Research Activity in ING-IND/16

Speaker: Dr. Annamaria Gisario
Sapienza Università di Roma,
Dipartimento di Ingegneria Meccanica e Aerospaziale,
Via Eudossiana, 18, 00184 Roma (Italy)

Laser in Mechanical Industry

LASER PROCESSING OF MATERIALS

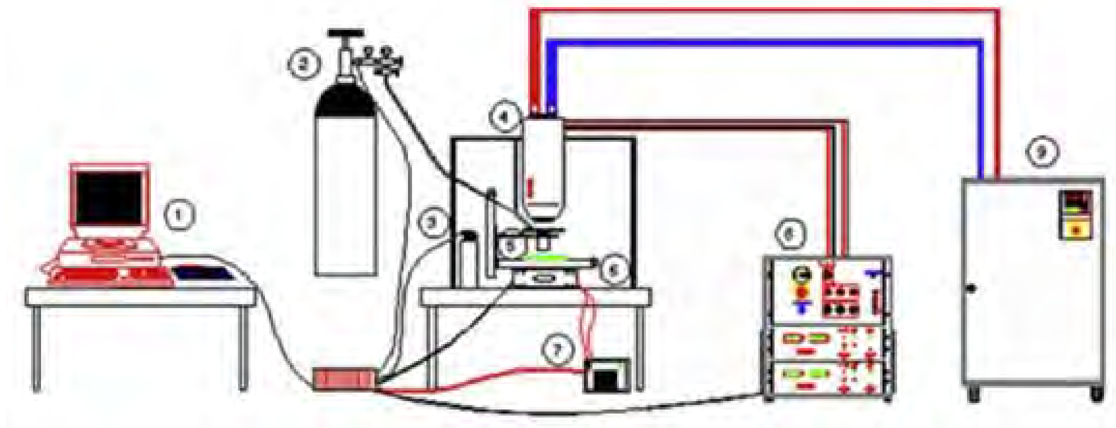
Laser Cutting	Laser Hardening	Laser Cleaning	Laser …
Laser Drilling	Laser Annealing	Laser Paint Stripping	
Laser Welding	Laser Cladding	Laser Recycling	
Laser Milling	Laser Sealing	Laser Forming	
Laser Marking	Laser Polishing	Laser Joining	

Laser is an intelligent light wave technology that can perform all technological tasks in all areas of studies very well with a great flexibility and with high accuracy

Laser can be used in a creative way!

HIGH POWER DIODE LASER

LASER APPARATUS



(1) Computer and data acquisition unit
(2) Gas cylinder
(3) CCd camera
(4) Diode laser head
(5) Workpiece
(6) Movement system
(7) Moving table Power unit
(8) Diode laser power unit
(9) Chiller

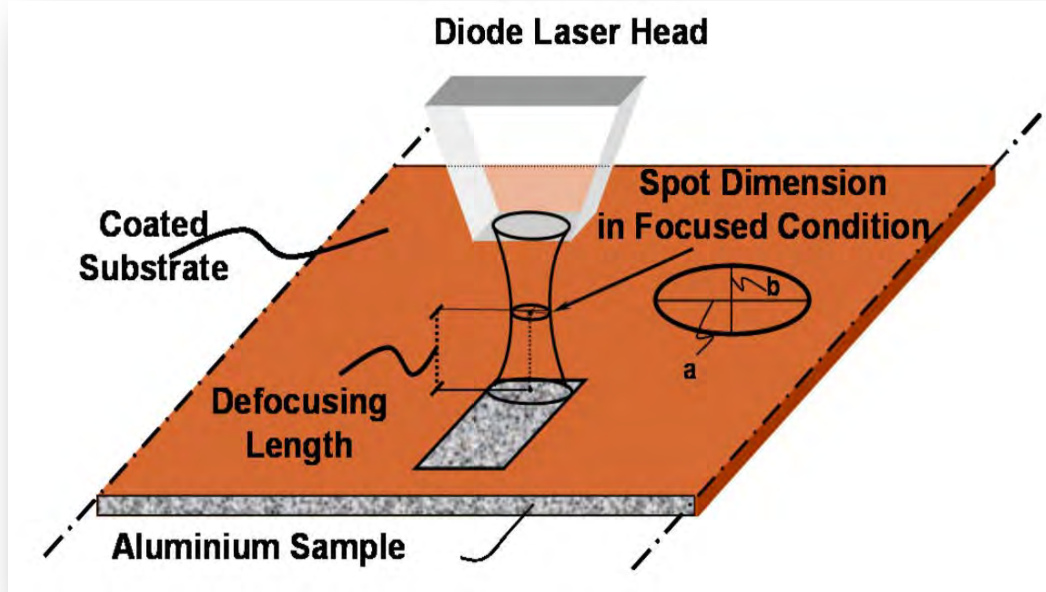
ROFIN SINAL DL015	
MAX POWER	1500 W
WAVELENGTH	~ 940 nm
SPOT SHAPE	elliptical
FOCAL SPOT SIZE	1,2mm x 3,8 mm
EFFICIENCY	30-50%
WEIGHT	8Kg

