



**IMT**

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# Laser Cleaning Technology

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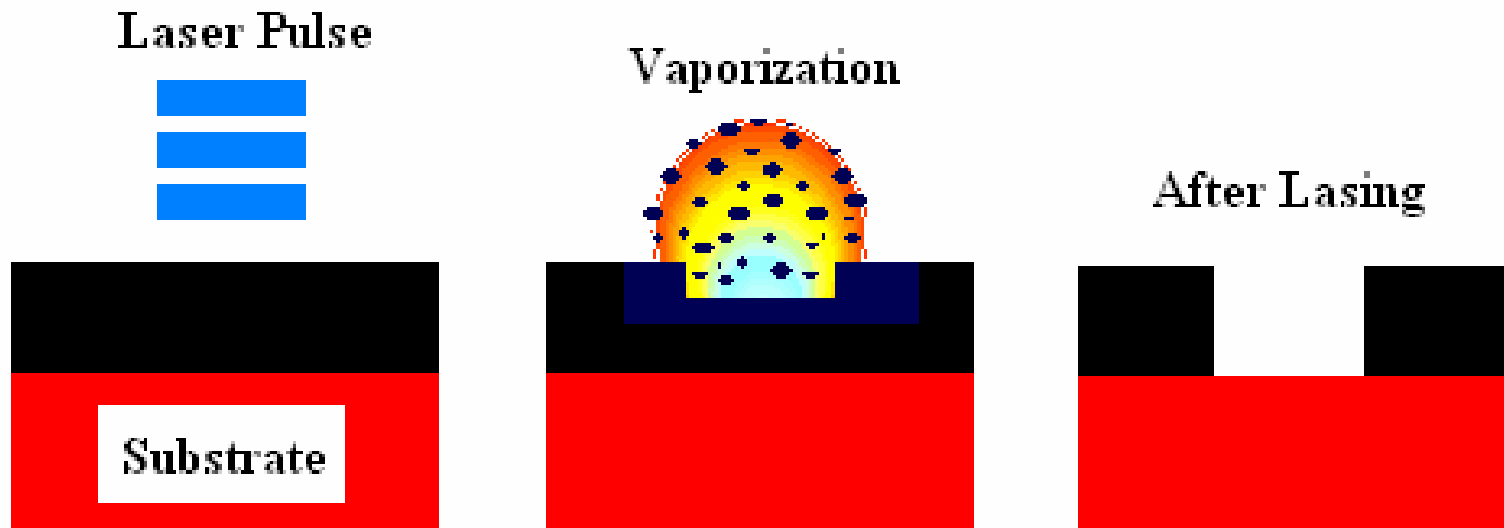
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  - > EUV mask cleaning
- Conclusions

# What is a laser cleaning?

- **Definition of laser cleaning**

: A process which removes contaminants from a surface by laser-surface interactions



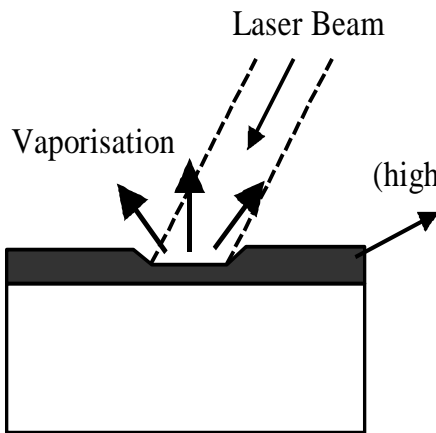
- **Cleaning mechanisms**

1. Photo-thermal effect
2. Photo-mechanical effect
3. Photo-chemical effect

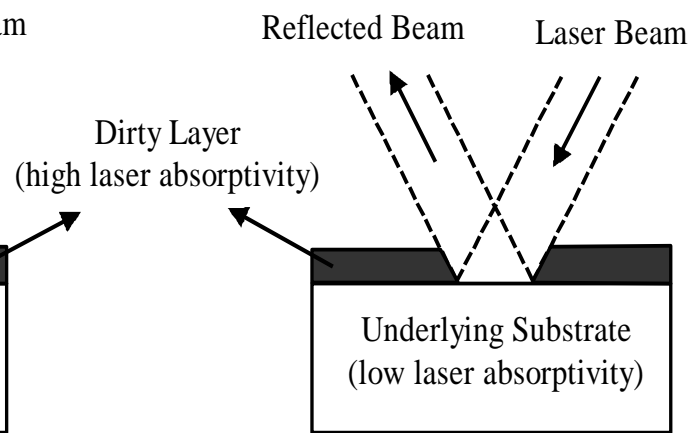
*Ref: 가 ,  
, 2002*

# Photo-thermal effect

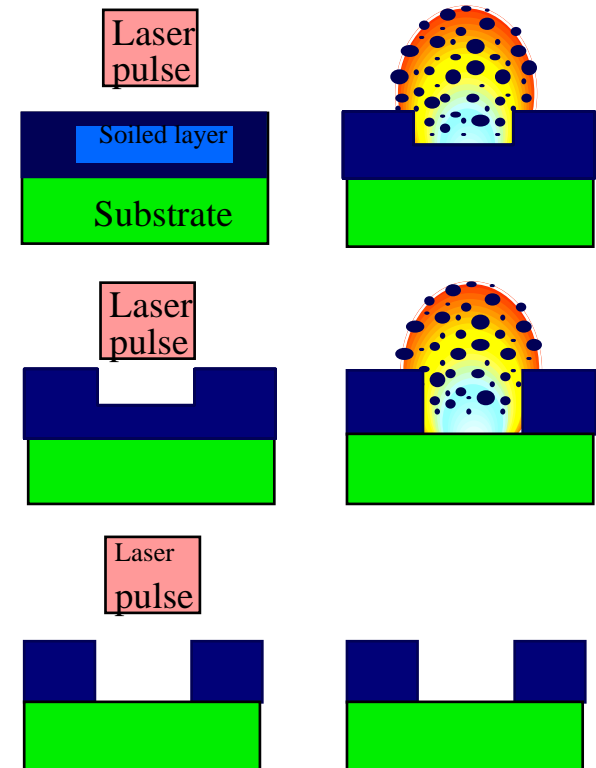
- ❑ Selective removal process by different photo-thermal effects on different surfaces
- ❑ Different laser absorption => different temp. rise => selective evaporation >> **"Self-limiting nature"**



