Simultaneous measurement of thickness and drying process of paint film by terahertz electromagnetic pulse

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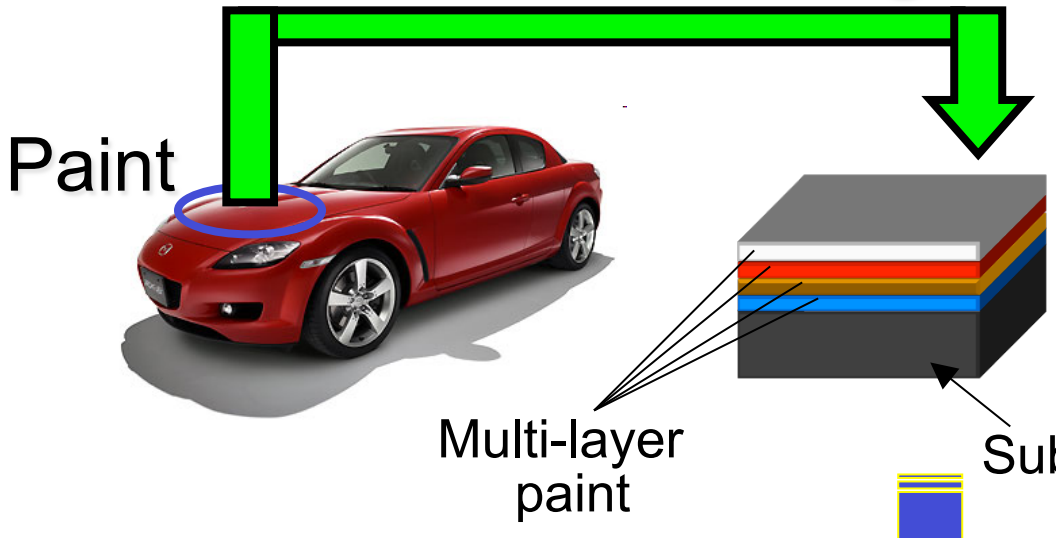
Background



○Visual effect

○**Protection**
〔Rust prevention, Water proof〕

Quality control of painting film

Required!

Painting thickness

Painting quality
(drying process, paint-off)

In-process monitoring

Conventional methods can not meet all the requirements!

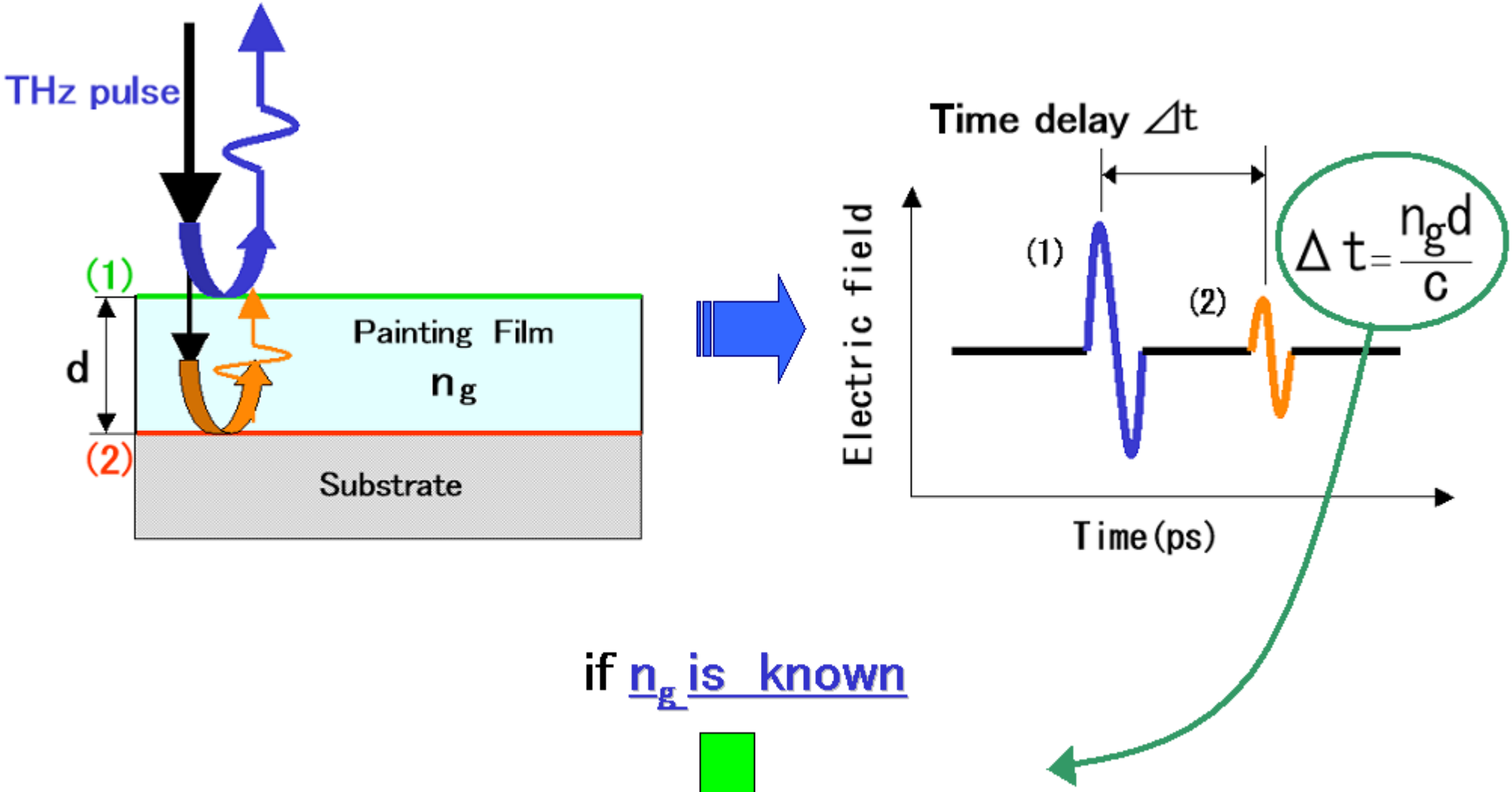
In-process monitoring of paint film using THz electromagnetic pulse

