

***Various welding and joining
technology for automotive***

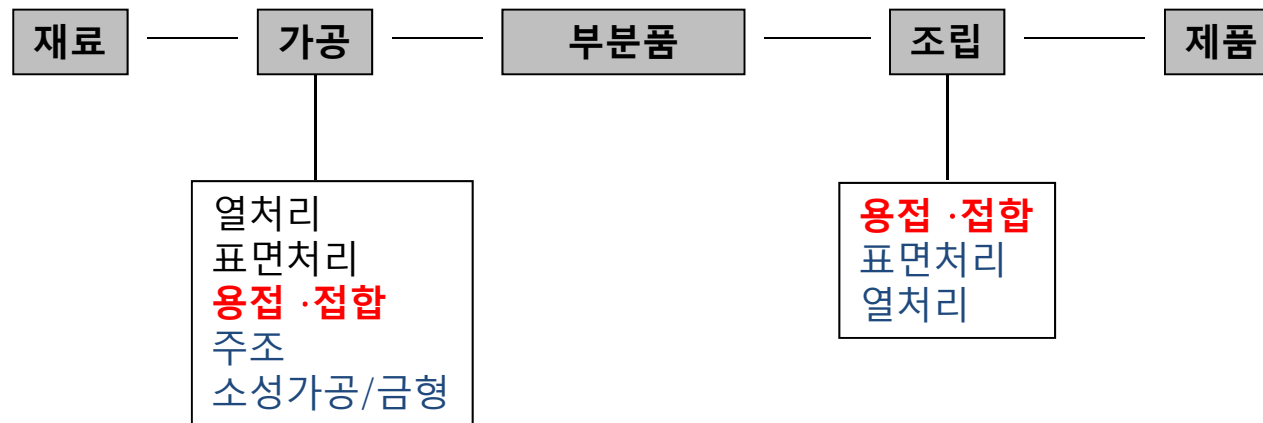
2016. 04. 24.

Minjung Kang

Introduction

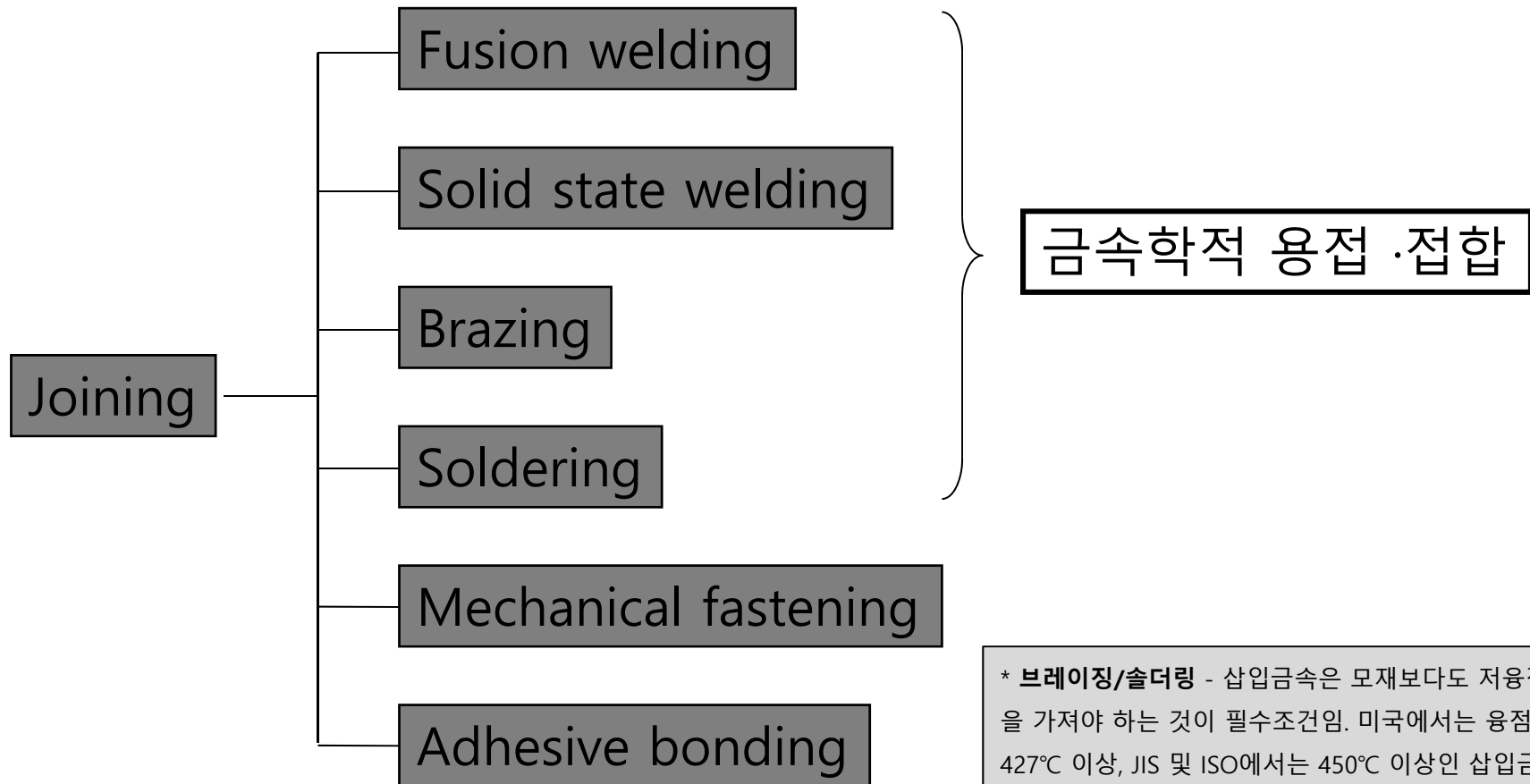
● Definition

- ☞ 열 또는 압력을 가하거나 열과 압력을 동시에 가하여 금속 또는 비금속을 국부적으로 결합시키는 것으로 용가재를 사용하기도 한다. (ASTM)
- ☞ 열, 압력 또는 열과 압력으로 금속을 가소성 상태나 액화상태로 하여 결합하는 것으로 모재와 유사한 용가재를 사용하기도 한다. (BS)



Introduction

● Classification



* 브레이징/솔더링 - 삽입금속은 모재보다도 저융점을 가져야 하는 것이 필수조건임. 미국에서는 용점이 427°C 이상, JIS 및 ISO에서는 450°C 이상인 삽입금속을 사용할 경우 브레이징이라고 하고 용점이 그보다 낮은 온도 영역의 경우는 솔더링이라고 함.

Welding process I – Arc welding

- **Arc welding process**

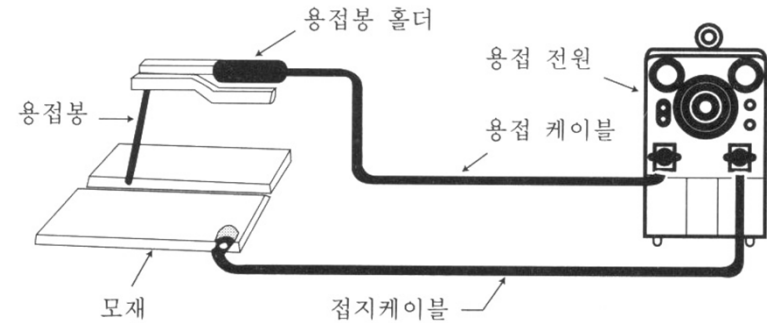


Welding process I – Arc welding

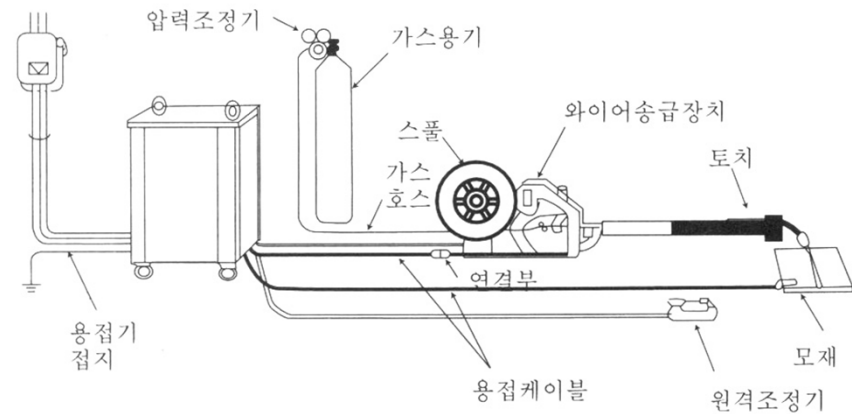
● Advantage/Disadvantage

- 장점
 - 장비가 단순하고 비교적 저가
 - 휴대 편리 (SMAW)
 - 적용부위 및 용접장소 용이성
- 단점
 - 낮은 생산성
 - 용접봉 건조
 - 다량의 슬래그 → 후속 공정 요구

- 사용하는 가스의 종류에 따라서 MIG, MAG, CO₂로 구분됨.
- GTAW (Gas tungsten arc welding)