Strong absorption of laser beam on the dark contaminated layer

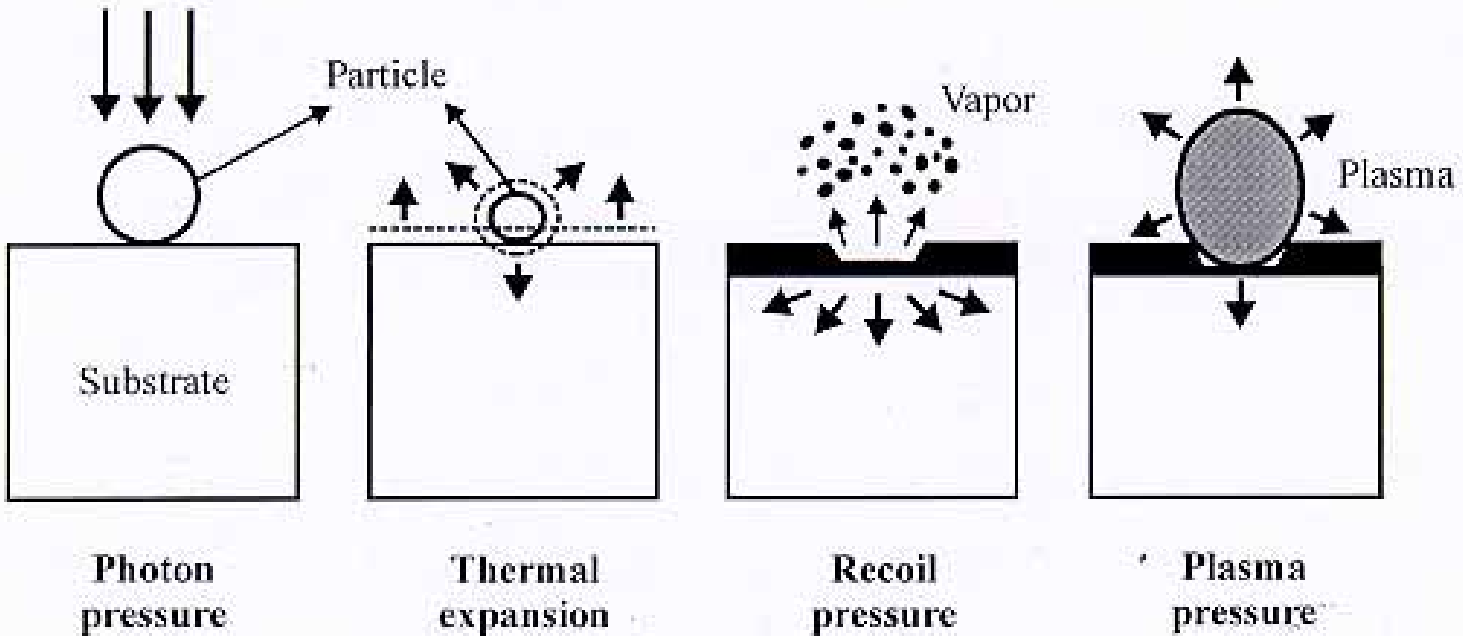


Reflection of laser beam on the bright substrate surface



# Photo-mechanical effect

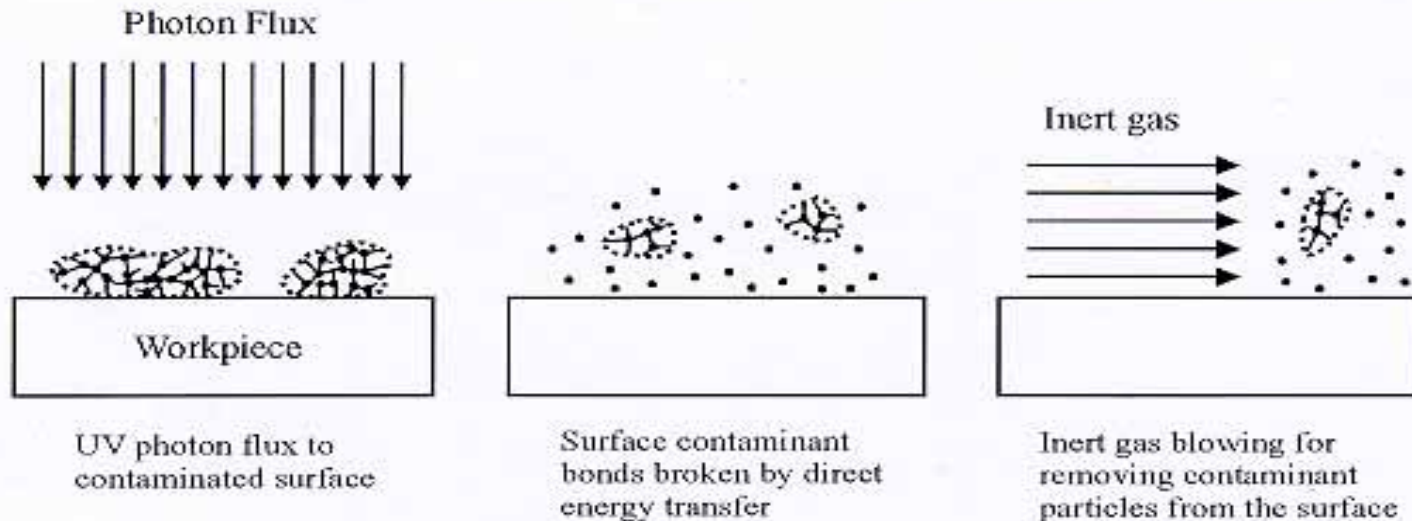
- Laser induced physical effects  
=> Cleaning efficiency enhancement



# Photo-chemical effect

- Principle: Direct bond breaking by energetic UV photon  
>> "Athermal and soft process"

Laser Source	Nd:YAG	Ruby	Ar ion	XeCl	Nd:YAG(4th)	KrF	KrCl	ArF
Wavelength(nm)	1064	694	365	308	266	248	222	193
Photon E.(eV)	1.16	1.78	3.38	4.01	4.64	4.98	5.56	6.4
Covalent bond type	H-F	Si-Si	C-H	C-Cl	H-O	H-H	O-O	C-C
Energy (eV)	1.04	3.26	3.5	4.12	4.44	4.52	5.16	6.29





# Process characteristics

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- **Unique characteristics**

- Physical process which ceases shortly after the laser pulse has ended
- Selective process which can be tuned for the removal of specific substances with a proper selection of wavelength
- Non-contact process which produces no contact wear
- Surface relief process without any mechanical loads
- Controllable process that a specific thickness of materials can be removed
- Environmentally preferable (or clean) process since it is a dry process



# Process characteristics

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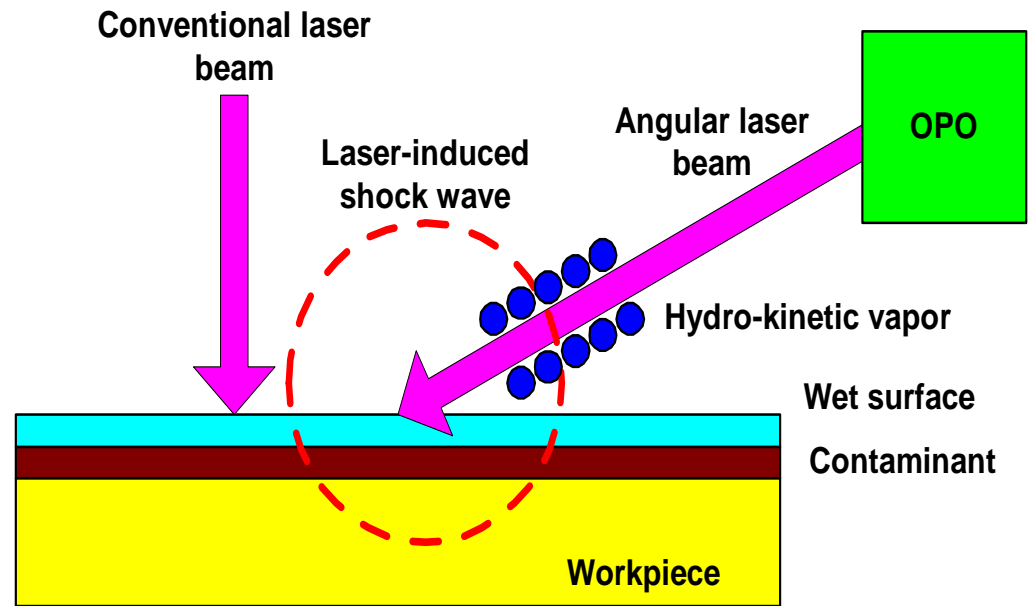
- **Disadvantages**