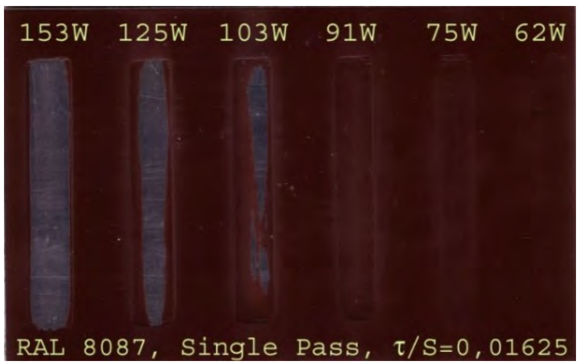
ADVANTAGES:

(1) Shorter wavelength of the beam → higher absorption coefficient
(2) Better temporal stability
(3) Investment costs and operating costs much lower
(4) very compact source
(5) Long life (up to 100,000 hours)
(6) higher efficiency
(7) No maintenance

LASER PAINT STRIPPING

SUBSTRATE: AL 2029-T3
PAINTED SAMPLES





INDUSTRIAL APPLICATION

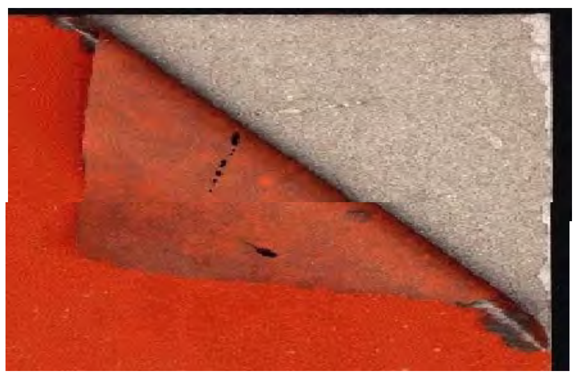
- ✓ aircrafts, boats, bridges
- ✓ mold cleaning in Injection Molding

LASER CLEANING

Rust removal on stainless steel substrates

Graffiti removal and Art Restoration

Pre-weld de-greasing and cleaning



LASER RECYCLING

Recycling of polycarbonate from CD or DVD

Geometry:

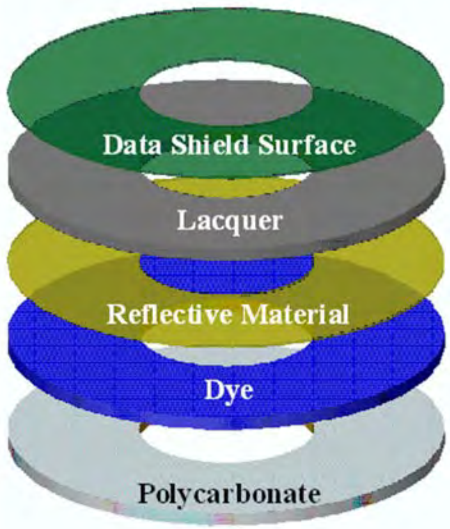
- Thickness = 1,2 mm
- Outer Diameter = 120 mm
- Inner Diameter = 34 mm