<Shield metal arc welding(SMAW)>

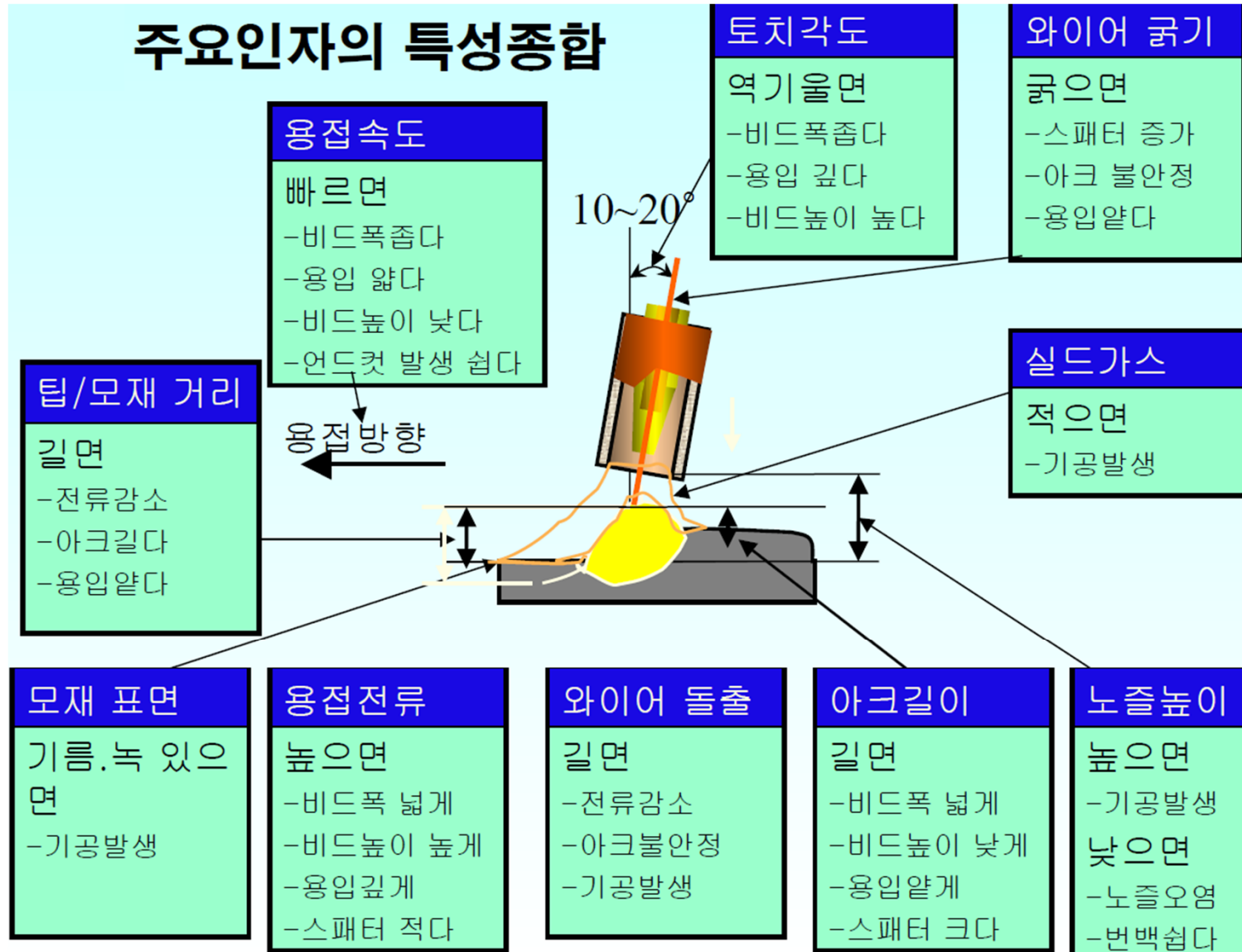


<Gas metal arc welding(GMAW)>



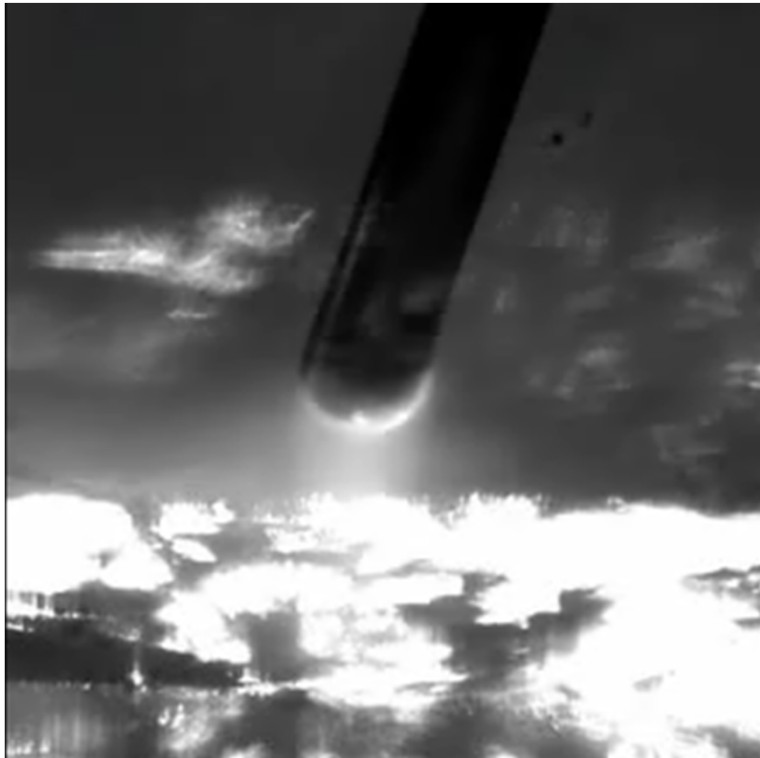
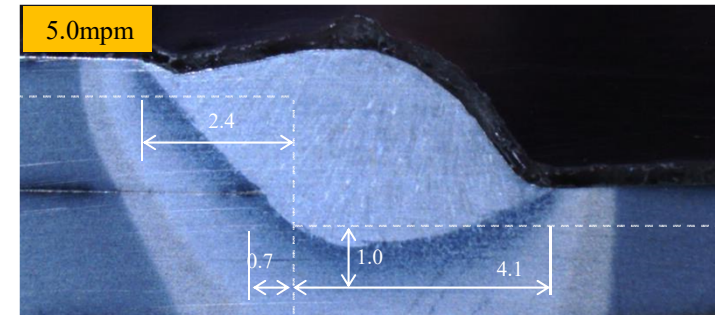
Welding process I - Arc welding

● Variations



Welding process I – Arc welding

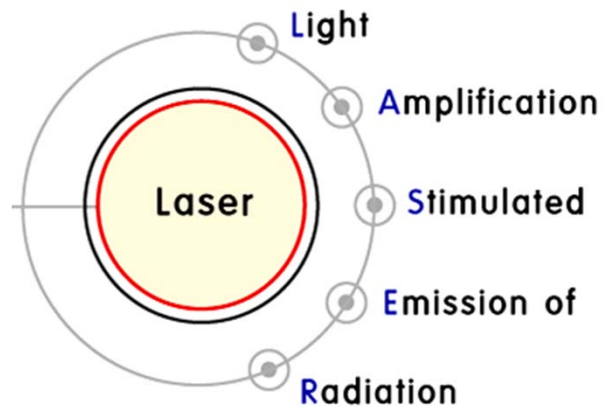
- **Movies**



Welding process II – Laser welding

● Laser welding process

LASER = “유도방출에 의한 빛의 증폭”



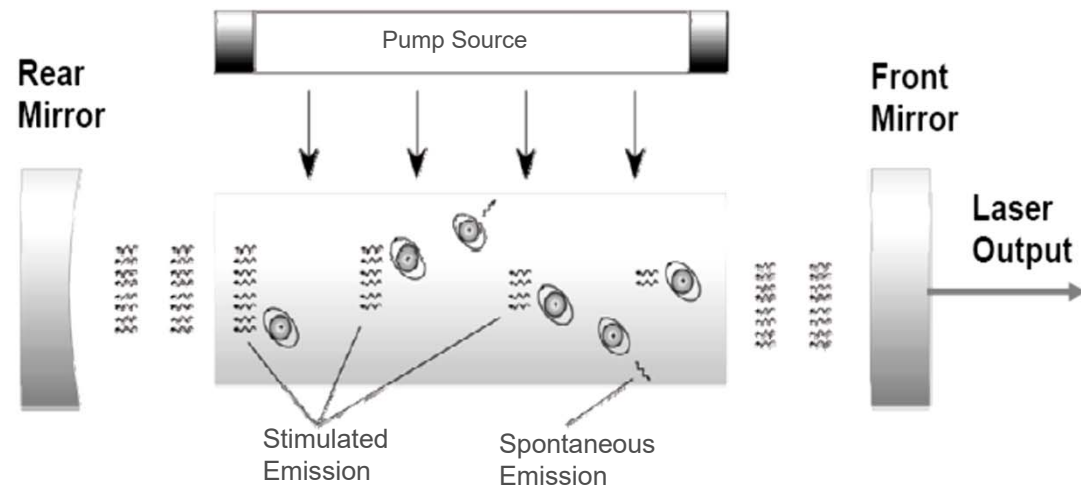
레이저 빛의 특성

1. 단색성 (Monochromatic)
2. 직진성 (Directionality)
3. 고휘도성 (Brightness)
4. 집속성 (Focusing ability)

레이저의 구성 3요소

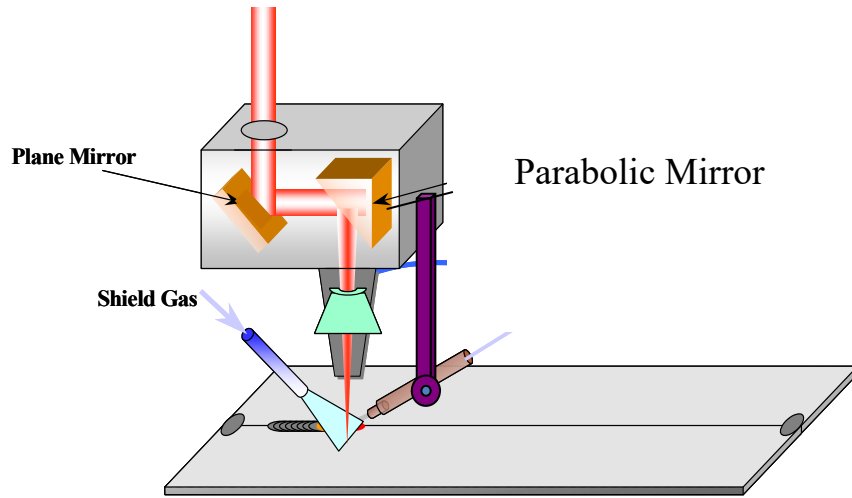
- 공진기(Resonator)
- 활성매질(active medium)
- 펌핑 소스(Pumping)