Quality control of painting film

Requirements		Conventional method (contact-type)	THz
Painting thickness	Non-contact, Remote	×	?
	Dried / Wet	△(only dried)	
	Single- / Multi-layer	△(only single)	
	Thickness distribution	×	
	Metal / Non-metal substrate	△(only metal)	
	Precision = ±0.5μm	○	
Painting quality	Paint-off	×	
	Drying process	×	

Present talk

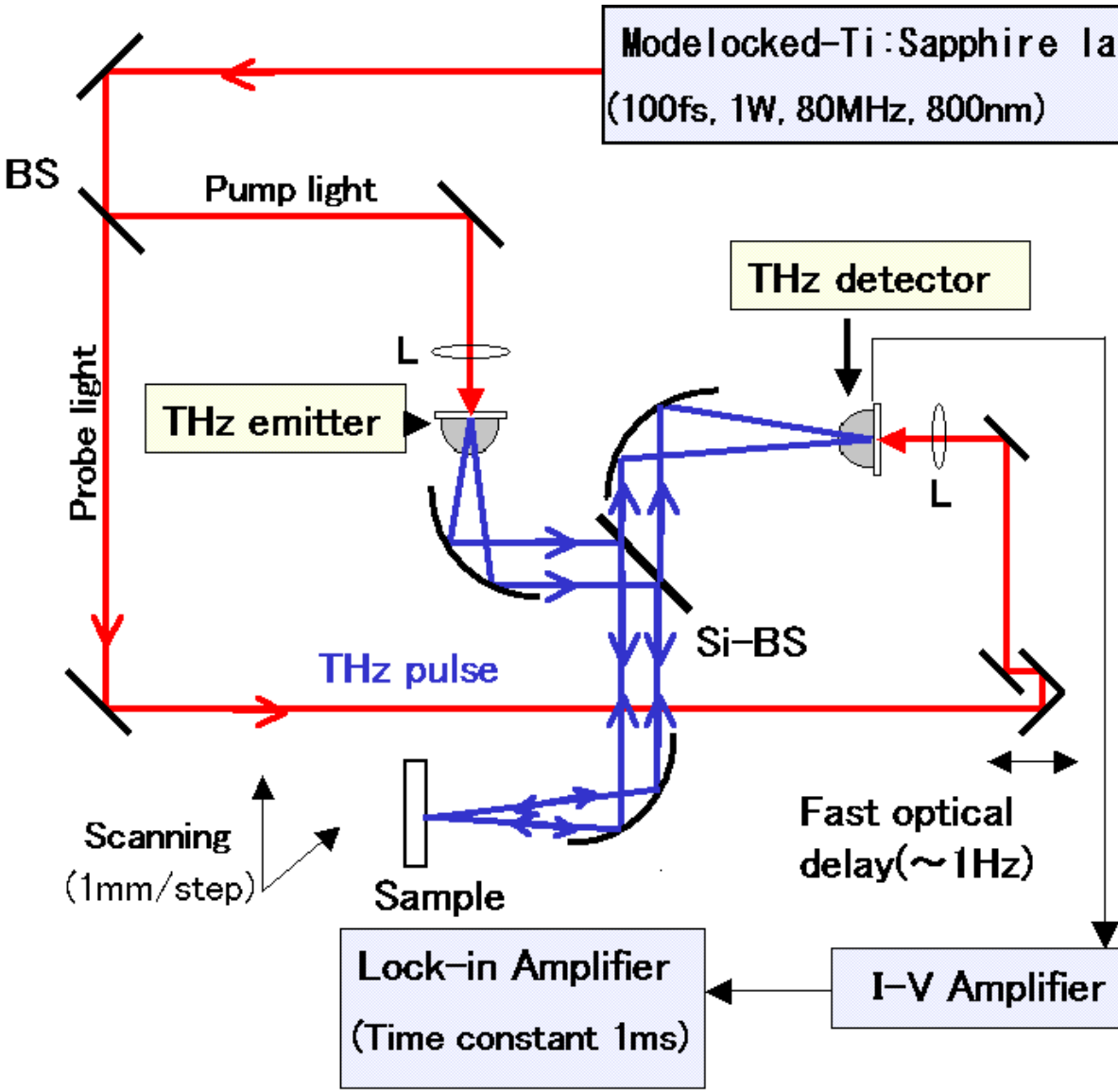
Principle



if n_g is known

d can be determined by ⊿t

Experimental setup