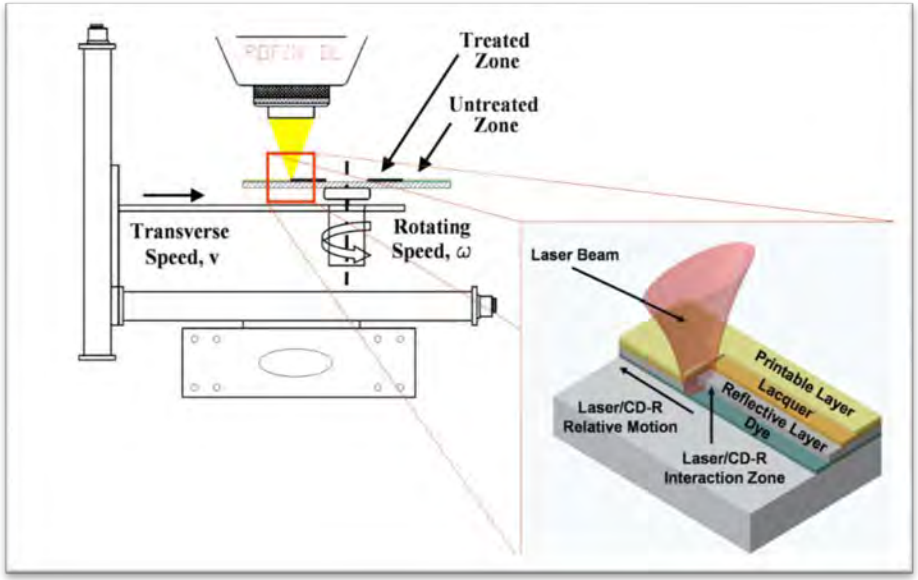
Bonding among layers:

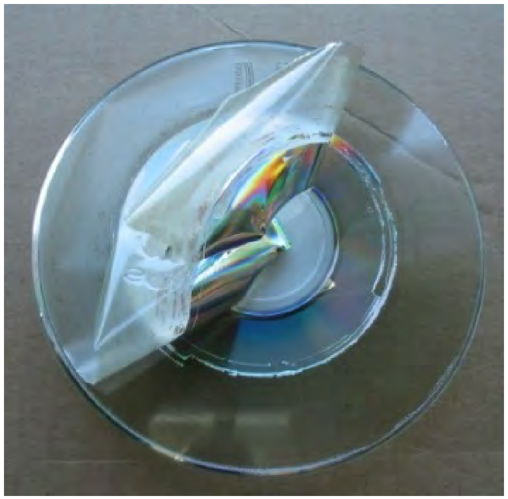
- Epoxy resin

Manufacturing time:

- > 5 s



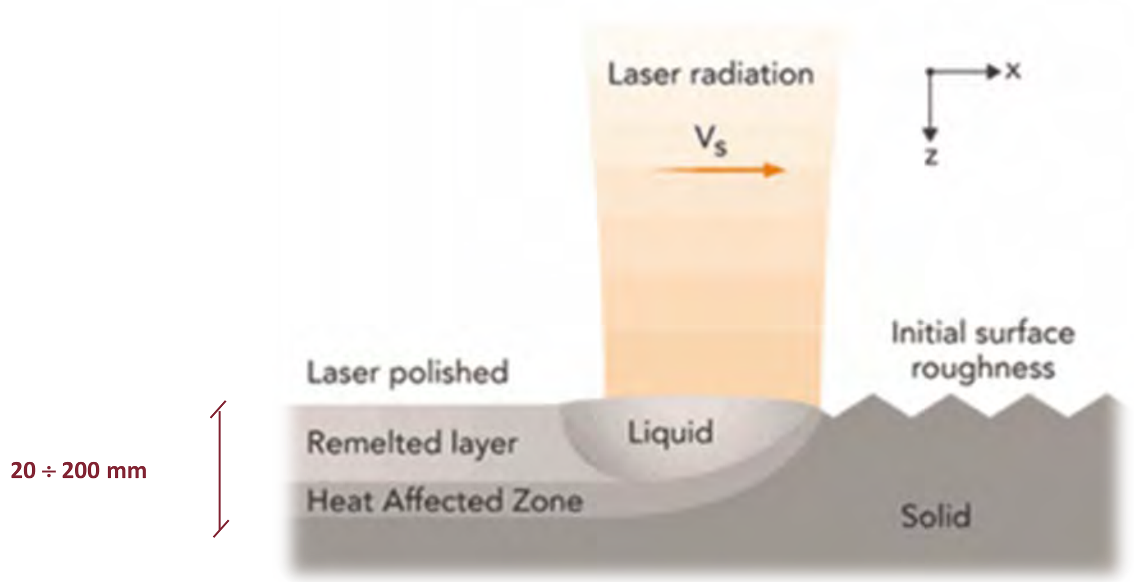




Treatment time:
4 s/CD

LASER POLISHING

Polishing with laser radiation is based on remelting a thin surface layer of the workpiece and the subsequent smoothing of the surface roughness due to surface tension.

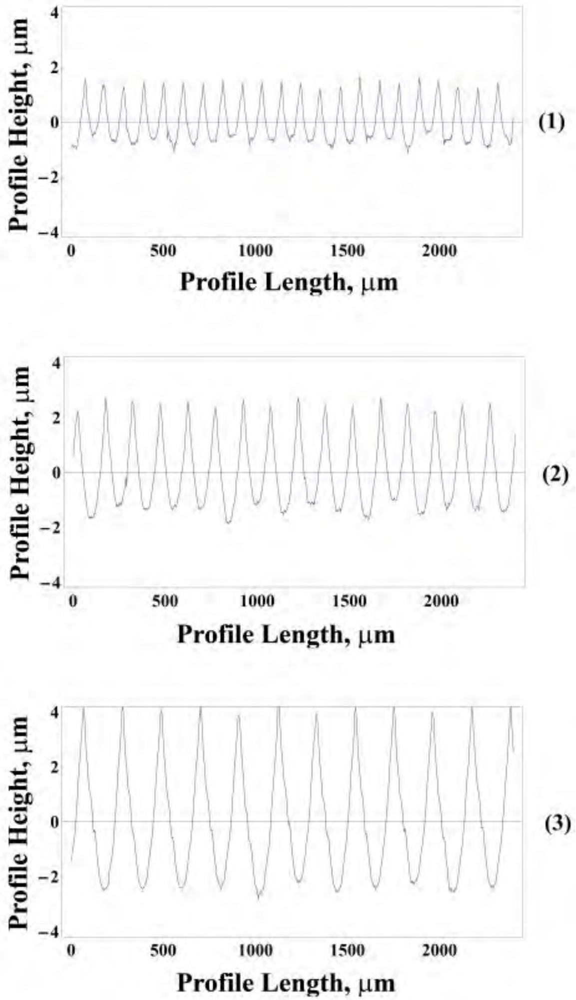


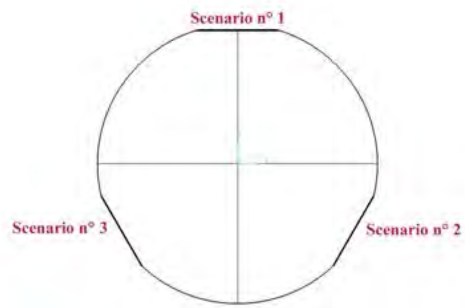
The innovation of laser polishing results from the fundamentally different active principle (remelting) compared to conventional grinding and polishing (abrasion).

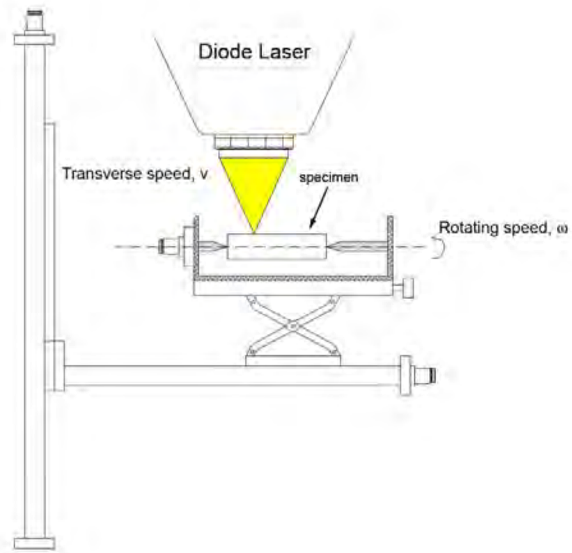
For metals diode-pumped solid-state lasers are normally used. Pulsed laser radiation with pulse durations of several 100 ns is used for metallic surfaces with a small initial surface roughness, e.g. after grinding. If the initial roughness is higher, e.g. after milling or EDM-processing, continuous laser radiation must be utilized. The remelting depth is in the range of several 100 nm for pulsed and up to 100 µm for continuous laser radiation.