- Slow process due to small laser spot size
- Expensive process due to high cost of laser system
- Delicate process requiring a tight control due to high energy density beam => substrate damage due to overexposure or residual contamination due to underexposure



# Advanced laser cleaning techniques

- ❑ Angular laser cleaning
- ❑ Wet (Steam) laser cleaning
- ❑ Hydro-kinetic laser cleaning
- ❑ Wavelength tunable laser cleaning
- ❑ Optical fiber delivered laser cleaning
- ❑ **Laser shock cleaning**





# Applications

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- Medical applications
- Conservation of artworks
- Industrial applications

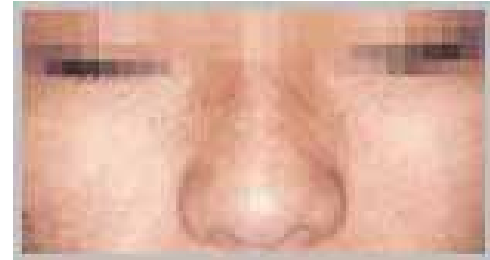
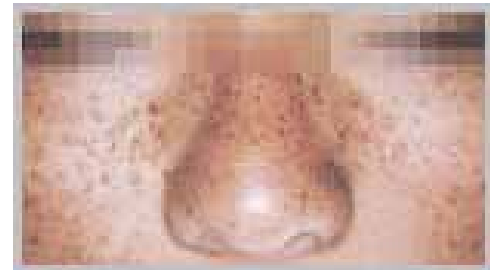
# Tattoo removal

- Laser used: Q-switched Nd:YAG (1064), Ruby (694), Alexandrite (720-795) lasers



# Spot or Fleckle removal

- Laser used: CO<sub>2</sub> laser (ablation) => Q-switched laser (Alexandrite or Nd:YAG: dark pigment removal) or Dye laser(300-1000: pale pigment removal)



# Dental Phobia



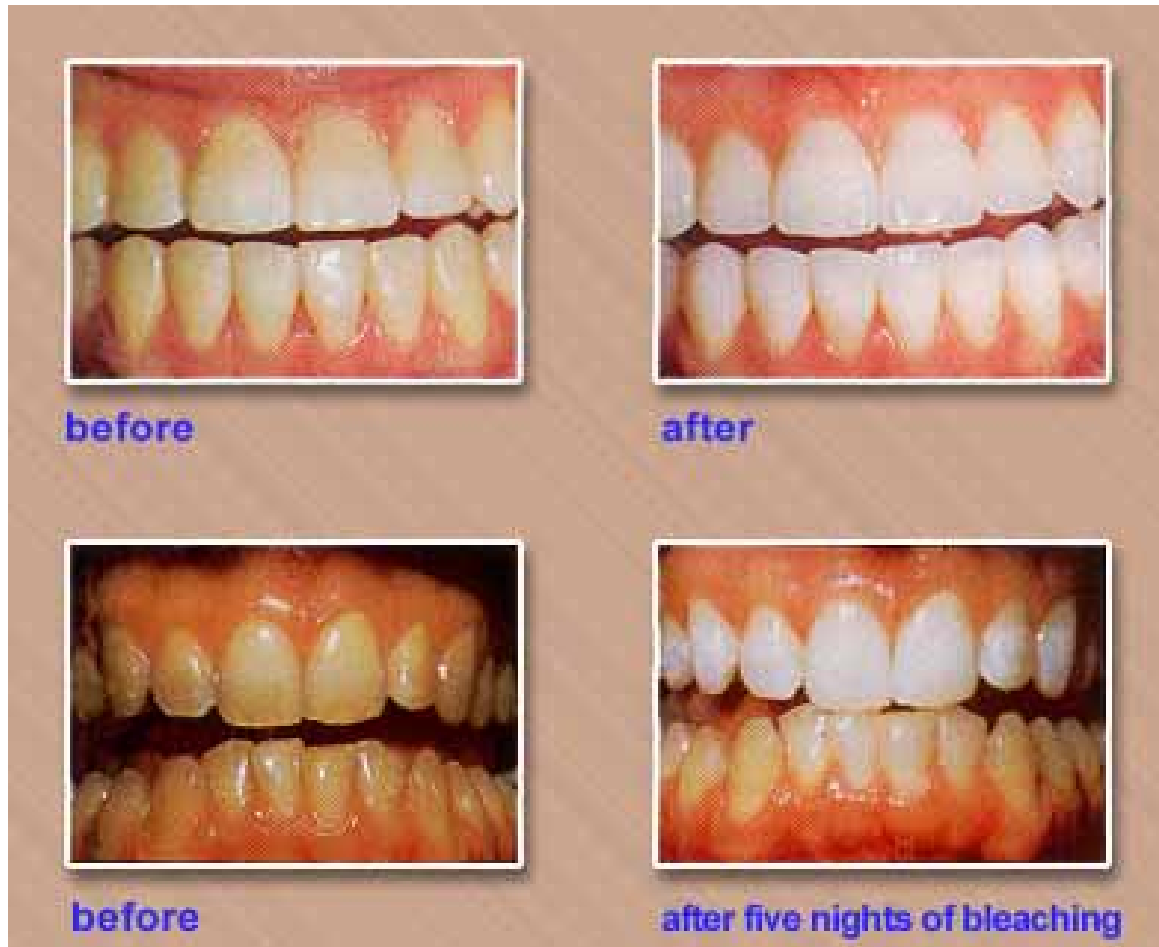
# Tooth scaling

- Laser used: Q-switched laser



# Tooth whitening

- Laser used: Ar laser (488 or 514 nm)



# Marble sculpture

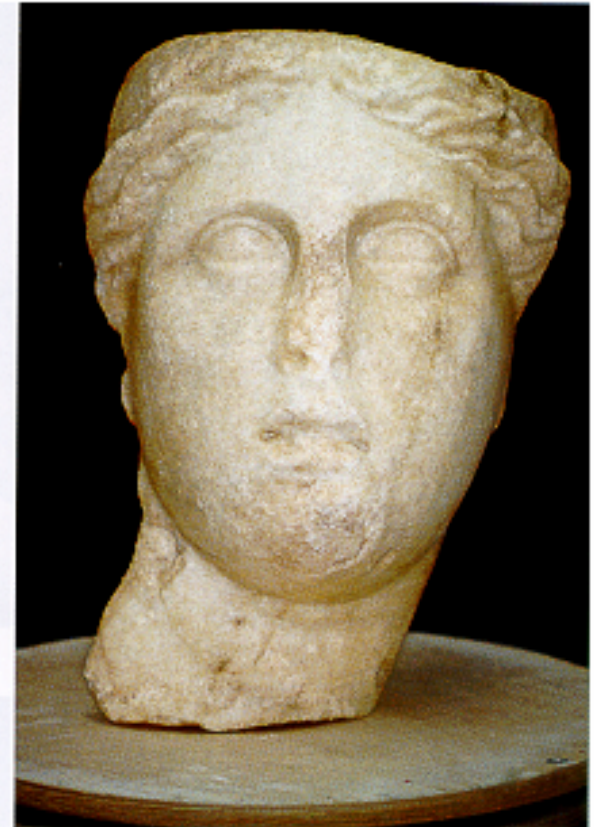
## BC 2C Hellenistic head of a women(28 tall), England