Basic performance

Pulse duration : 0.8ps

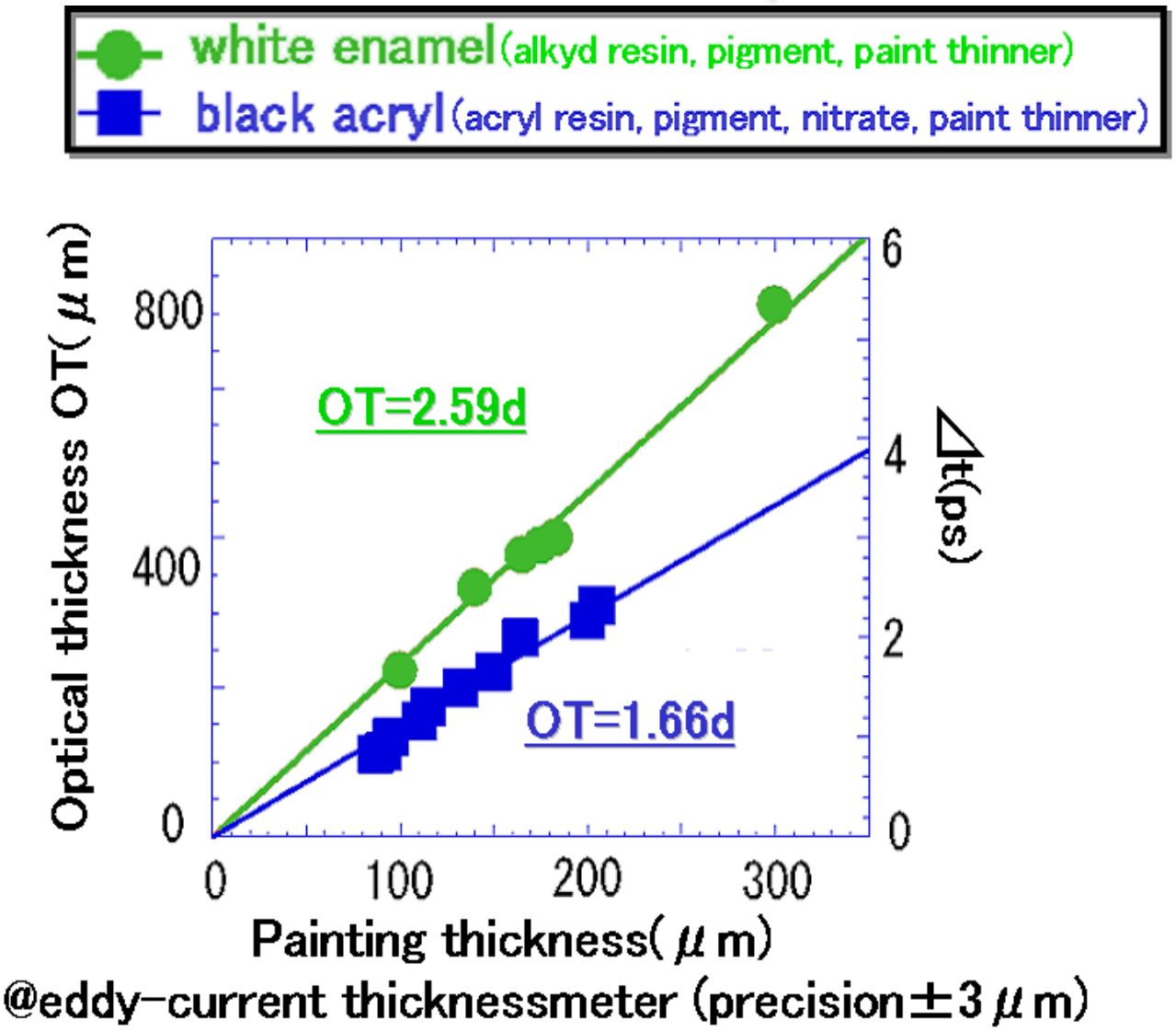
Spatial resolution : 1.7mm

SNR : 100

1 delay scan : 1sec

(1) Painting thickness measurement

Relationship between painting thickness and optical thickness



Group refractive index n_g

White enamel : 2.59

Black acryl : 1.66

Thickness measurement

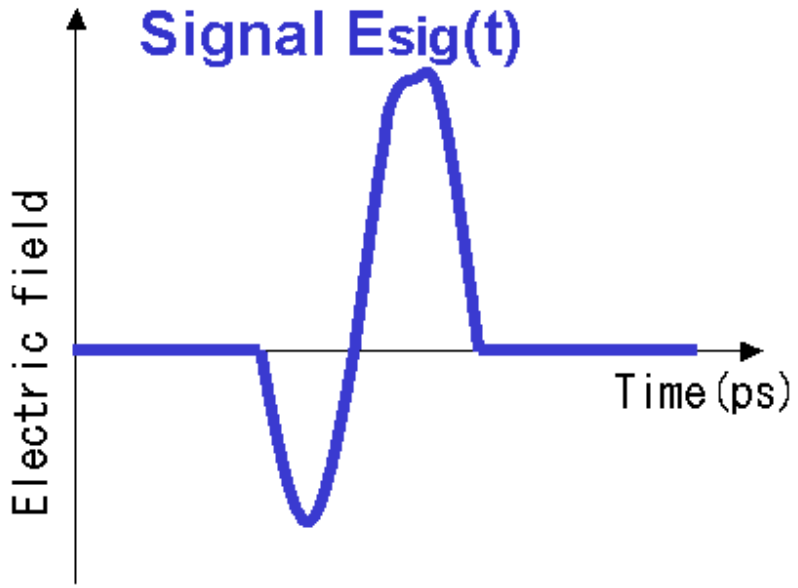
Precision : 5 μm

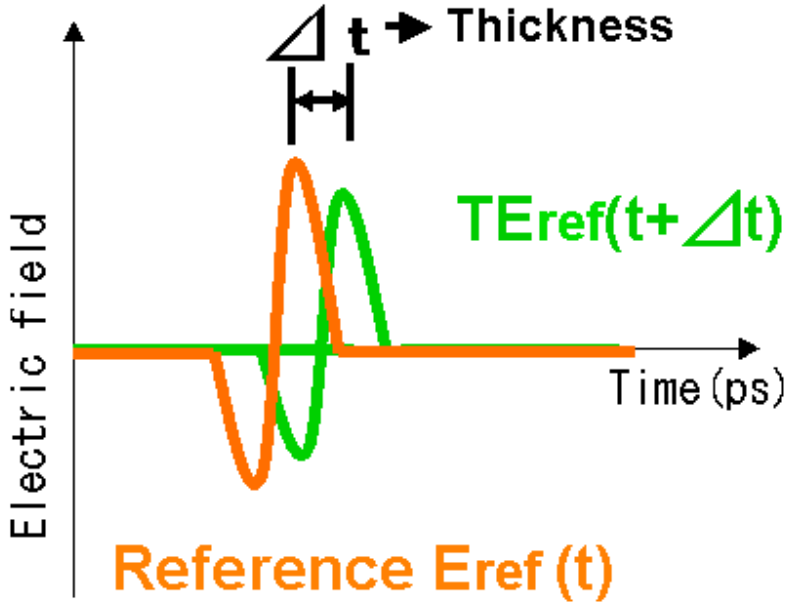
Resolution : 80 μm

Insufficient !