LASER FINISHING ON MILLED SURFACES

Laser finishing can be a suitable way to modify the typical peak-to-valley topography induced by milling process of metal substrates in a nearly ‘custom-made’ surface texture.

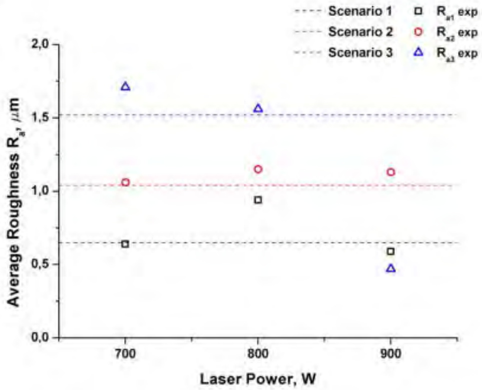




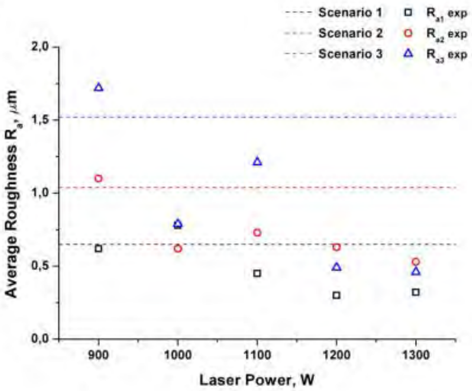


Laser beam speed, mm/s	Rotating speed, rpm	Peripheral speed, mm/s	Laser Power, W
3	≈ 52	≈ 68	700 ÷ 900
5	≈ 86	≈ 112	900 ÷1300
7	≈ 120	≈ 157	1300 ÷1500

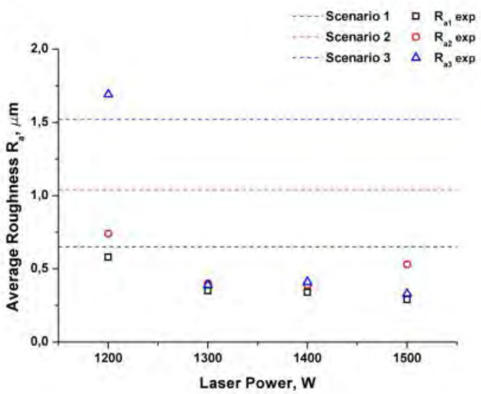
(a)



(c)

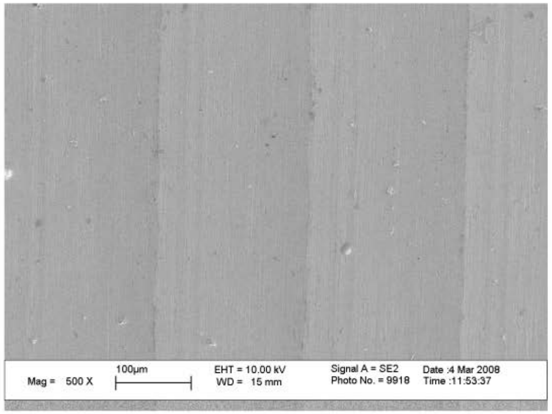


(e)

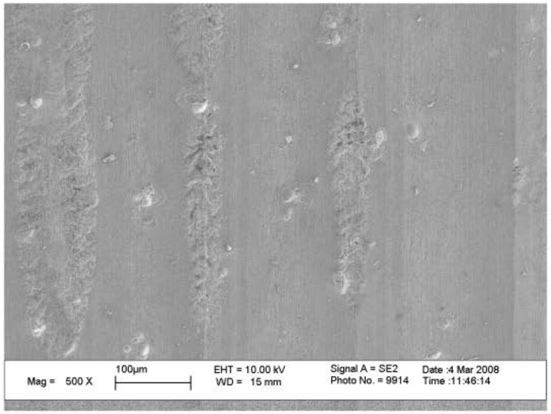


The milled surface approaches asymptotic values of the roughness parameters, with final values not depending on the starting values of the surface after the milling process but only on the operational settings.