**Initial appearance  
covered with soil  
and limewash  
after excavation**



**After initial laser cleaning:  
0.4-0.75 J/cm<sup>2</sup> + water =>  
soil removal**



**After completion of laser cleaning:  
1.5 J/cm<sup>2</sup> => pick off the remnants  
of limewash and soil**



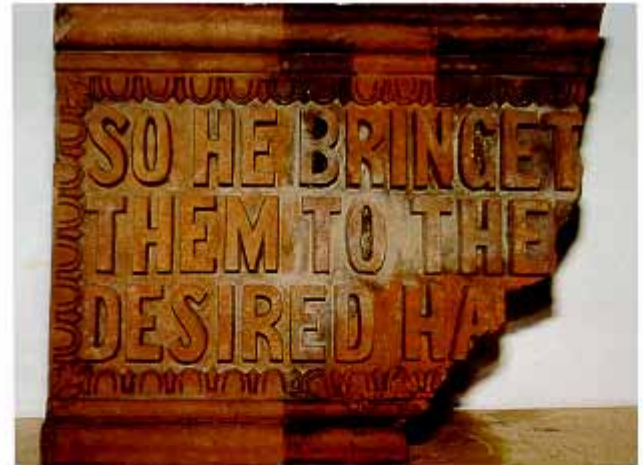
# Terracotta

17C over-lifesized statue of Neptune,  
England



Half cleaned:  $0.3 \text{ J/cm}^2 \Rightarrow$  black dirt layer,  $0.5 \text{ J/cm}^2 \Rightarrow$  thick and strong bound dirt layer

19C architectural panel, Liverpool



19C  
architectural  
detail (30 cm  
width),  
Liverpool

# Painting

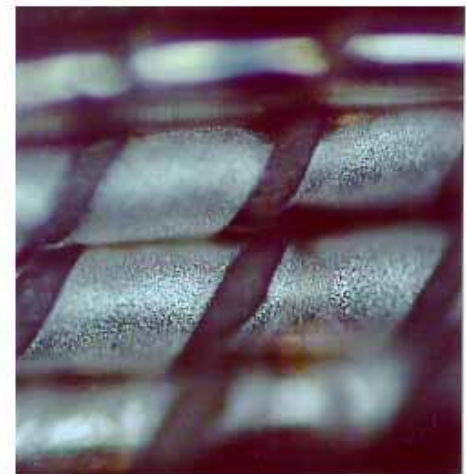
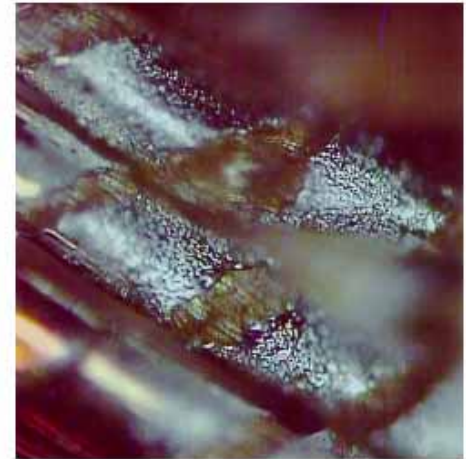
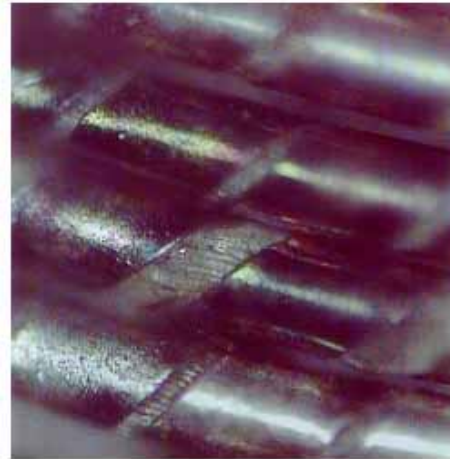
## 17C painting icon, Greek



**Light figure restored: Excimer laser in a very controlled manner => dirt particles, fungi, organic and inorganic compounds on paint-protecting varnish without the change of pigments**

# Silver

## Swedish novel cloth fabricated by silver thread



**Wavelength effect:**  
-1064 nm: both Ag and silk damage  
-532 nm: silk damage  
-266 nm: no damage

# Tire-mold cleaning

- Tyre residue removal (every 2-3 weeks) => blasting methods (glass beads with high pressure)
- Excimer laser (licensed process: Radiance process)



•Other application:  
tire-marking  
indicating class (rain  
tire) or logo

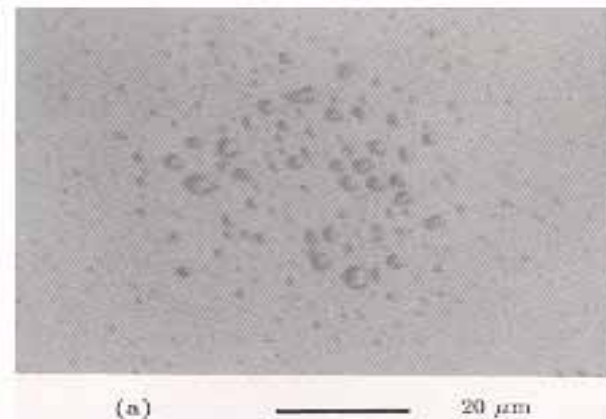
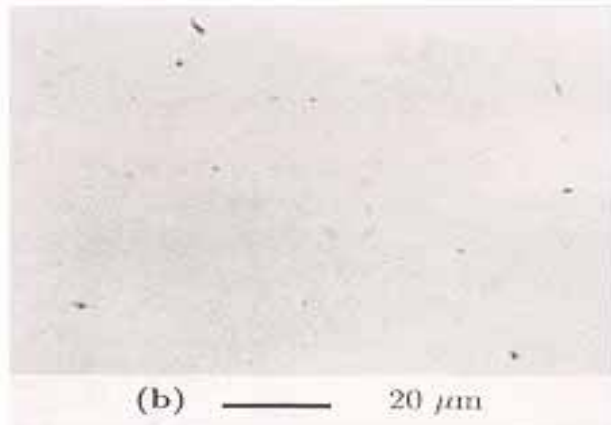
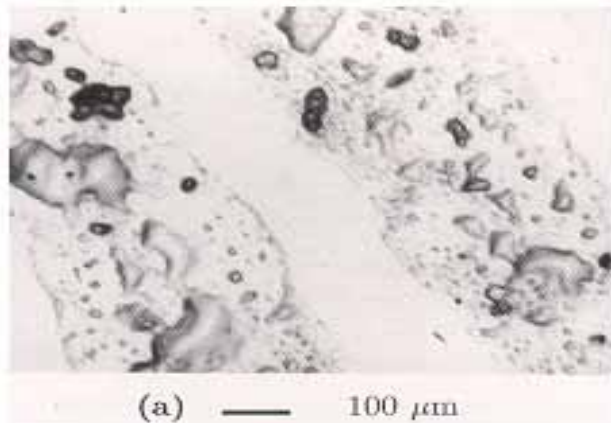
# Robot for tire cleaning

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# Glass and quartz surface cleaning

- Fingerprints removal from glass and quartz surfaces
- KrF excimer laser: 0.4-0.5 J/cm<sup>2</sup>