Improvement of thickness resolution

～Separation of convoluted echo pulse based on two-parameter fitting ～





Reference Eref (t)

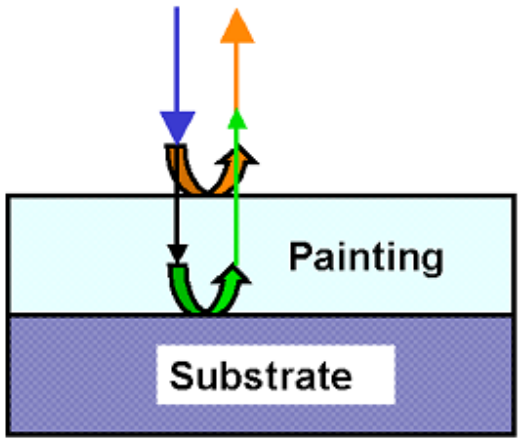
Signal $E_{sig}(t) = E_{ref}(t) + TE_{ref}(t+\Delta t)$

⊿t : time delay

T : transmittance

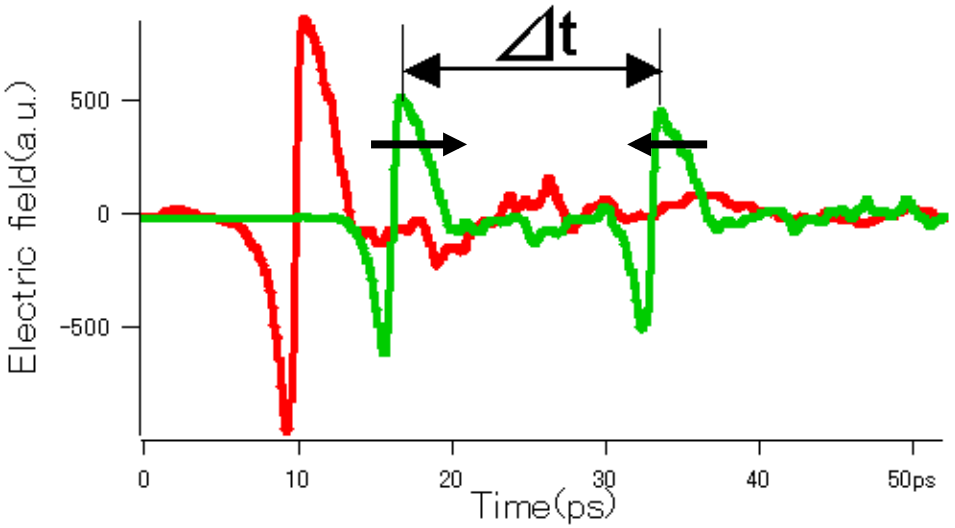
Unknown parameter

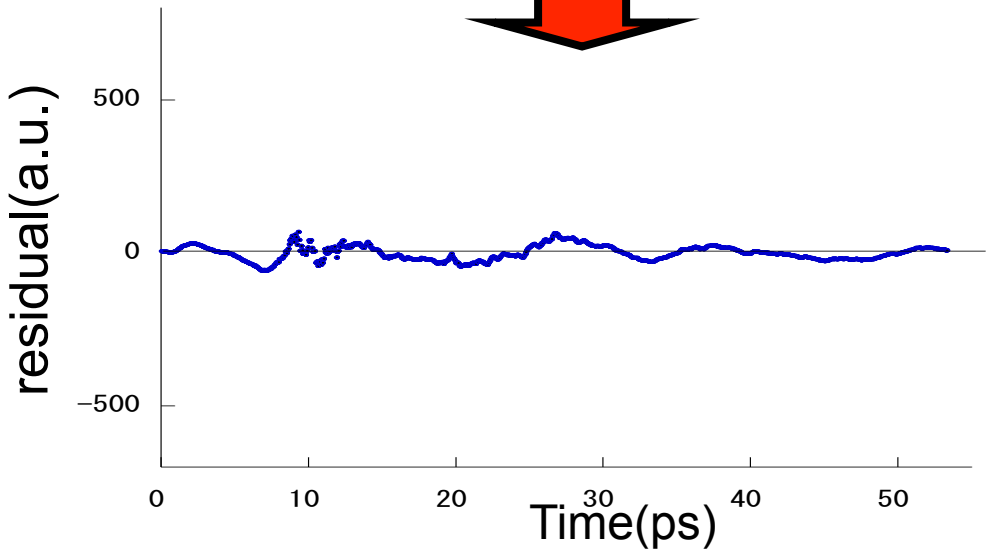
Parameter fitting to $E_{sig}(t)$



Measurement of thin painting film

Sample：black acryl (thickness=17μm)