Ex) Flash Lamp Nd:YAG Laser

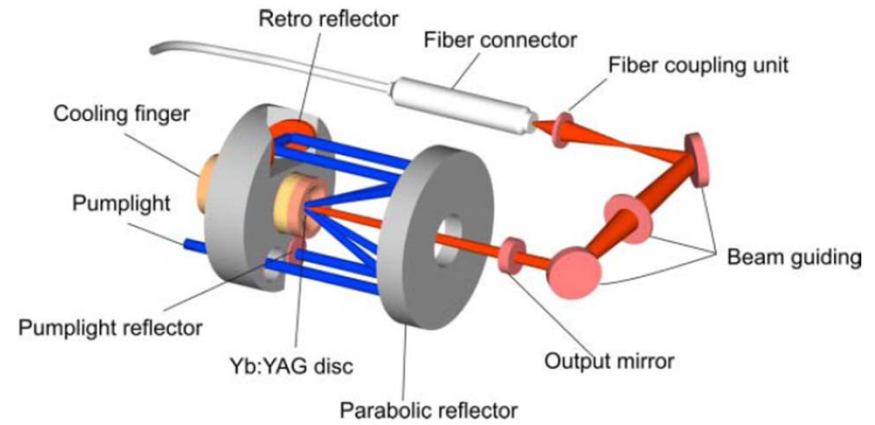


Welding process II - Laser welding

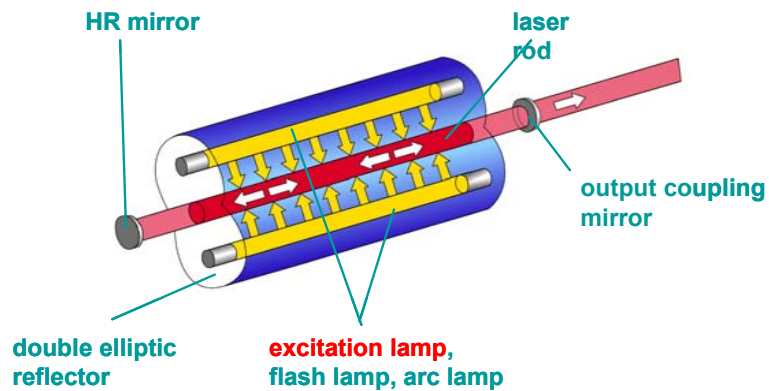
Classification



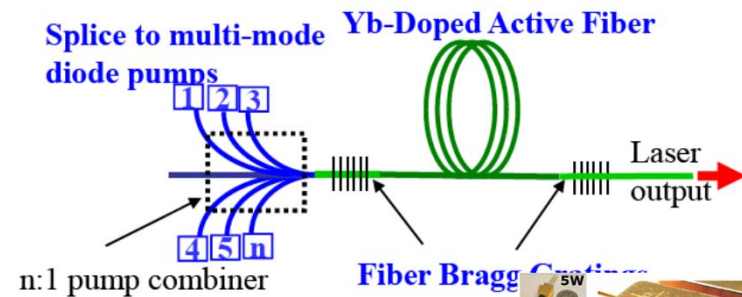
CO₂ 레이저



DISK 레이저



Nd:YAG 레이저

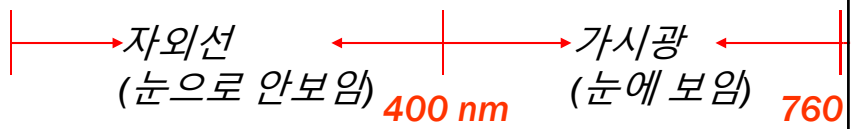
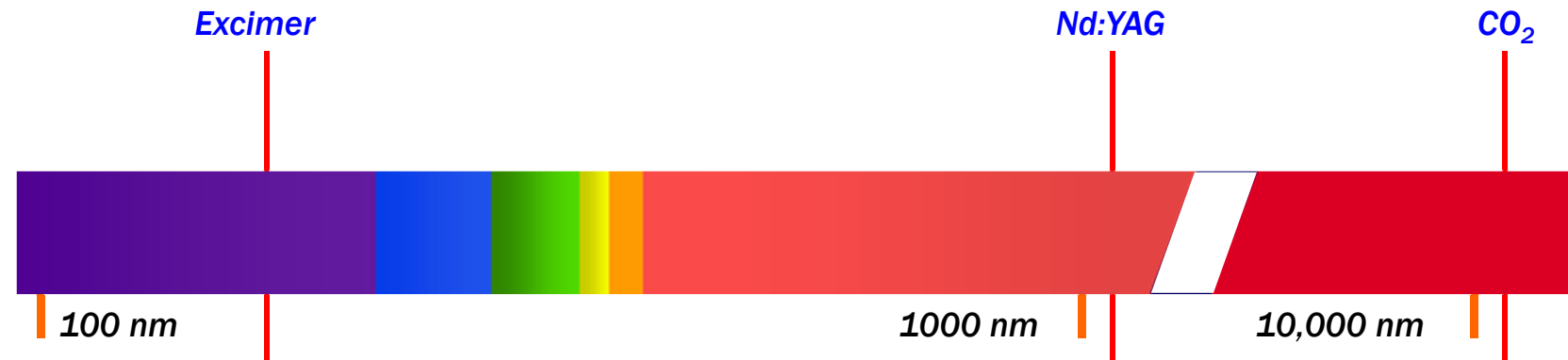