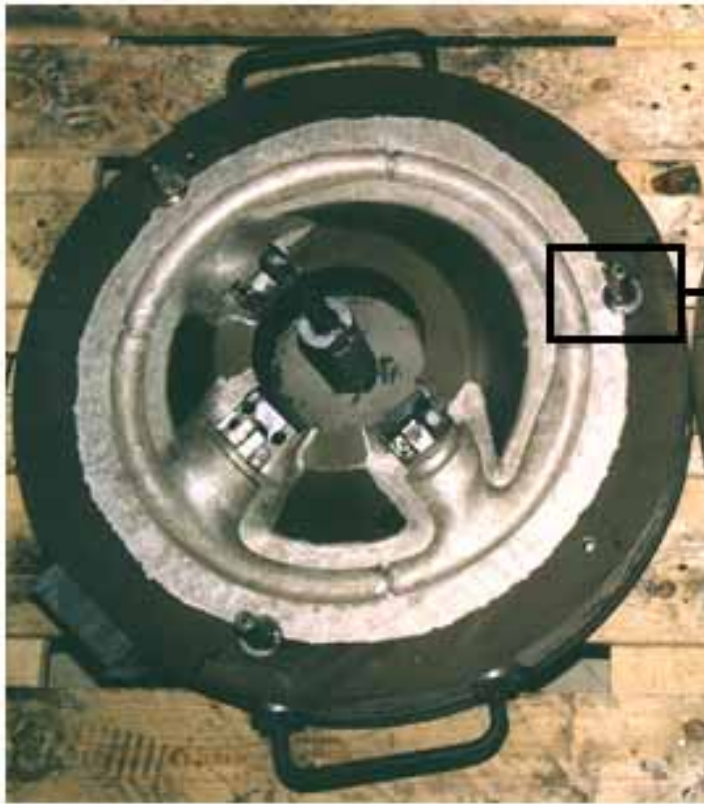


**1200 pulses  
from the  
front side**

**400 pulses  
from the  
back side**

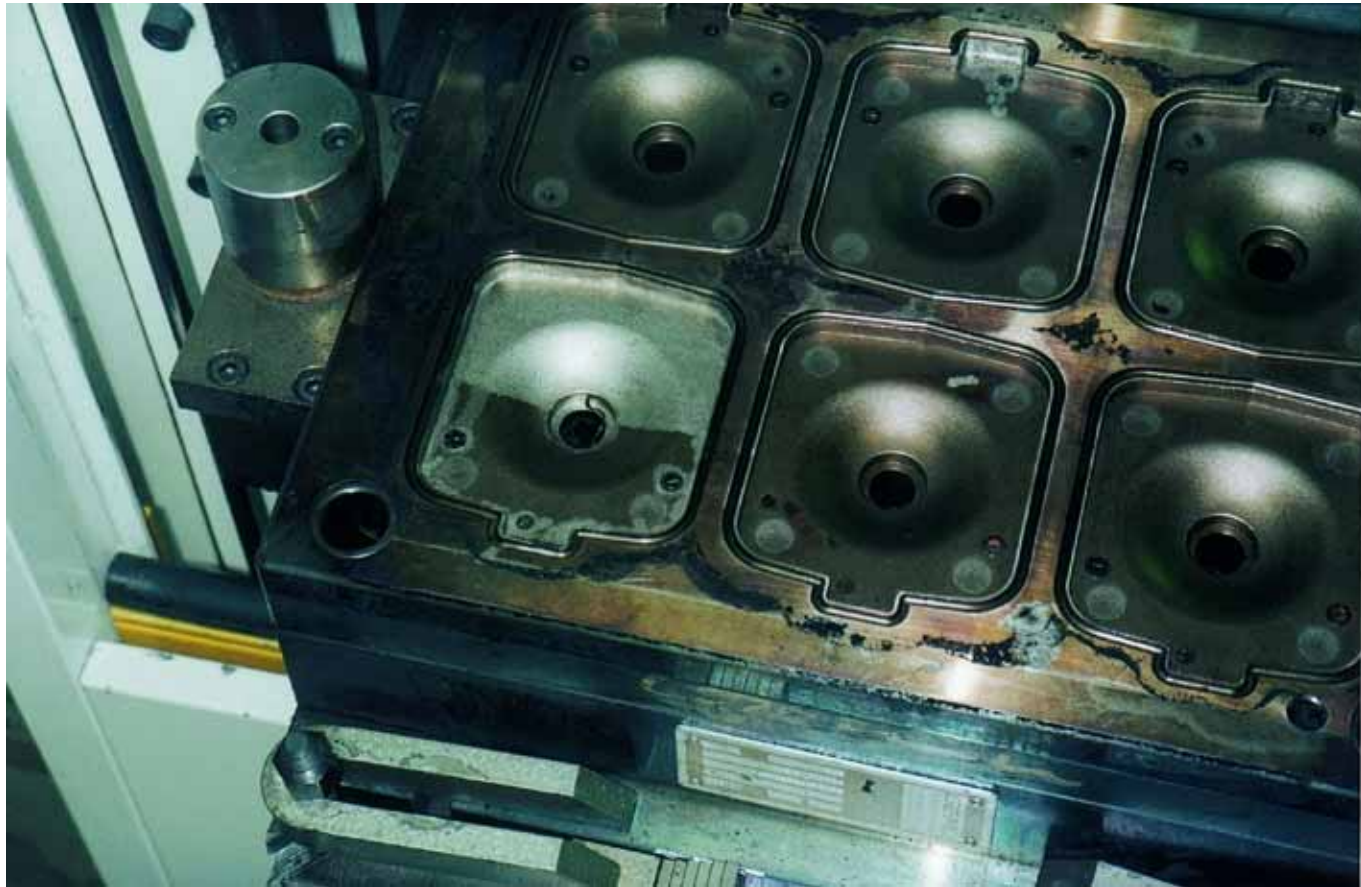
# Plastic mold cleaning (1)