Green：fitting signal

Red：measurement signal

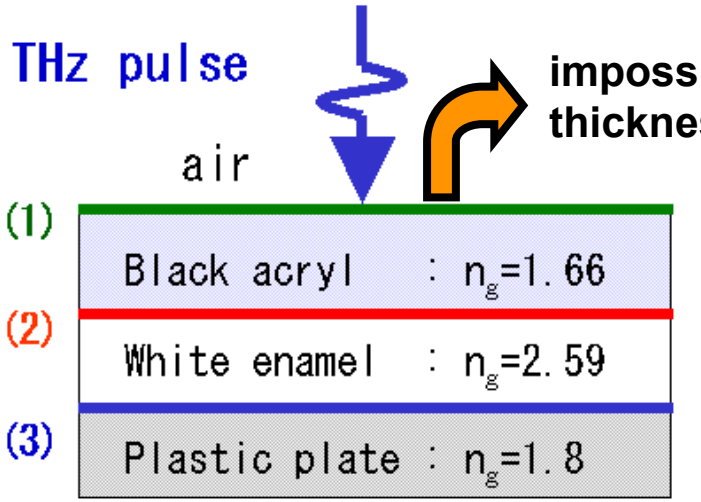
Blue：Residual between measurement signal and fitting signal

Thickness = 18μm

Resolution is improved

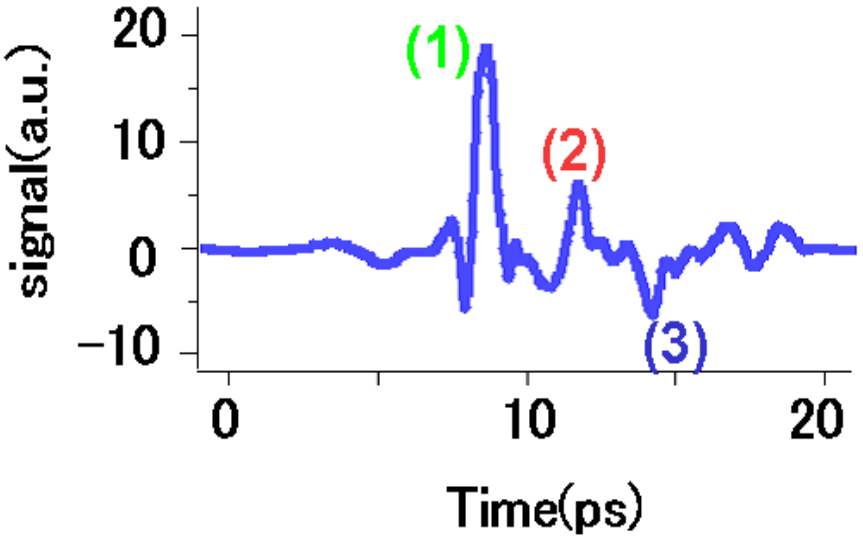
(2) Distribution measurement of painting thickness