FIBER 레이저

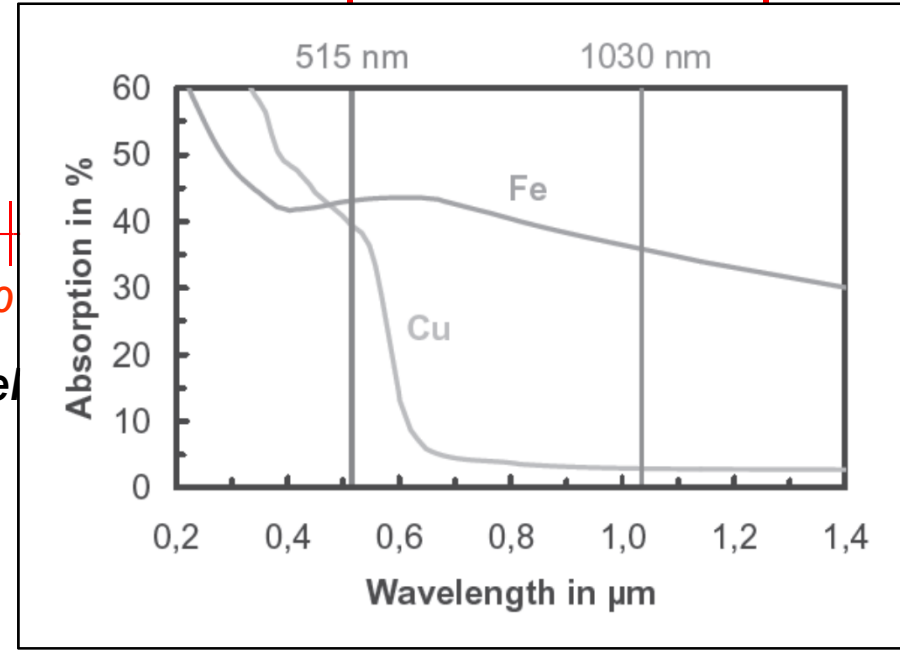


Welding process II - Laser welding

☞ 전자기파 스펙트럼 및 레이저 빛의 영역

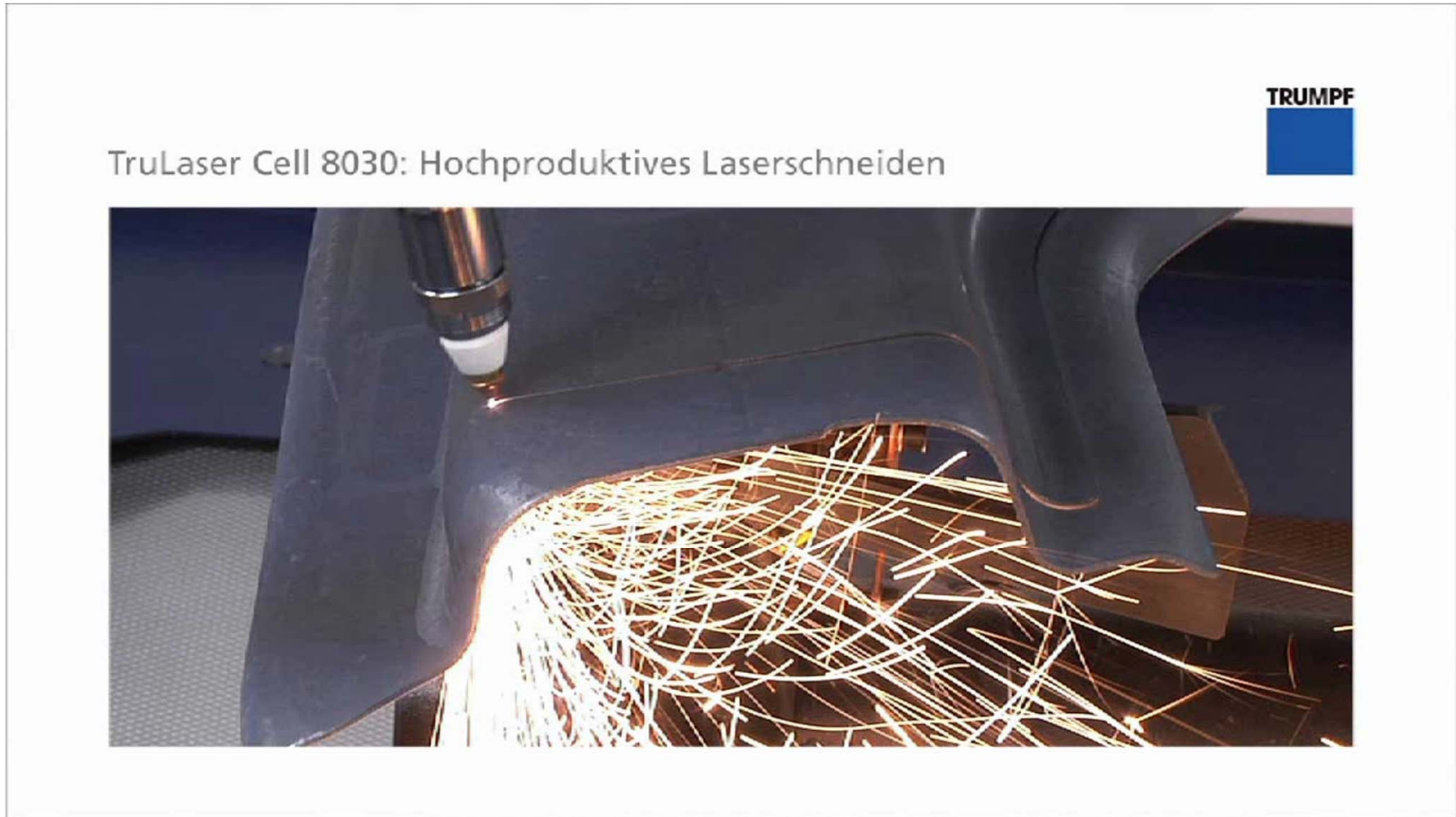


Wavelength



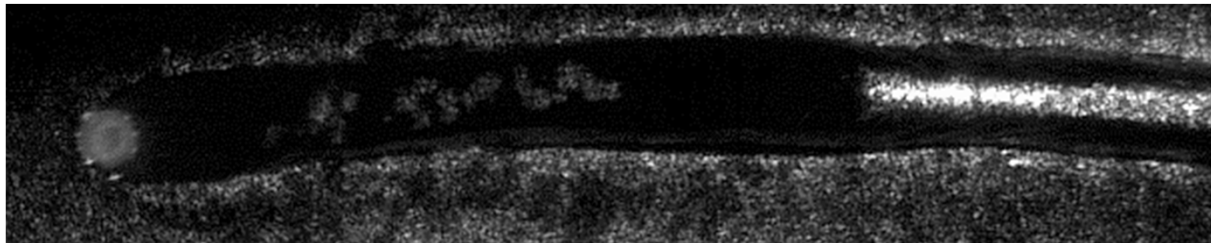
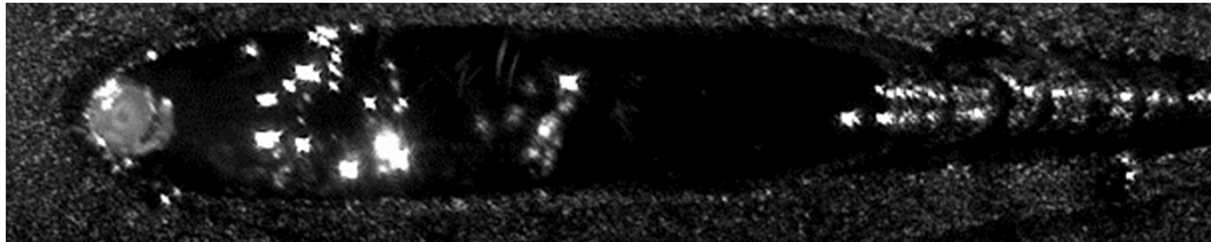
Welding process II – Laser welding

- **Movies (Laser cutting)**



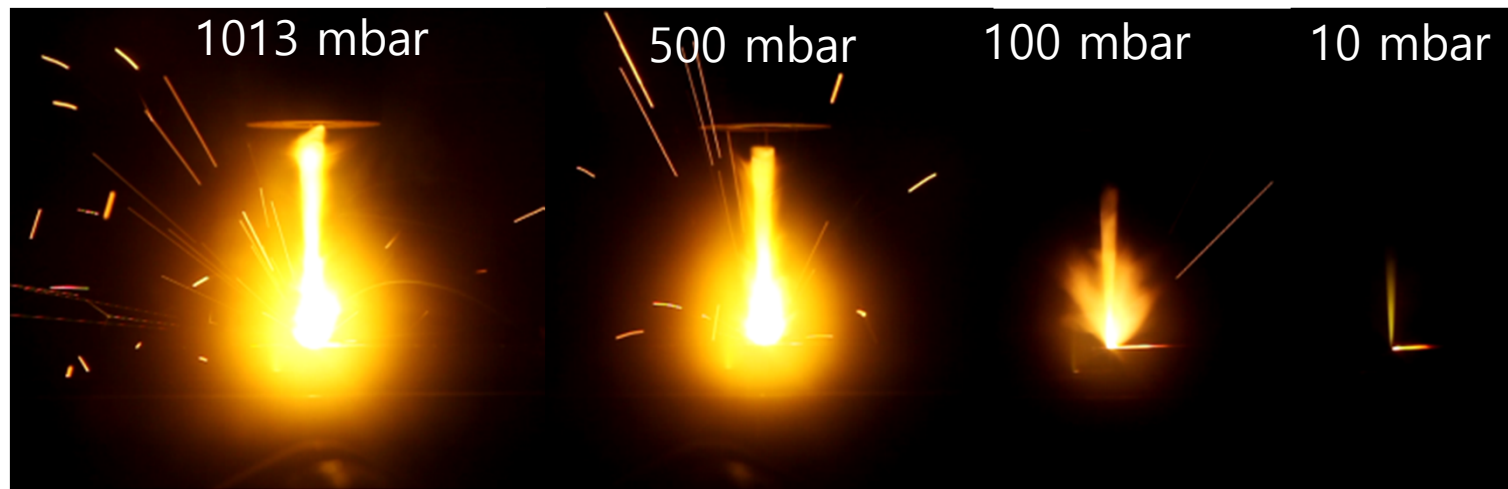
Welding process II – Laser welding

- **Movies (Laser welding at different pressure)**



Welding process II – Laser welding

Welding with Solid State Laser => below atmospheric pressure



source: V. Rominger

Reducing the ambient pressure causes severe reduction

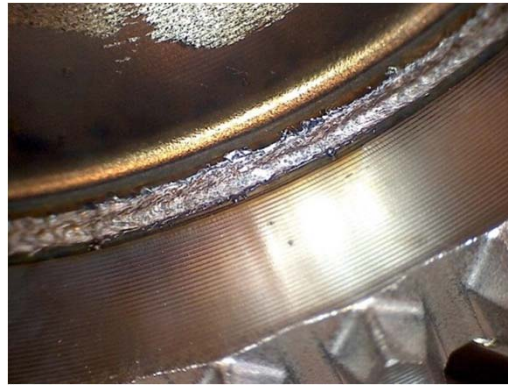
- the metal vapor plume in size and brightness
- the spatters

- S355 – 10 mm
- $P = 6000 \text{ W}$
- $v_s = 2,0 \text{ m/min}$
- $f_p = -2 \text{ mm}$

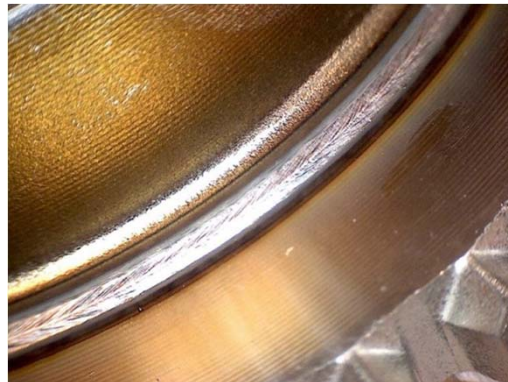


Welding process II – Laser welding

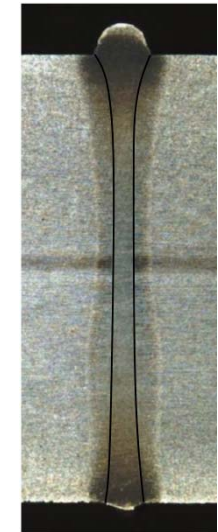
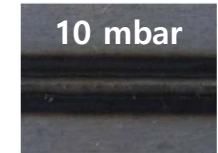
1013 mbar