- ❑ Fiber delivered Nd:YAG laser cleaning



# Plastic mold cleaning (2)

- ❑ Fiber delivered Nd:YAG laser cleaning
- ❑ In-situ process





# Rubber & Glass mold cleaning

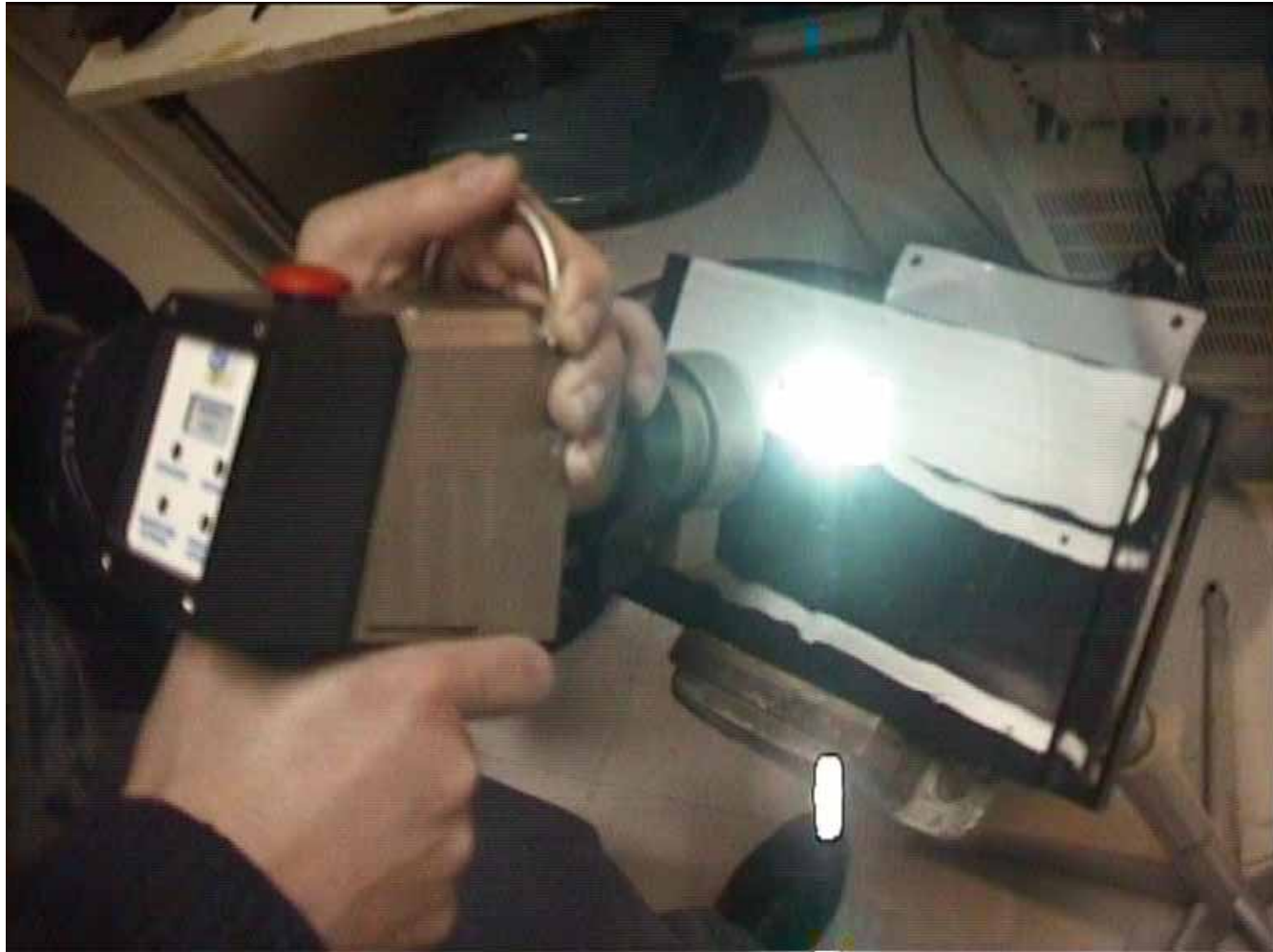
- ❑ Fiber delivered Nd:YAG laser
- ❑ Cleaning time : < 5min.



*In-situ cleaning*

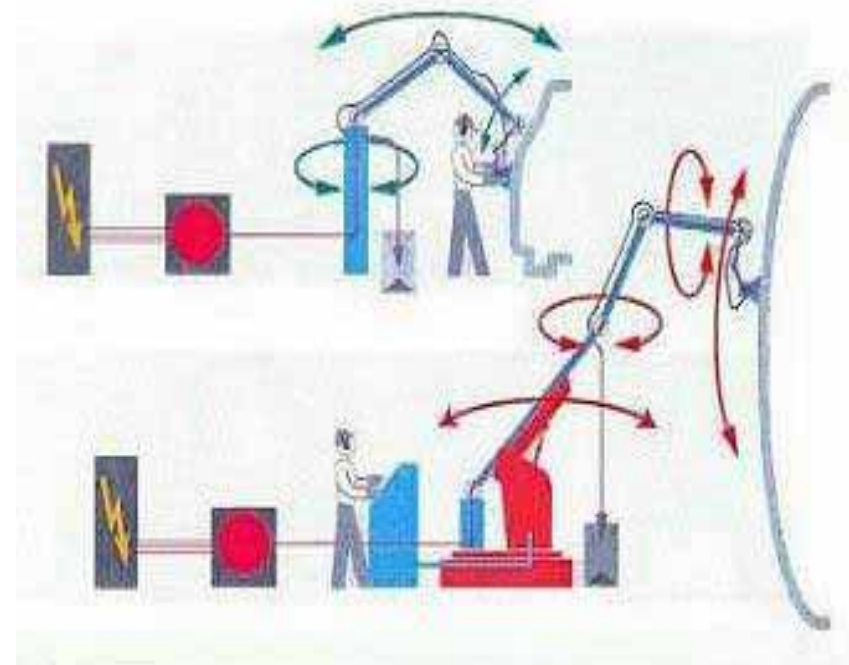
# Anodizing removal from metal

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# Aircraft paint-stripping

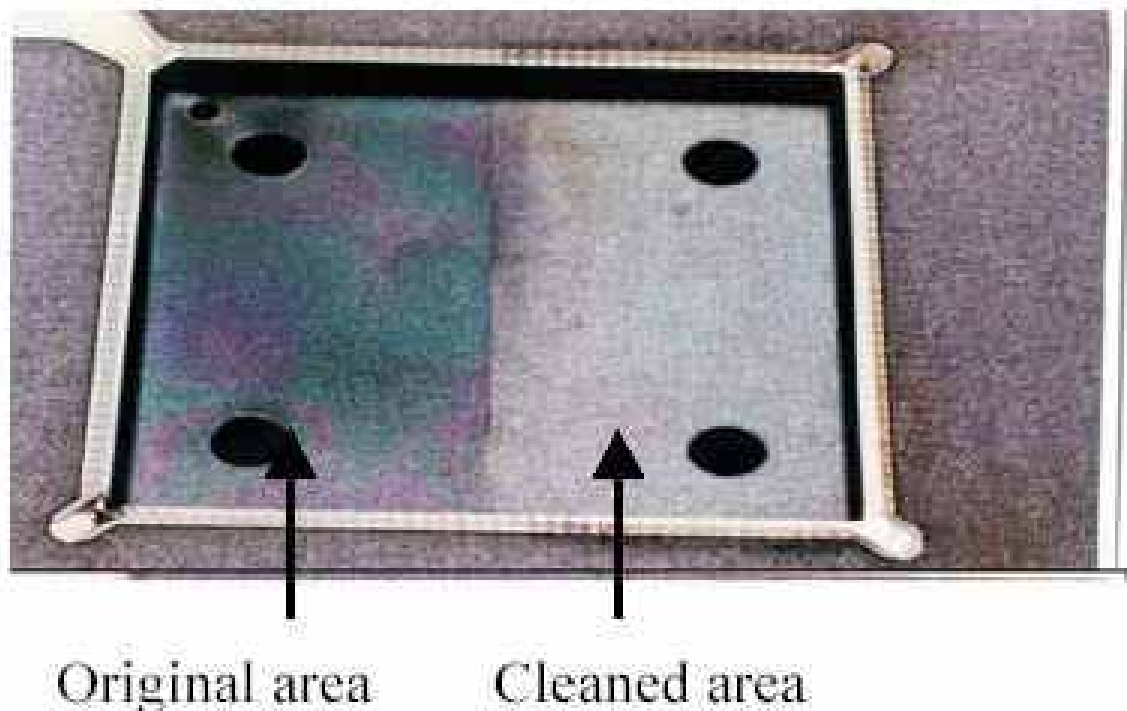
- Al & Ti based alloy: paint layer => blasting, grinding & chemical stripping
- TEA CO<sub>2</sub> laser or Nd:YAG laser