Thickness distribution of multi-layer painting

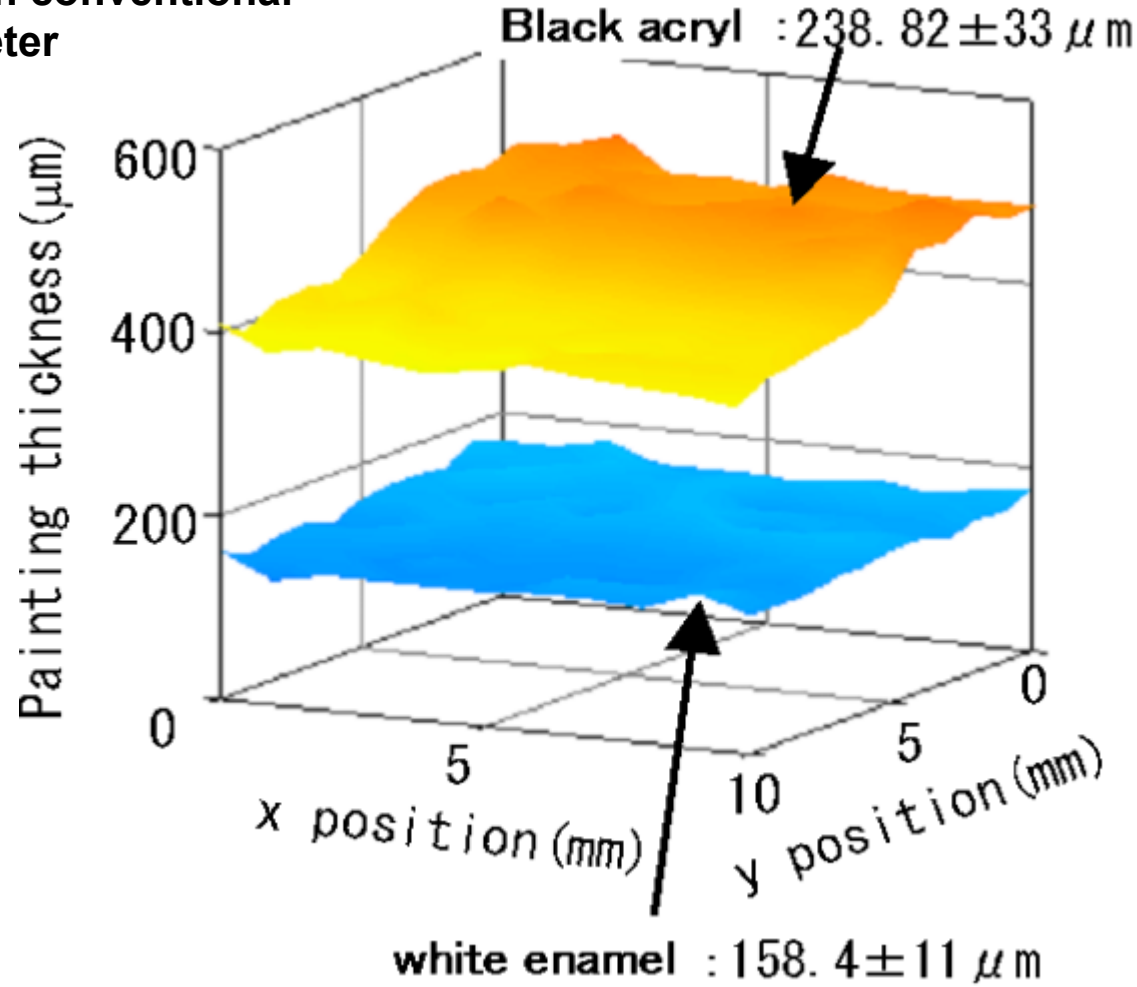


impossible in conventional thicknessmeter

Sample



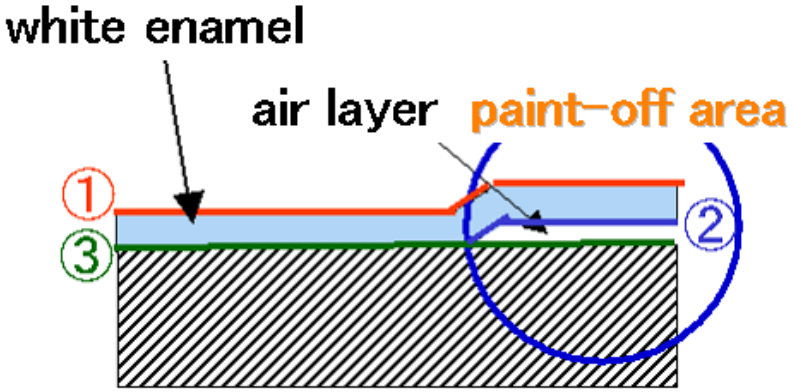
THz pulse echo



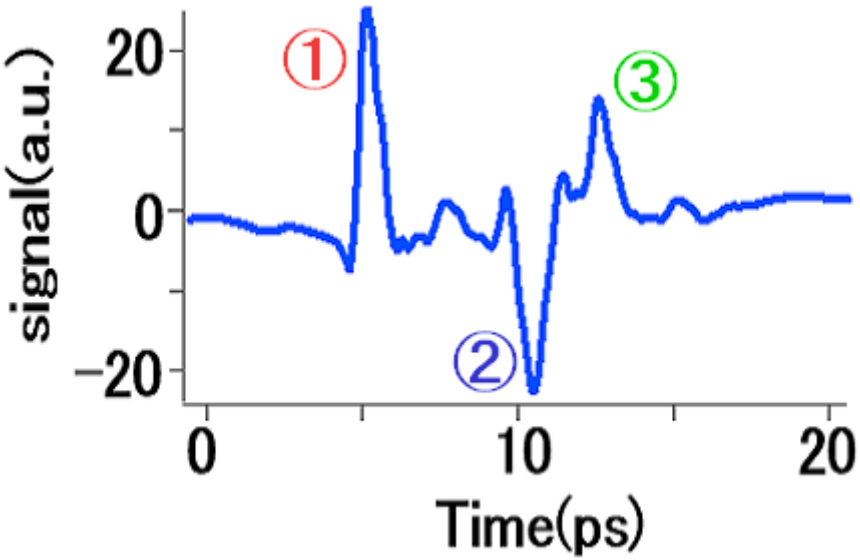
Total measurement time = 5min

THz imaging

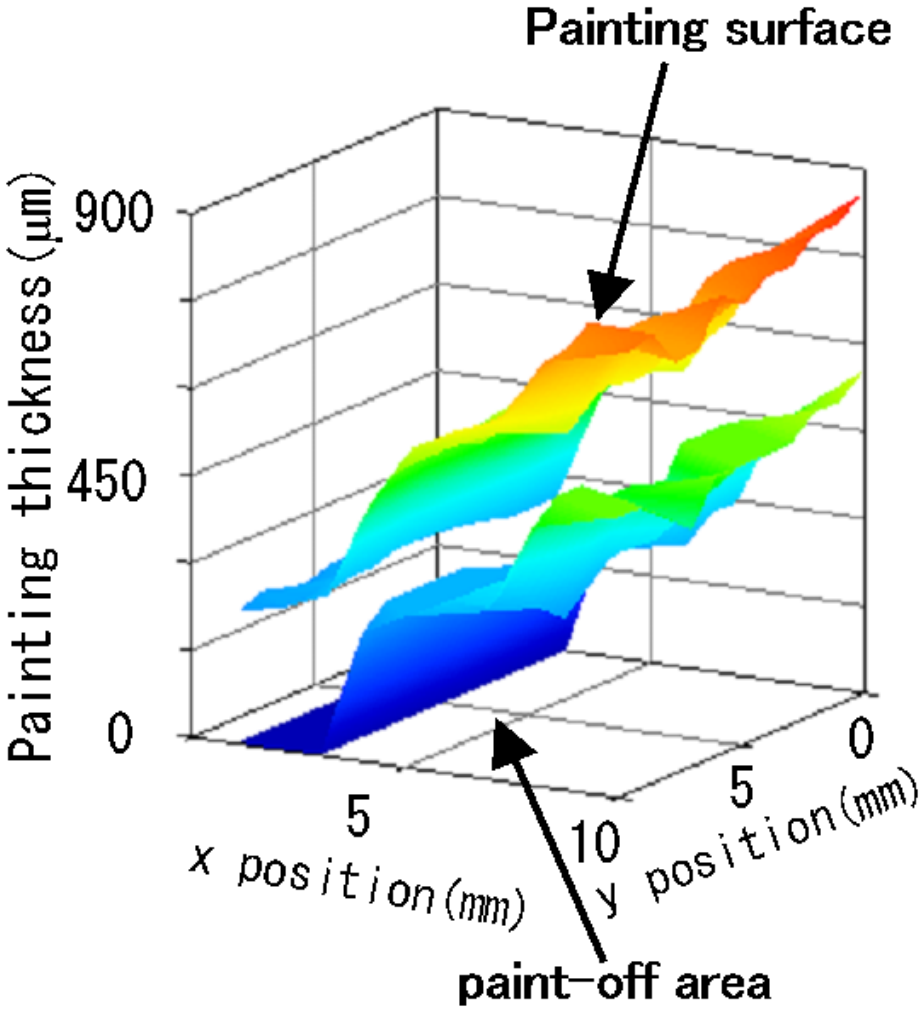
Detection of paint-off area



Sample



THz pulse echo

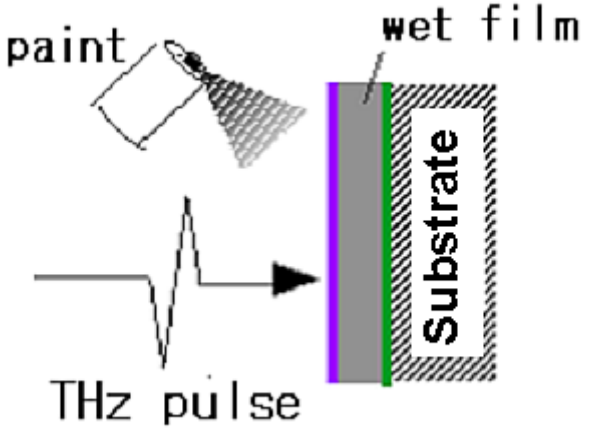