10 mbar

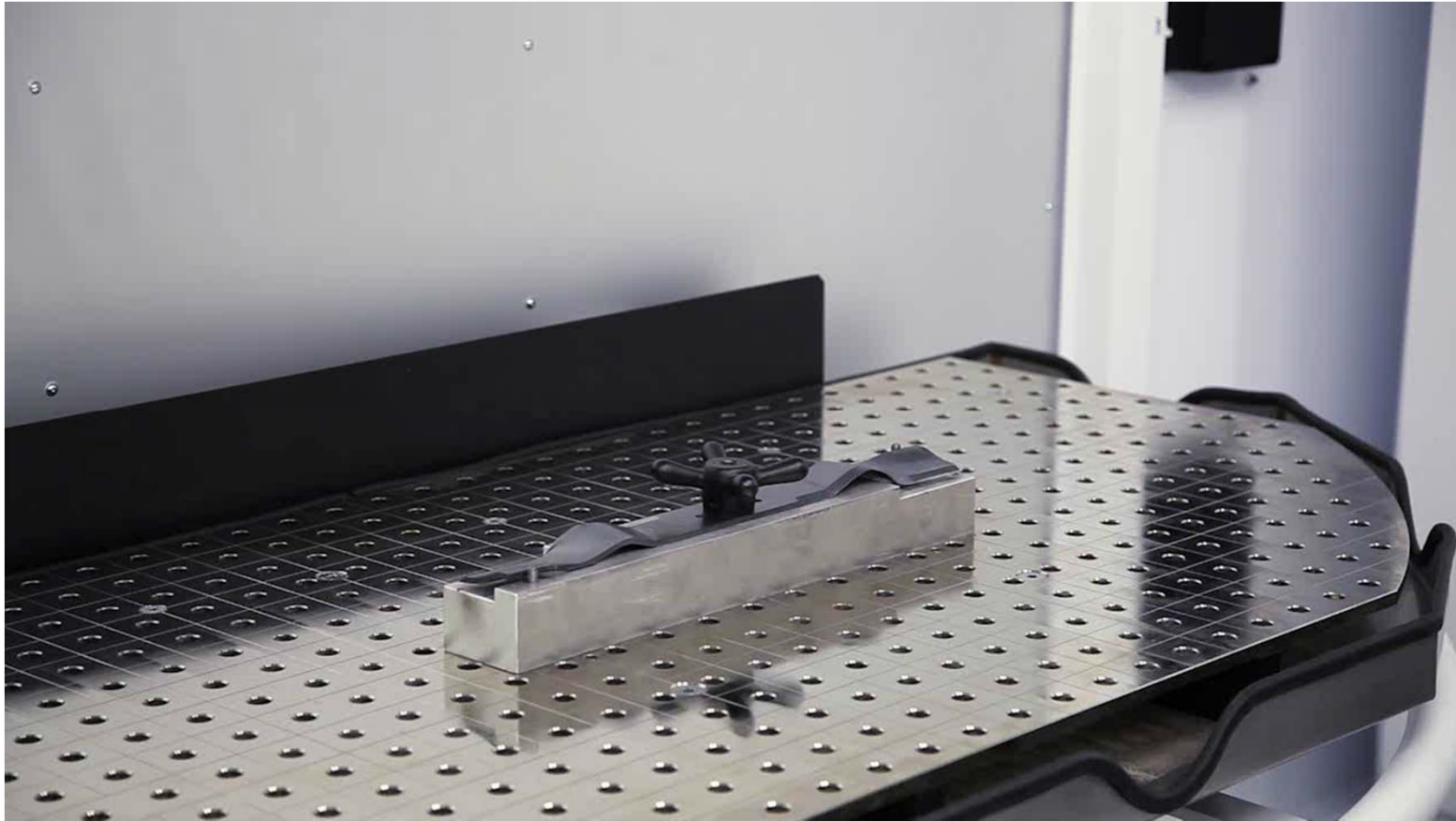


10 mm full penetration



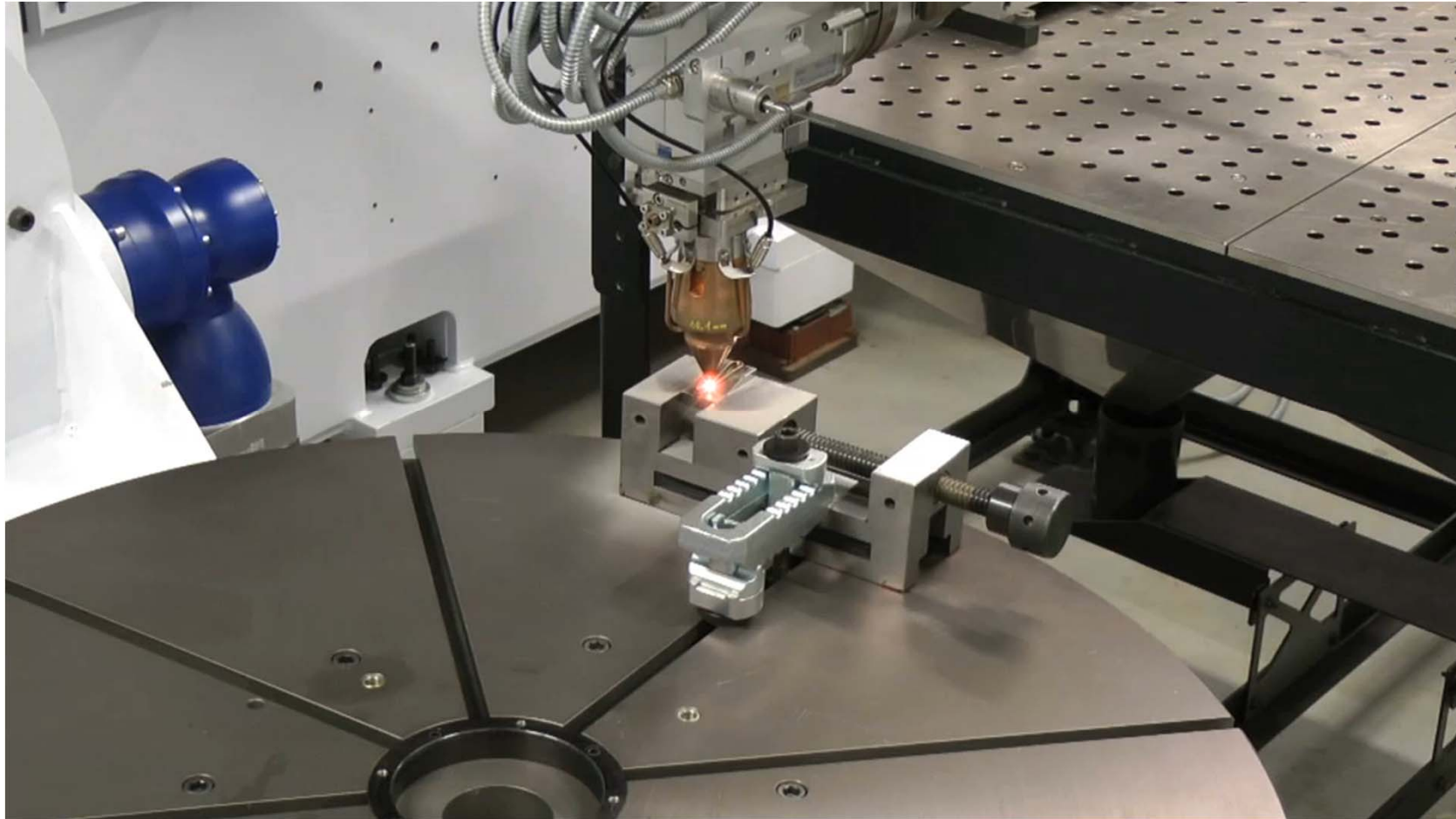
Welding process II – Laser welding

- **Movies (Laser metal deposition)**



Welding process II – Laser welding

- **Movies (Laser metal deposition)**



Welding process III - SPOT welding

Spot welding process

Joule의 공식 :

$$Q = I^2 \cdot R \cdot t$$

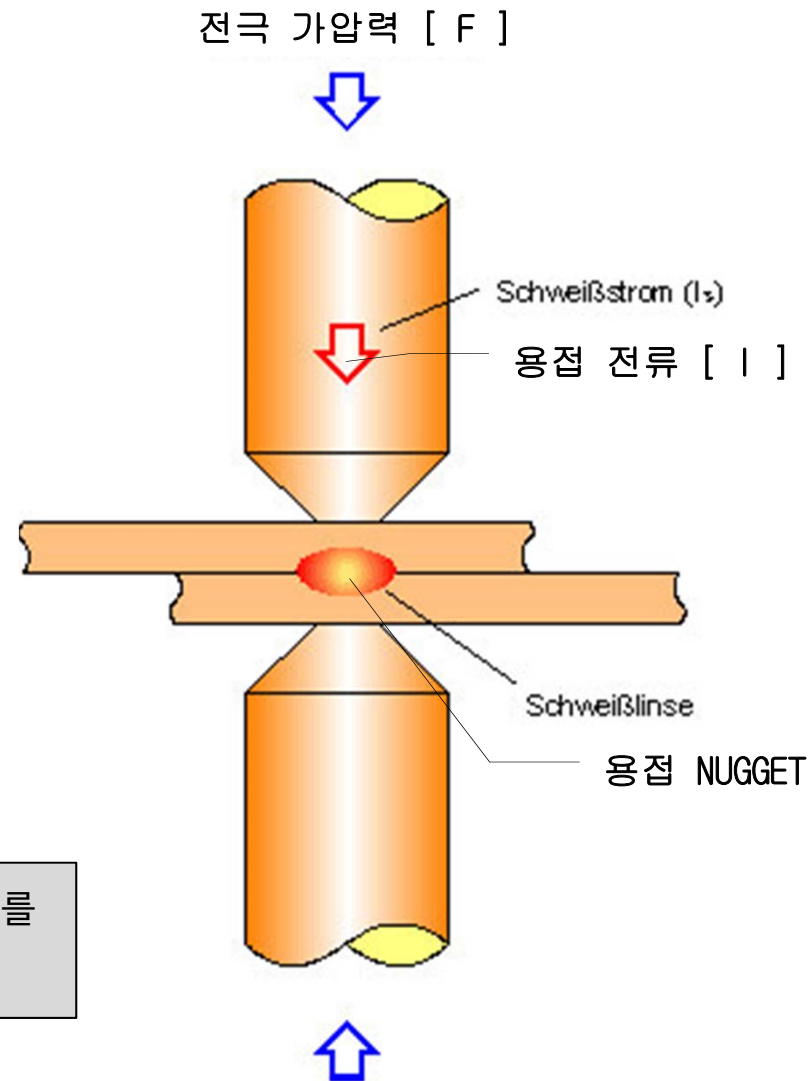
I: 전 류 [A]

R: 저 항 [Ω]

t: 시 간 [s]

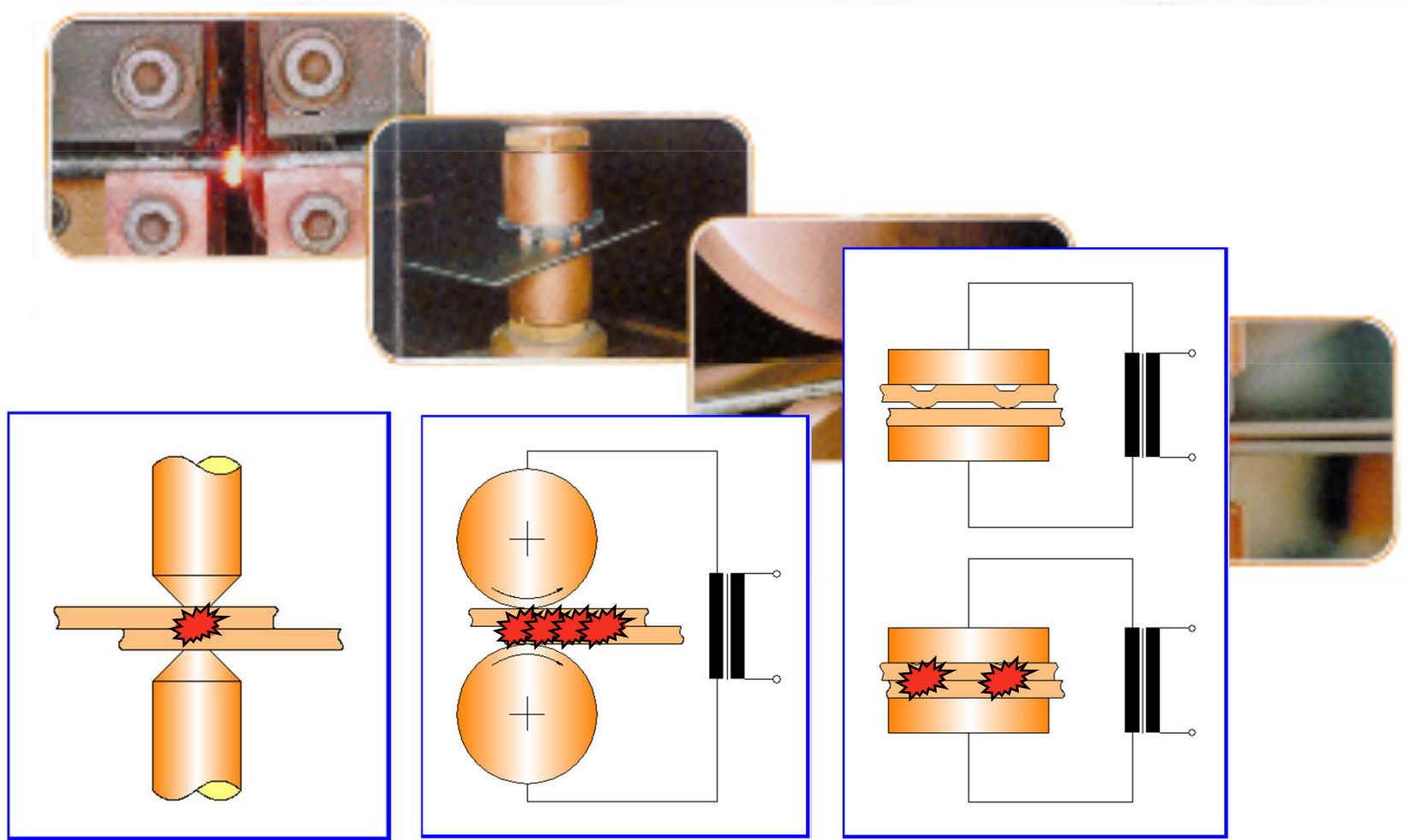
Q: 발열량 [Ws], [J]