# IC mold cleaning (1)

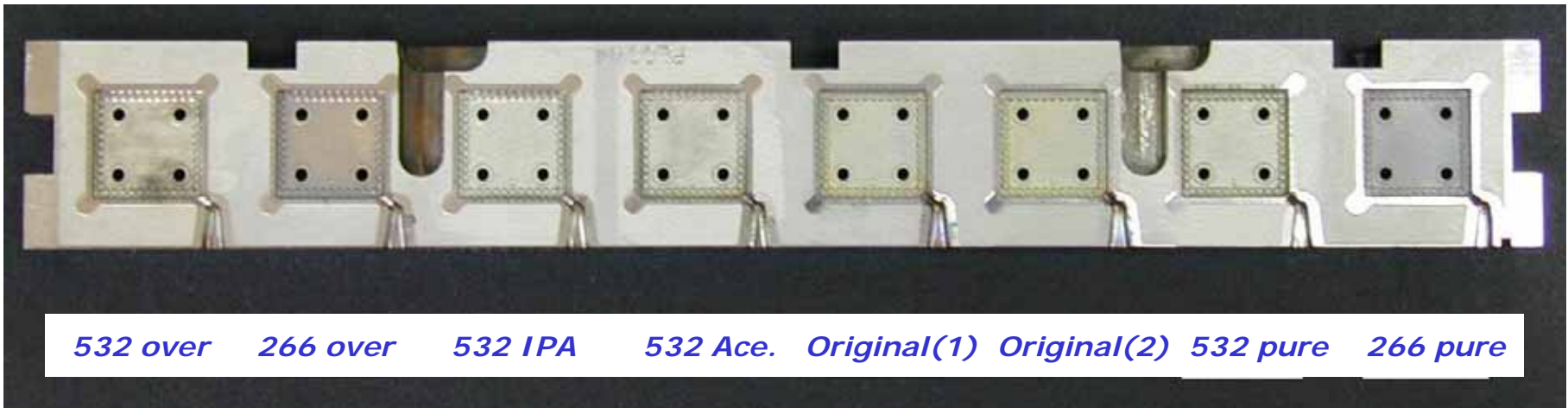
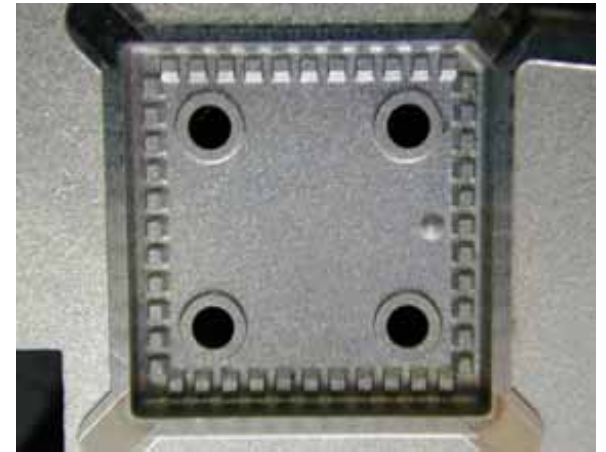
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- Oil, grease and wax removal is required before the molding process.
- KrF excimer radiation: 248 nm, 23 nsec, 400 mJ/cm<sup>2</sup>



# IC mold cleaning (2)

- Cleaning conditions
  1. Nd:YAG laser, 532nm or 266nm
  2. Dry & IPA & Acetone assisted



# IC package deflashing

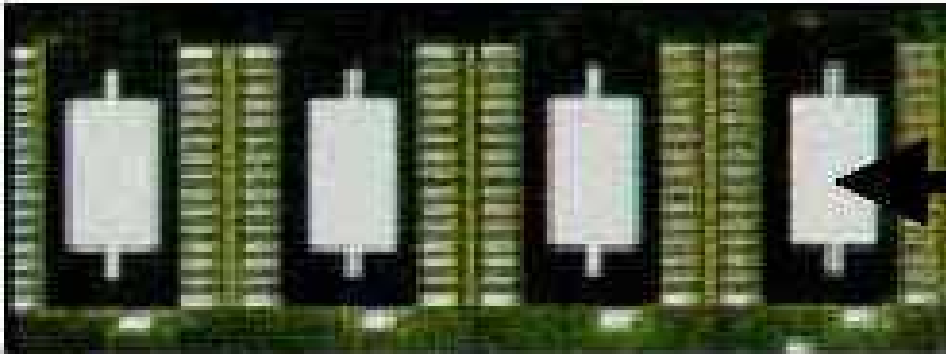
- Plastic mould excess removal from the heat sink surface
- SHG ND:YAG radiation: 532 nm, 7 nsec, 300 mJ/cm<sup>2</sup>

a



Flash on  
Heat sink

b



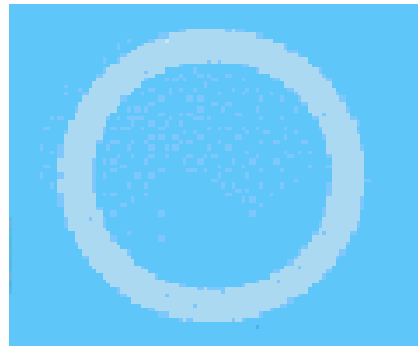
Heat sink

# Semiconductor equip. cleaning

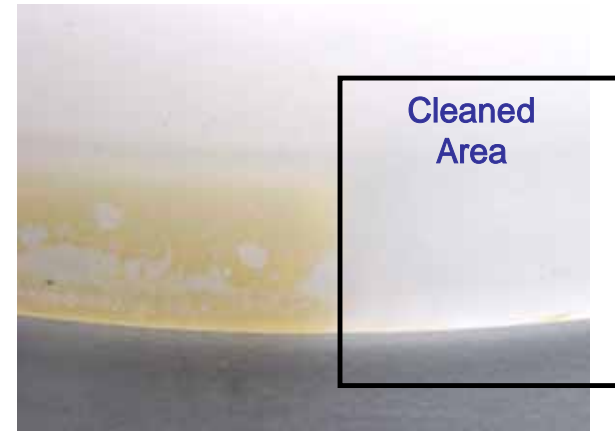
- Processing components cleaning in PVD & CVD equipment
- Al based contamination on Quartz ring & disk



