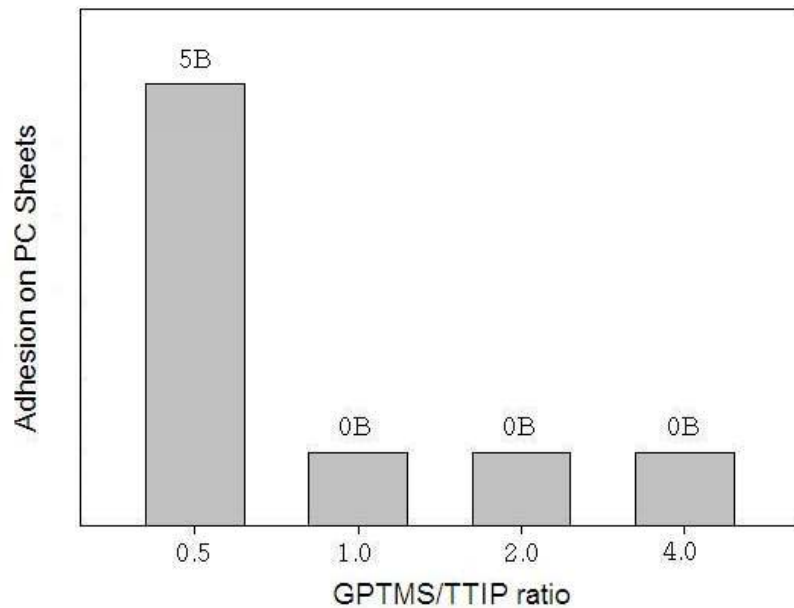


Use of GPTMS only as a Silane Coupling Agent

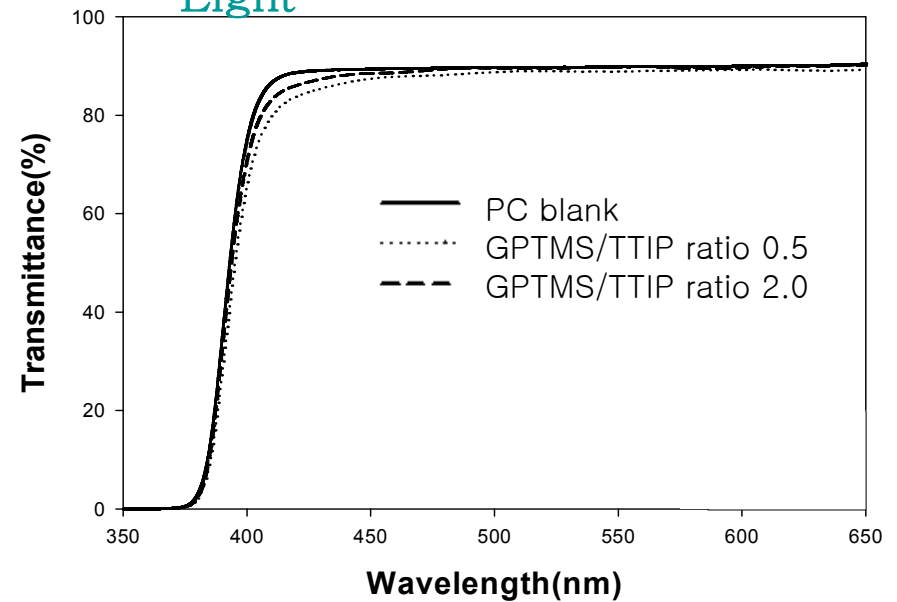
Effect of GPTMS content

TTIP:GPTMS:AA:H₂O:EtOH:HCl = 1:variables:4:4:4:0.01

Adhesion on PC sheets

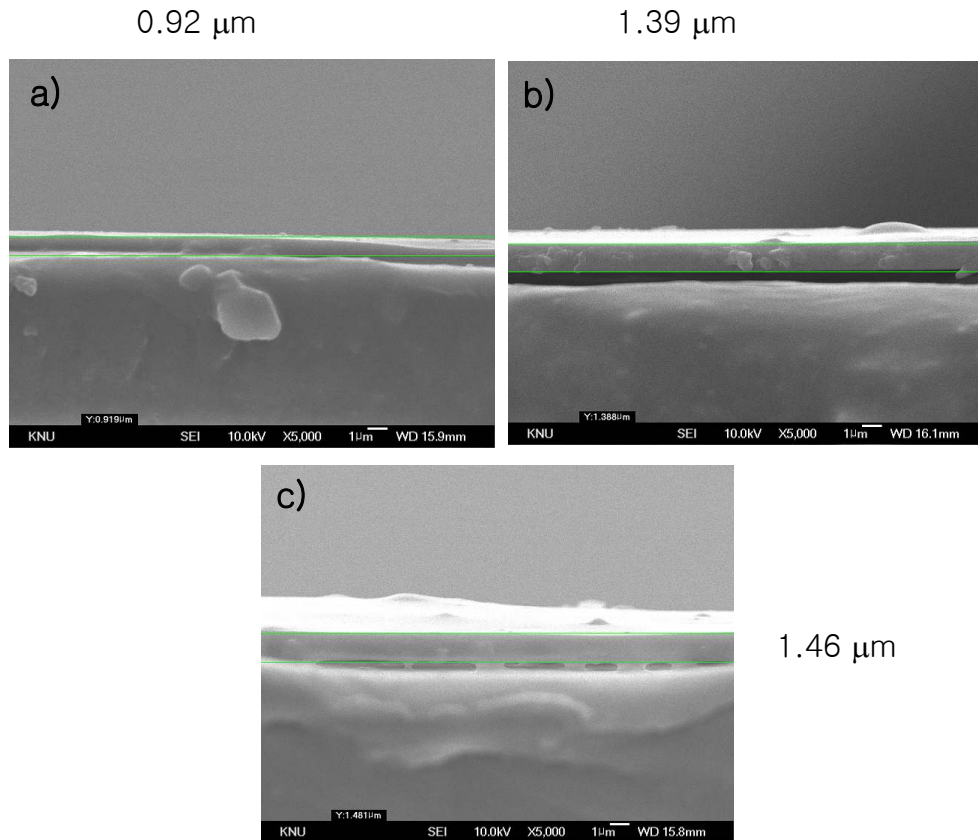