용접할 금속과 금속을 전극으로 가압하고 전류를 흘려 주울열에 의해 용접부를 녹여 접합



Welding process III - SPOT welding

- **Classification**



점 용접 (SPOT)

연속 용접 (SEAM)

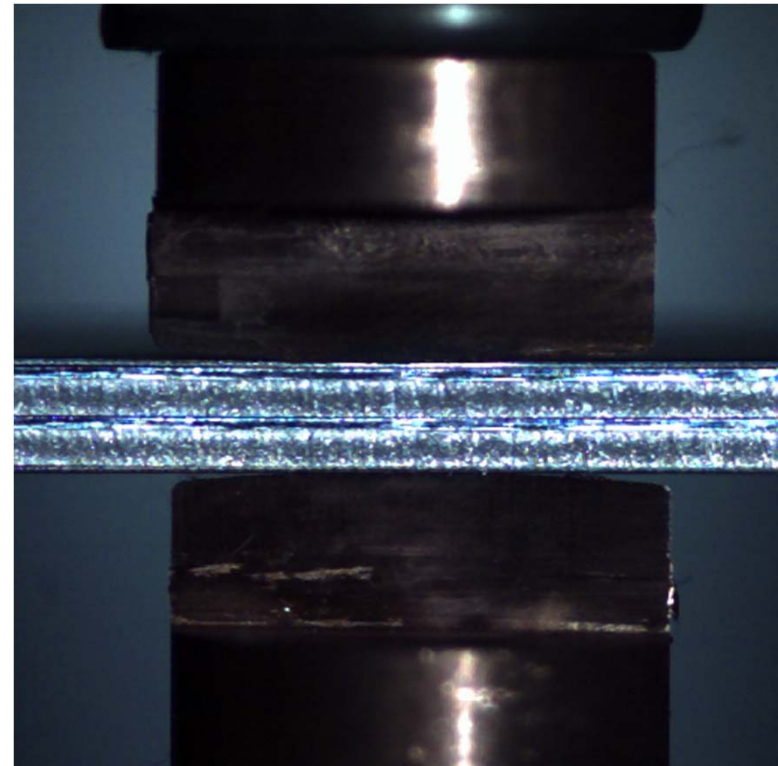
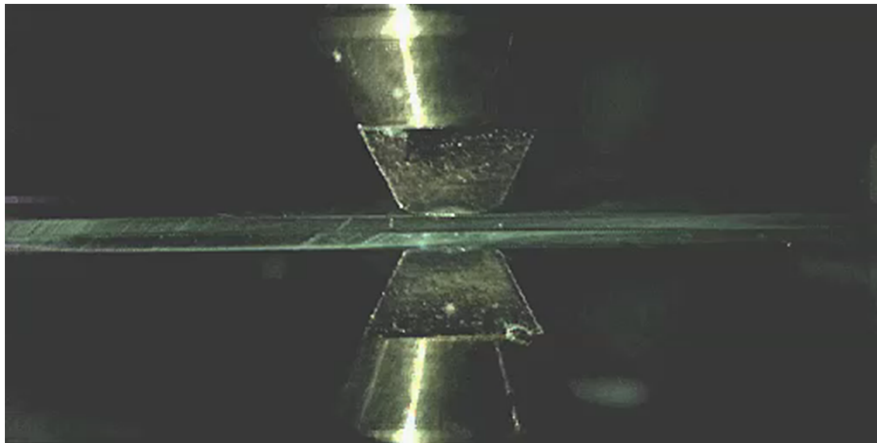
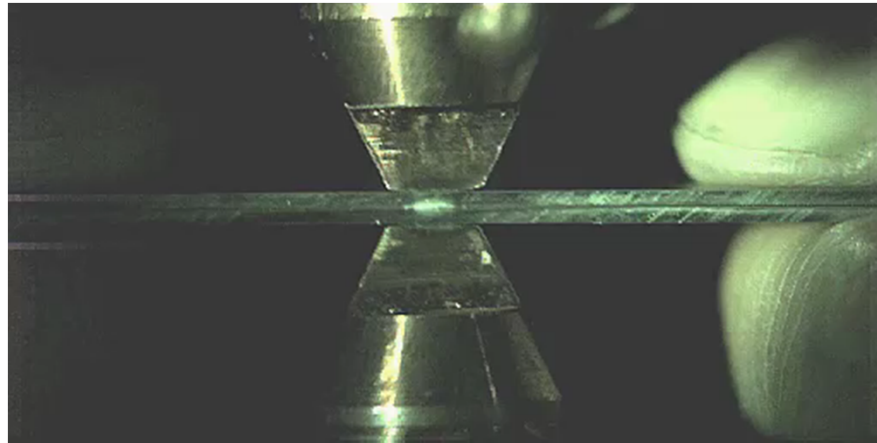
돌기 용접 (PROJECTION)



Welding process III – SPOT welding

● **Movie**

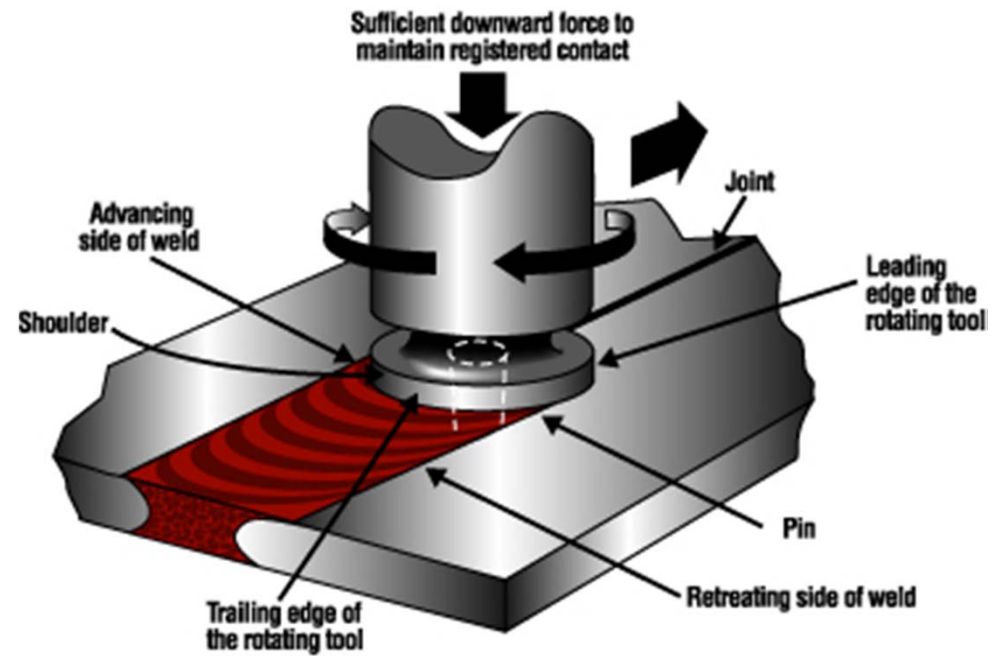
8 cycle (133 ms)



Welding process IV – FSW

● Friction stir welding process

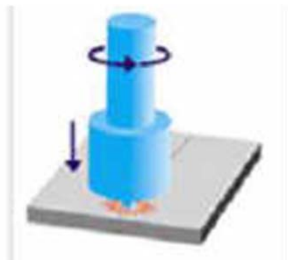
- Tool의 회전에 의한 Pin과 피접합체의 상호 마찰열 발생
- 재료의 소성유동으로 강제적 혼합



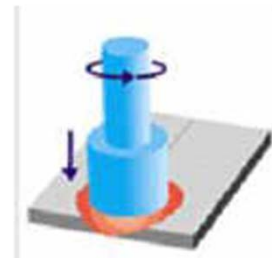
1)Rotating



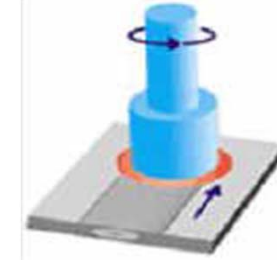
2)Plunging



3)Heating



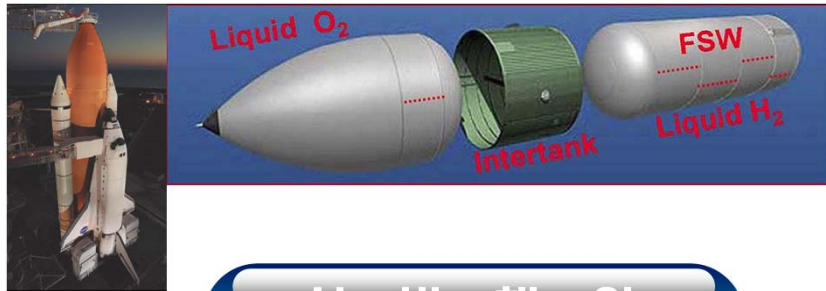
4)Translating



Welding process IV – FSW

우주항공

- 보잉사의 Delta II 로켓의 중앙 동체부
- 3 Airbus 3XX 항공기의 날개 및 동체일부
- 2착륙장치용 door
- Eclipse 500 상업용 항공기