**Before cleaning**



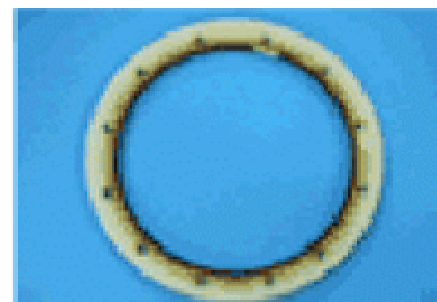
**After cleaning**



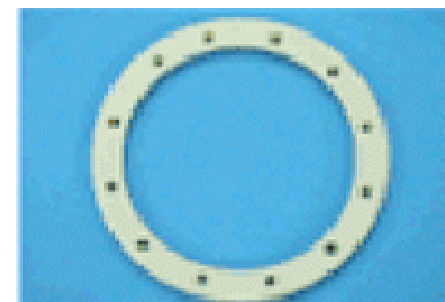
**Before cleaning**



**After laser treatment**



**Before cleaning**

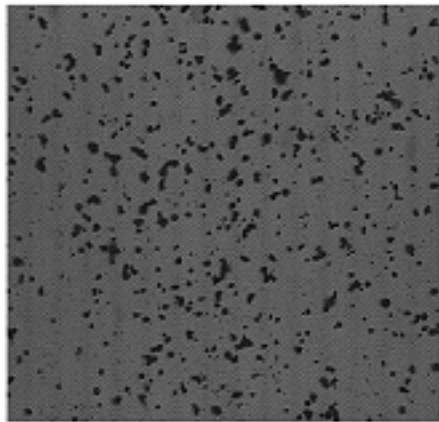


**After laser treatment**

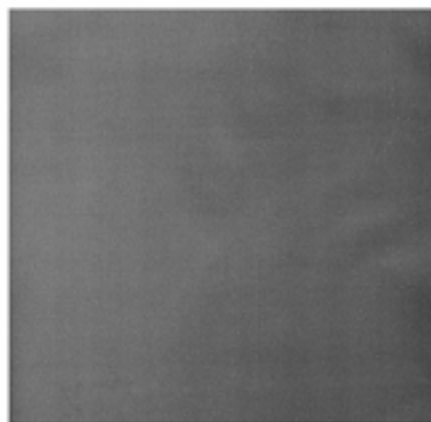
*Ceramic ring confinement*

# Semiconductor wafer cleaning

- Removal of particles from Si wafer => wet cleaning
- Particle control in DRAM fabrication (SIA)
  - : Min. Feature Size:  $0.18\mu\text{m}$  =>  $0.13\mu\text{m}$  =>  $0.09\mu\text{m}$  =>  $0.07\mu\text{m}$
  - : Critical Particle Size:  $0.09$  =>  $0.065$  =>  $0.045$  =>  $0.035\mu\text{m}$
- Much tighter control of particle required with device shrink

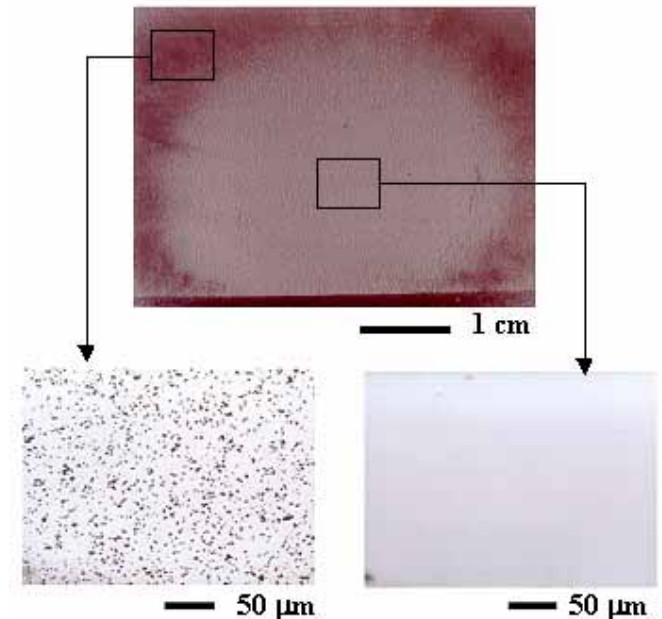


Before cleaning



After cleaning ( $0.18\text{J}/\text{cm}^2$ )

*1 $\mu\text{m}$  Cu particles removal*

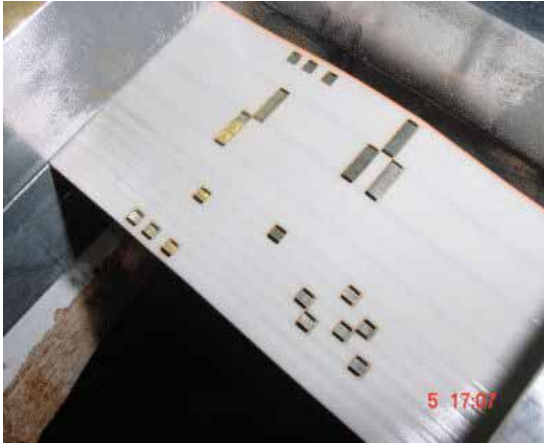


*Laser Shock Cleaning (IMT)*



# Wire stripping & Decoating

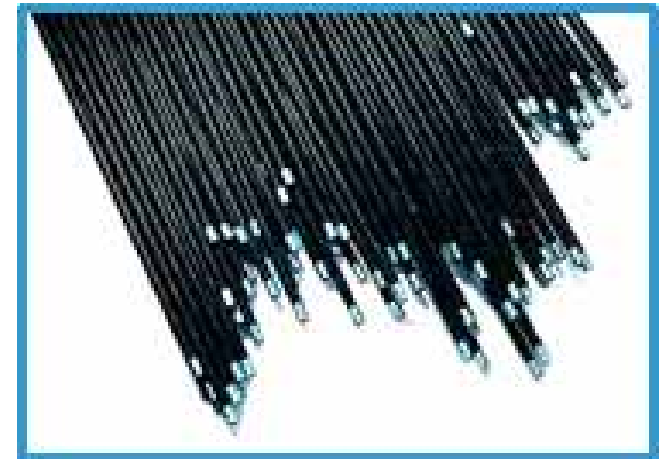
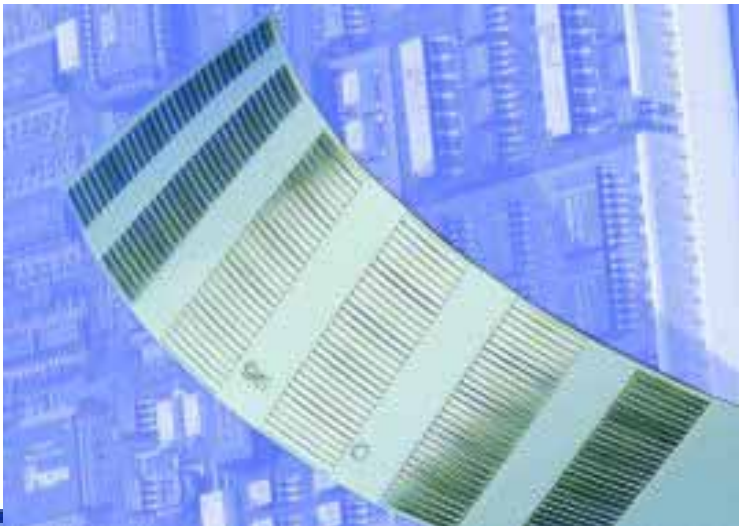
- TEA CO2 or UV laser



Local stripping  
of Flat cable



Decoating of tubes and hoses



Decoating of break lines

# Comparison of cleaning processes

	Media blasting	Dry ice cleaning	Wet chemical cleaning	Laser cleaning
<b>In-situ cleaning (op. Off-line)</b>	No	Yes	No	Yes
<b>Labor required</b>	High	Medium	High	Low
<b>Level of automation</b>	Low	Low	Low	High
<b>Noise level</b>	Medium	High	Low	Low
<b>Substrate wear</b>	Yes	No	Medium	No
<b>Environmental hazards</b>	Medium	Medium	High	Low
<b>Post-cleaning waste</b>	High	Low	High	Low



# Conclusions

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- **Laser cleaning** has unique characteristics compared with conventional cleaning techniques
- **The application of laser cleaning** is expanding rapidly since it is precise, selective and environmental friendly cleaning method.
- **A creative idea from industrial fields** is most important to implement the new technology successfully.