Transmittance of Visible Light



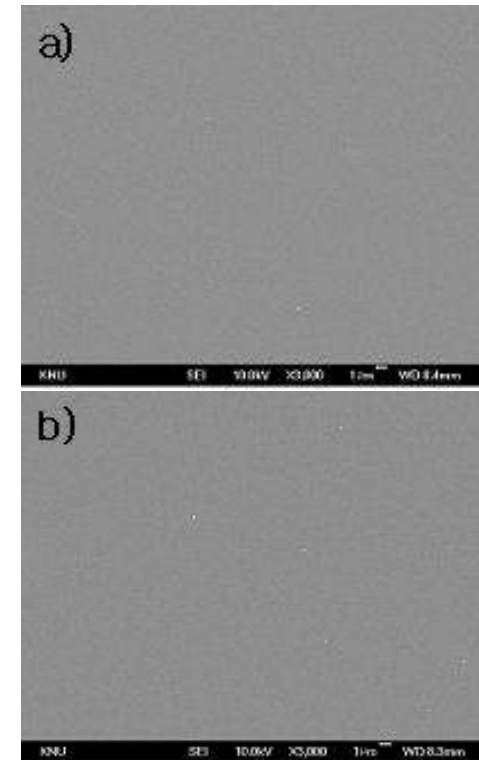
Use of GPTMS only as a Silane Coupling Agent

SEM photomicrographs of coated films on PC sheets



SEM photomicrographs of the cross section of PC sheets with different GPTMS content.