운송기기

- Aluminum Wheel (Kuka등),
- Seat Frame (SAPA, Volvo등)
- Engine Supporter Mount



선박해양

- Marne Aluminum사 선박용 대형부품
- Deck
- Floor
- 어선용 냉동기 냉각판

철도차량

- Hydro Aluminum – TGV 객차의 roof
- Hitachi
 - 신칸센과 경전철 객차의 벽체
 - Roof floor의 Double skin 구조



Welding process IV – FSW

● Variation

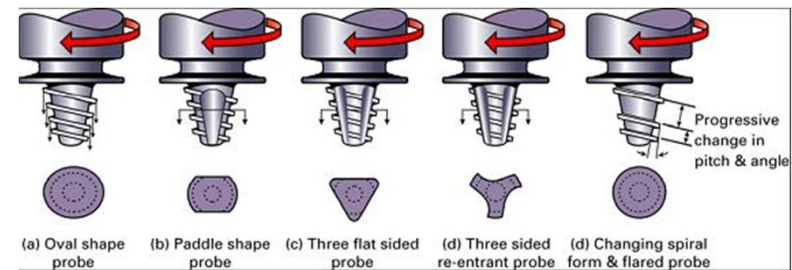
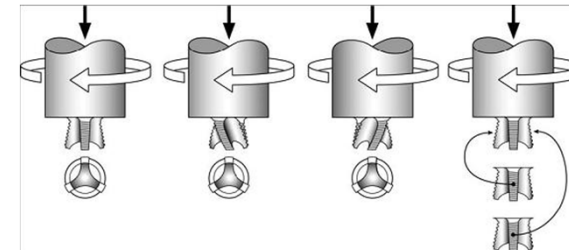
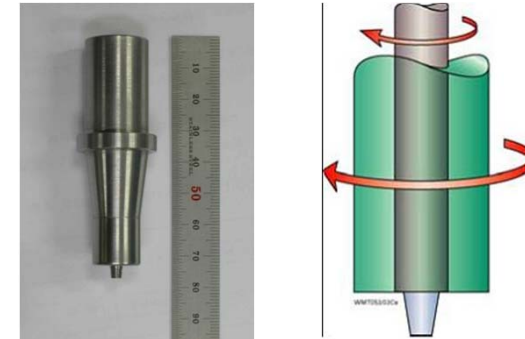
1. Tool의 형상 : shoulder & pin

2. Tool의 회전속도(rpm)

3. 용접속도(이송속도)

4. Tool의 삽입각

5. Tool의 삽입 깊이



Welding process IV – FSW

- **Application**



Welding process IV – FSW

● Movie



590 DP



780 DP



980 DP



1180 TRIP



경량



1500 HPF



Paper review

- **Laser welding of fully austenitic twinning induced plasticity steels**

- **Materials: TWIP, HCP980X, S420MC**

- **Equipment: 16 kW \square Disk laser**

Table 3 chemical composition of test material

Alloy	C [wt. %]	Mn [wt. %]	Al [wt. %]	Si [wt. %]	Cr [wt. %]
HSD [®] 600	0.7	15	2.5	2.5	-
HCT980X*	0.15	1.5	0.04	0.5	-
S420MC	0.035	0.6	0.04	0.02	0.13
S700MC*	0.06	1.85	0.04	0.05	0.06

*source: SSAB data sheets

Table 4 mechanical properties of test material derived from tensile tests

Alloy	t [mm]	BE [- A ₈₀]	YS [MPa]	TS [MPa]
HSD [®] 600	1.5	52	600	1020
HCT980X	1.5	11	810	1000
S420MC	1.5	17	420	540

Table 2 laser system used for experiments

Manufacturer	Trumpf	
Laser Name	TruDisk 16002	
Maximum Laser Power	P _L	16,000 W
Laser Type [†]	Yb:YAG	
Wavelength [†]	λ	1030 nm
Beam Parameter Product [†]	BPP	8 mm*mrad
Handling	3-axis CNC	
Fiber Diameter	d _f	200 μ m
Collimator: Focal Length	f _c	200 mm
Focusing Lens: Focal Length	f	560 mm
Spot Diameter	d _s	~560 μ m

[†]source: TruDisk 16002 data sheet

Paper review

Hot cracking

: residual melt가 dendrite를 채워주지 못하면 고온균열 발생.

Local tensile stress가 중요한 역할을 함.

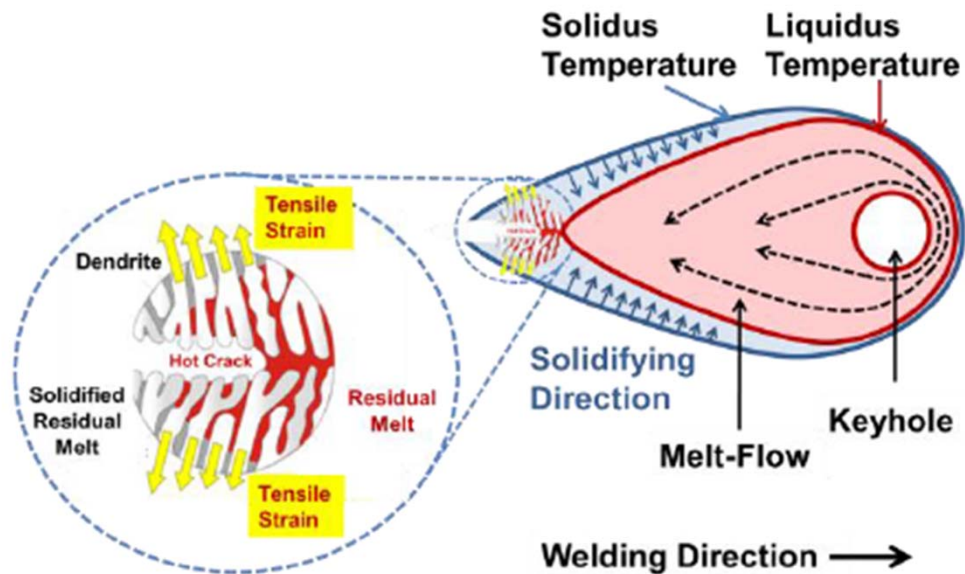


Figure 1: Depiction of the welding process and melt flow with dendrite-solidification [5].

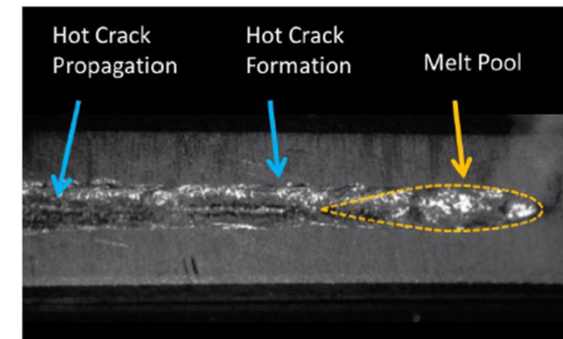


Figure 7: Single image from high-speed video sequence showing the formation of a hot crack right behind the melt pool.

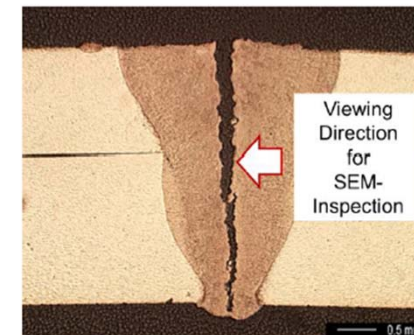


Figure 8: Cross section of the weld seam in the highly crack-sensitive test specimen.

Paper review

Spatter formation during laser welding

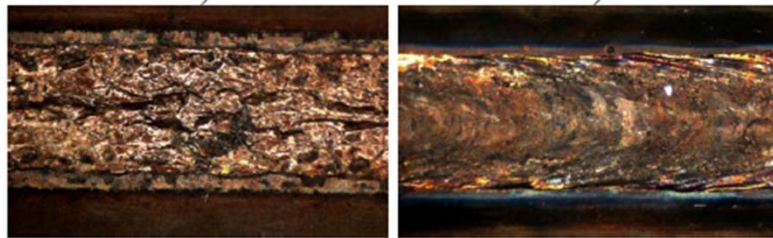
* Hot cracking

: GMA 또는 spot 에서는 발생한다고 보고되었으나, 레이저 용접에서는 낮은 입열로 인하여 관찰되지 않음.

v_f [m/min]	2	3	4	5	6	7	8	9	10
S420MC	0	0	0	0	7	3	2	3	0
TWIP	0	0	3	4	13	14	10	5	2
TWIP+Ar	0	0	0	0	0	0	0	0	0

legend: spatter counts per 50 mm weld seam
 none (green) low (yellow) medium (orange) high (red)

Figure 4 comparison of spatter formation at different feed rates; P_L : 4 kW, f : 560 mm, d_f : 560 μ m, z_f : 0 mm, Ar: 20 l/min (TWIP+Ar only)



P_L : 4 kW, v_f : 2 m/min

P_L : 4 kW, v_f : 2 m/min, Ar: 20 l/min

Figure 5 comparison of two laser welded TWIP seams; a) no shielding gas, b) argon used as shielding gas