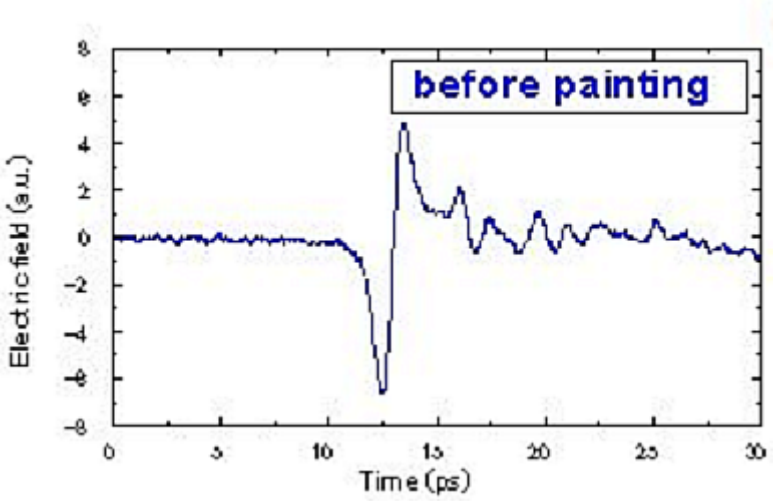
Max paint-off thickness: 555μm

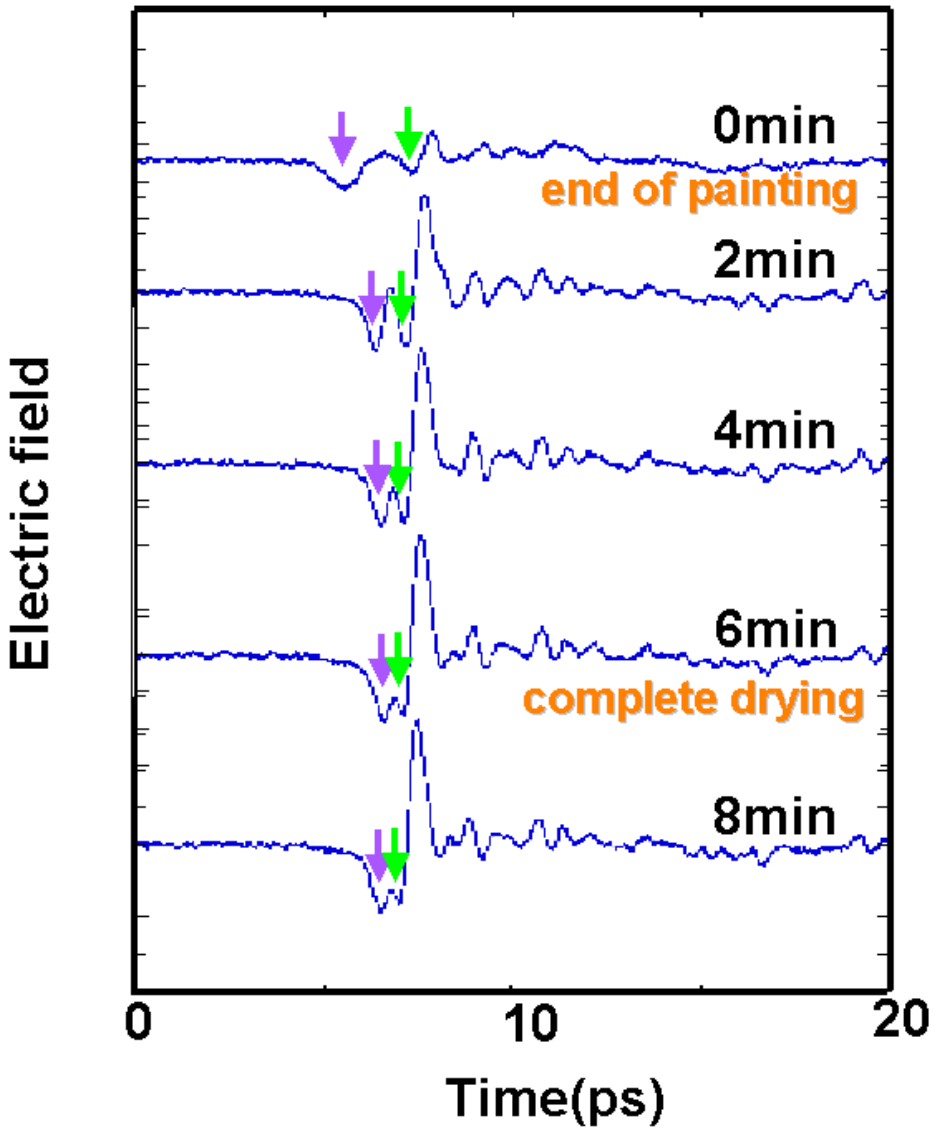
THz imaging

(3) Monitoring of dry process

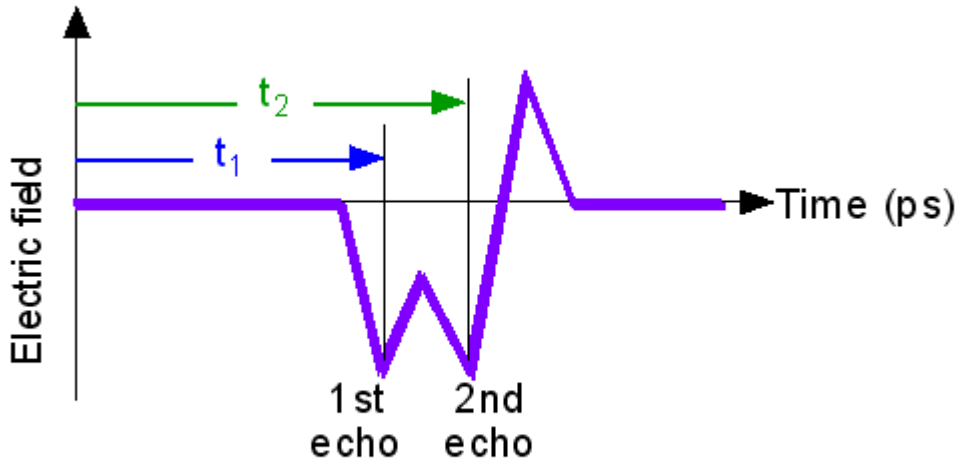
Temporal change of wet paint film

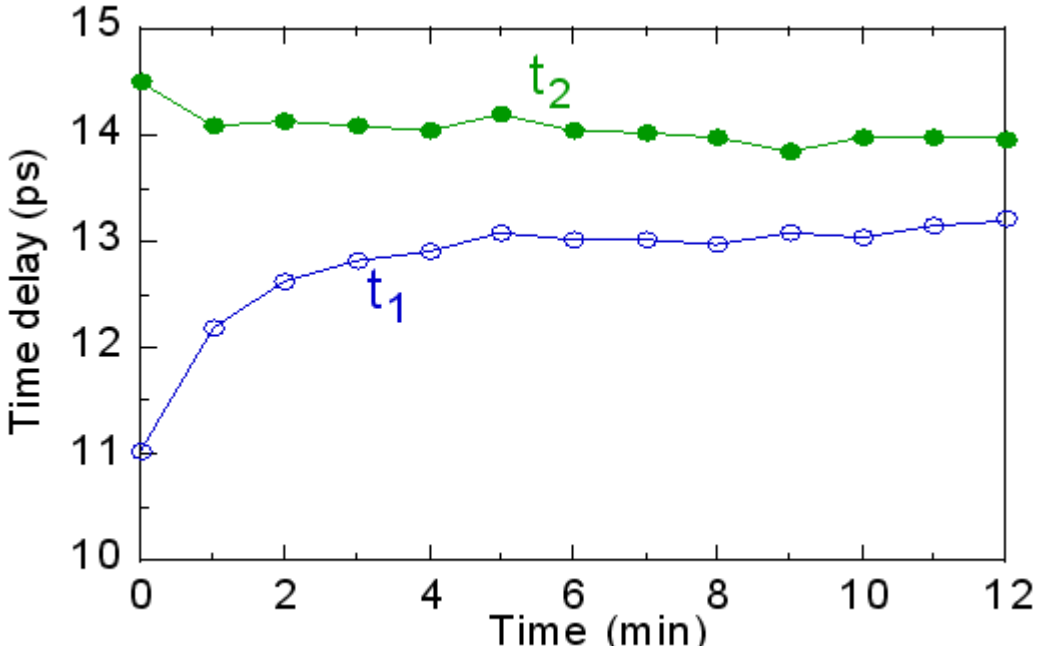


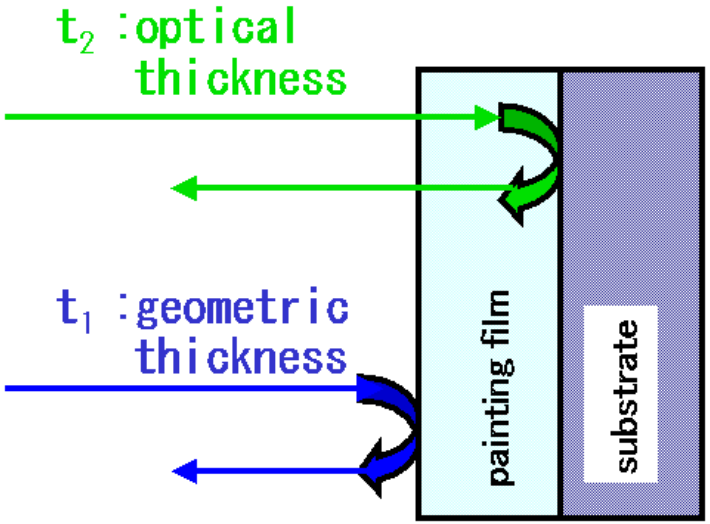




Dry-state monitoring based on delay time of pulse echo







During drying process

d→decrease, n_g →increase

$n_g \times d$ →constant

Drying process ∝ t_1

Relative thickness ∝ t_2

Summary

Requirements		Conventional method (contact-type)	THz
Painting thickness	Non-contact, remote	×	○
	Dried / wet	△(only dried)	○
	Single- / Multi-layer	△(only single)	○
	Painting distribution	×	○
	Metal / non-metal substrate	△(only metal)	○
	Precision = 0.5 μm	○	△
Painting quality	Paint-off	×	○
	Drying process	×	△

Acknowledgements

NEDO and Mazda Motor Corporation, Japan