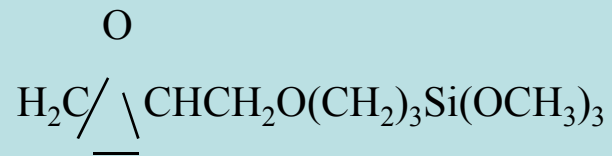
- a) GPTMS/TTIP 0.5, b) GPTMS/TTIP 1.0,
- c) GPTMS/TTIP 2.0



SEM photomicrographs of the coating surface of PC sheets with different GPTMS content. a) GPTMS/TTIP 0.5, b) GPTMS/TTIP 1.0

Use of the mixture of GPTMS and MPTMS

GPTMS (glycidoxypropyltrimethoxysilane)



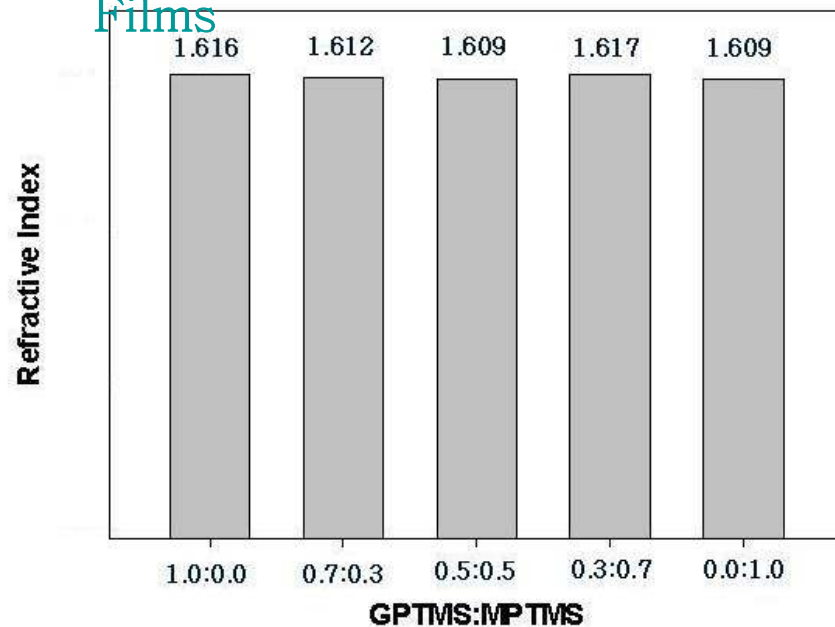
MPTMS

(methacryloxypropyltrimethoxysilane)