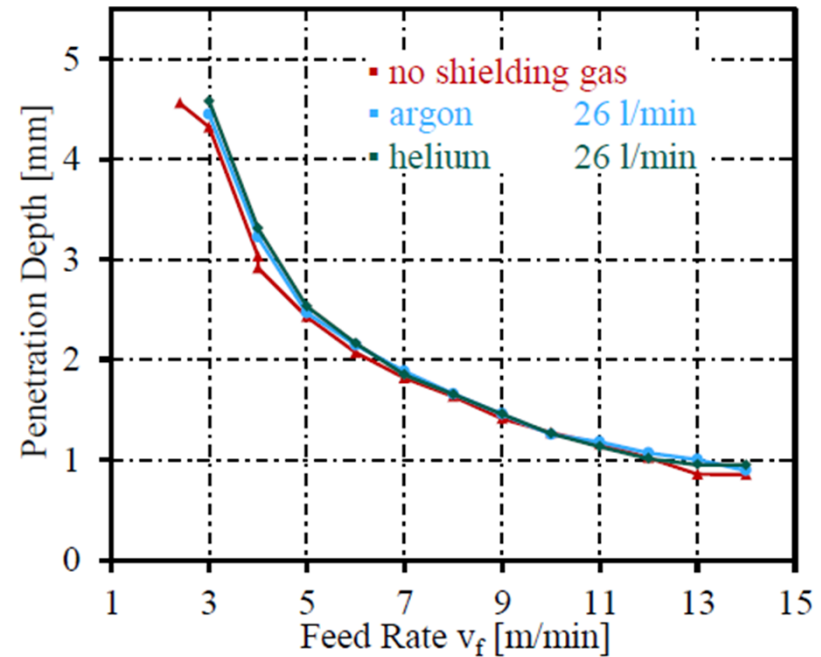


Figure 6 influence of inert gases on penetration depth of laser welded TWIP alloys; P_L : 3kW, z_f : 0 mm, gas flow (Ar & He): 26 l/min

Paper review

● Micro-section and hardness distribution

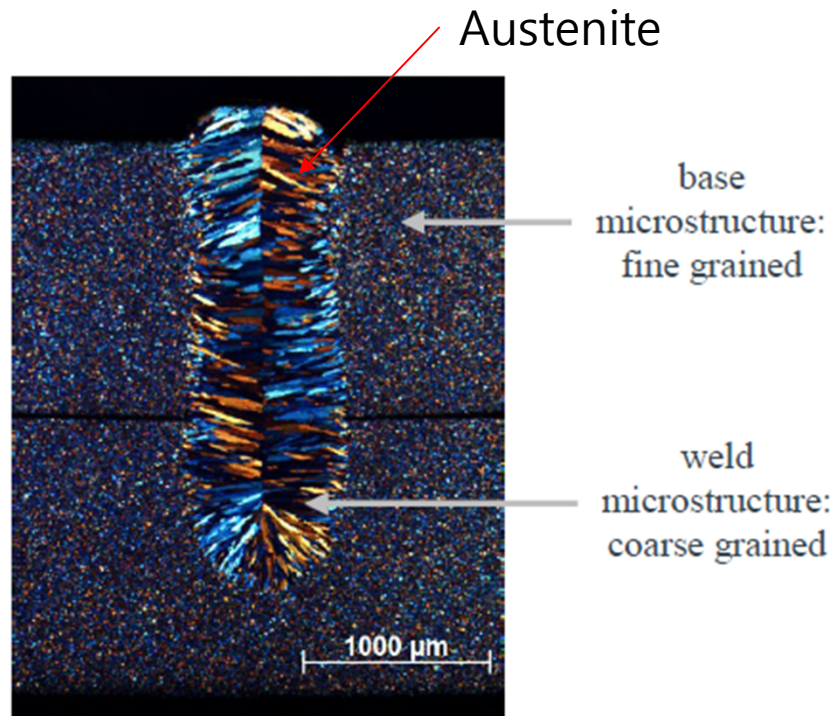


Figure 7 microsection of single lap seam: HSD[®]600 t = 1.5 mm + HSD[®]600 t = 1.5 mm; corrosive: nital + aqueous sodium sulfite (20%); PL: 4 kW, v_f : 7 m/min, f: 560 mm, d_f : 560 μm , z_f : 0 mm, Ar: 20 l/min

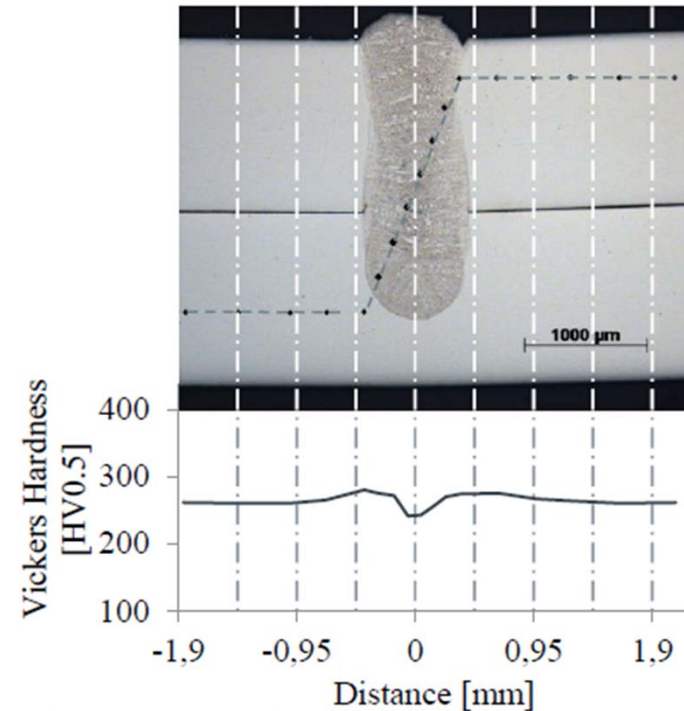


Figure 8 Vickers hardness measurement through a laser welded HSD[®]600-seam; P_L: 4 kW, v_f : 7 m/min, z_f : 0 mm

Paper review

- **Appearance of failure specimen**

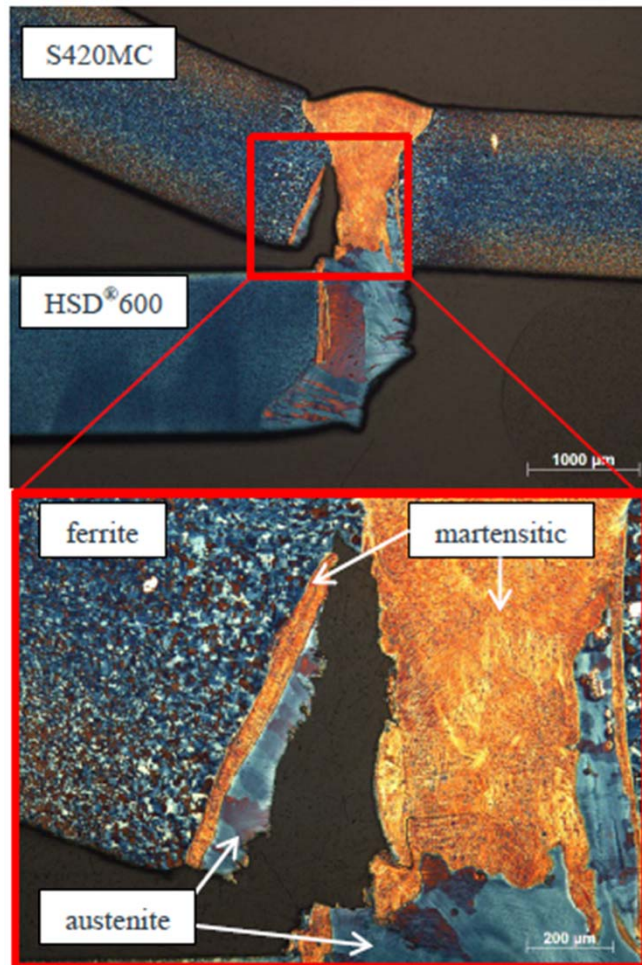


Figure 12 appearance of a through welded, dissimilar seam (HSD[®]600, S420MC); P_L : 4 kW, v_f : 3 m/min, z_f : 0 mm



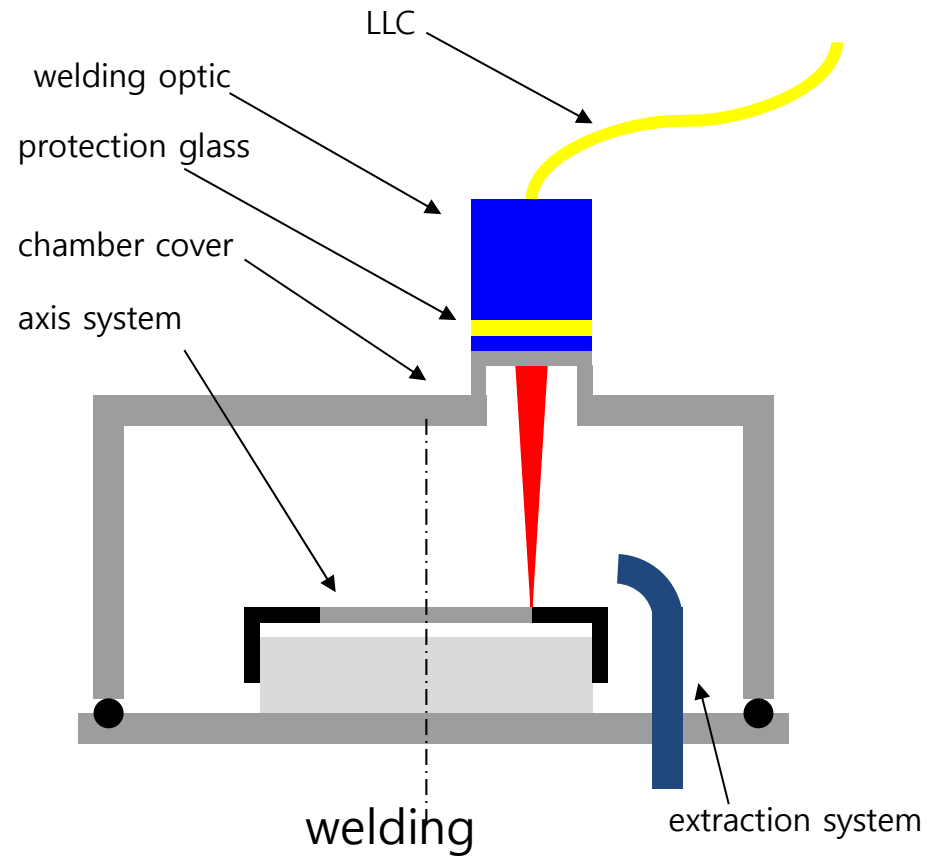
THANK YOU FOR YOUR ATTENTION !



KITECH Korea Institute of Industrial Technology



Laser Welding below Atmospheric Conditions



Metal-Plastic-Joining

- Bring in with the Laser macro- and microscopical structures of the metal surface
- Spray warmed plastic on these structures
- „Connecting“ of both materials