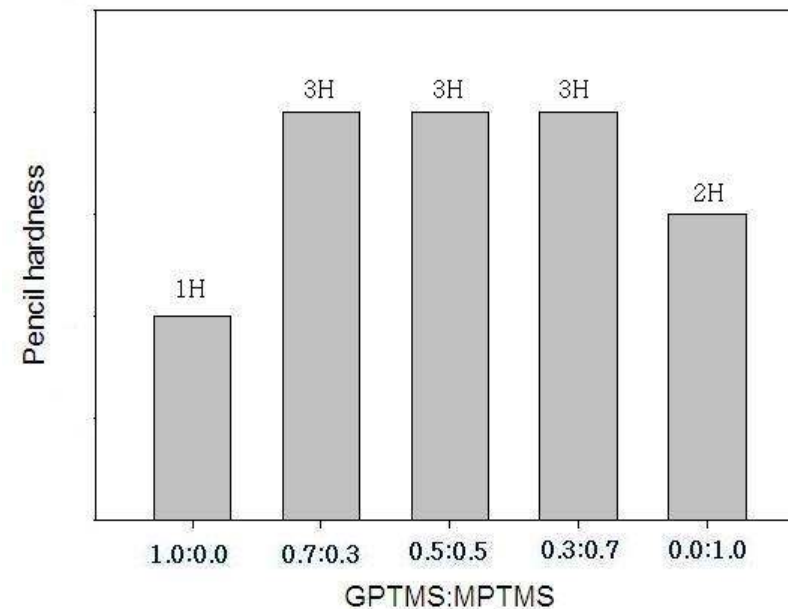


TTIP:GPTMS+MPTMS:AA:H₂O:EtOH:HCl = 1 : 1 : 4 : 4 : 4 : 0.01

Refractive Index of Coating Films



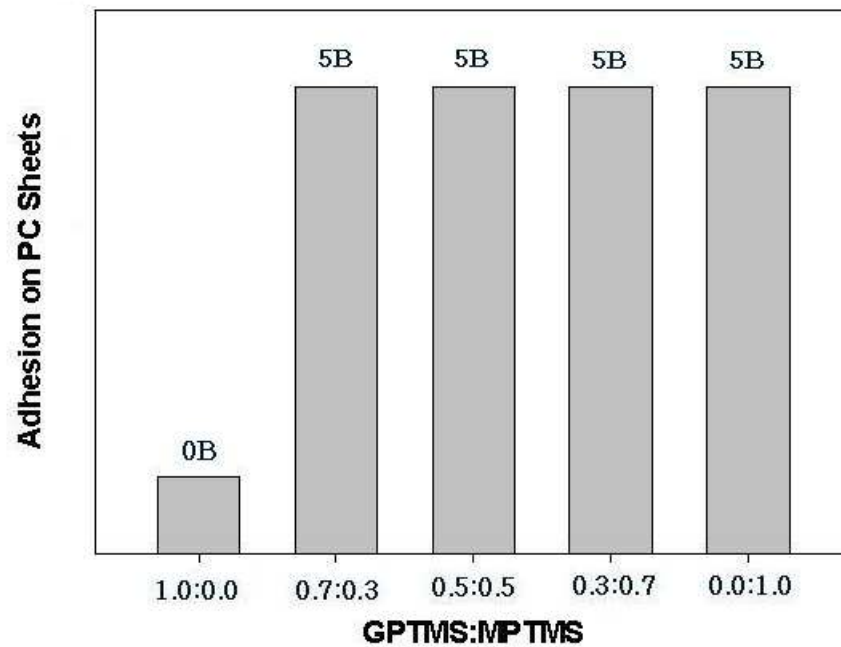
Pencil Hardness of Coating Film



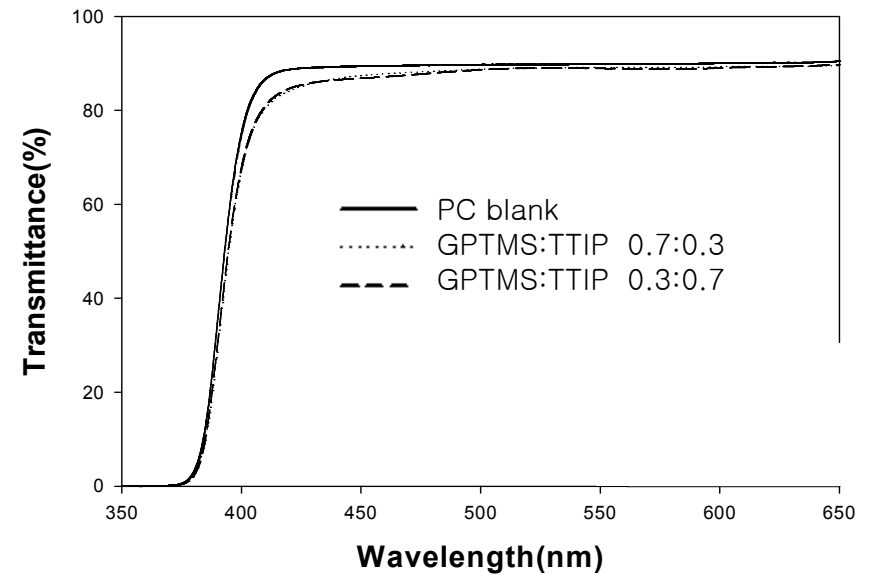
Use of the mixture of GPTMS and MPTMS

TTIP:GPTMS+MPTMS:AA:H₂O:EtOH:HCl = 1 : 1 : 4 : 4 : 4 : 0.01

Adhesion on PC sheets



Transmittance of Visible light



Summary

- ❖ Organic-inorganic hybrid hard coatings for high refractive index plastic sheets were prepared by using TTIP and GPTMS as precursors by the sol-gel method.
- ❖ The refractive index of coated PC sheets increased with decreasing the GPTMS content, while the pencil hardness of the coated film increased with increasing the GPTMS content.
- ❖ When the mixture of GPTMS and MPTMS as silane coupling agents was used, both the pencil hardness and adhesion on PC sheets were more improved than when GPTMS only was used.