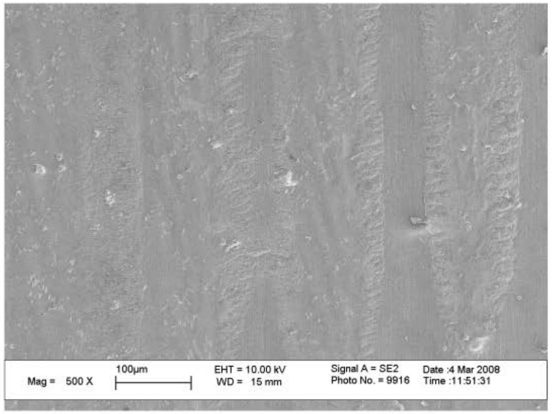
SEM Analysis



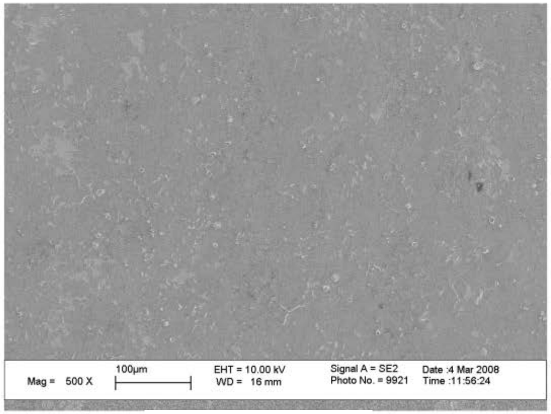
(a) Untreated



(b) Under treated



(c) Fairly treated



(d) Treated

LASER REMELTING ON SINTERED SURFACES

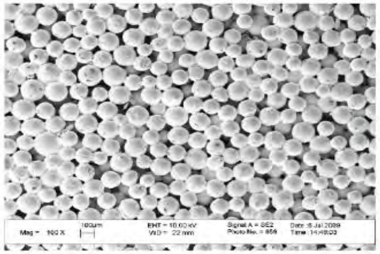
Chemical composition of sintered filter:

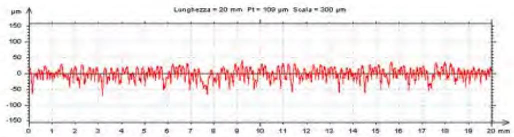
Cu 88-89%

Sn 10-11%

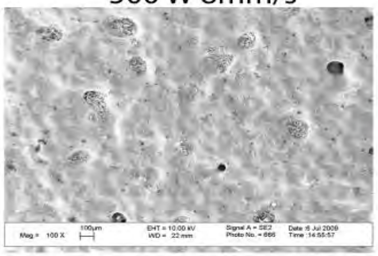
P 0.2-0.5%

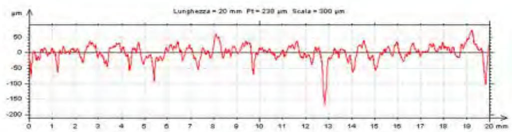
Non trattato



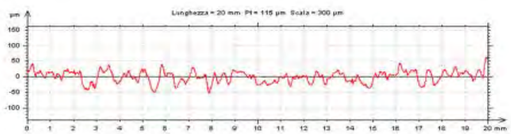


500 W 8mm/s

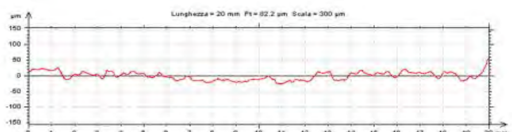


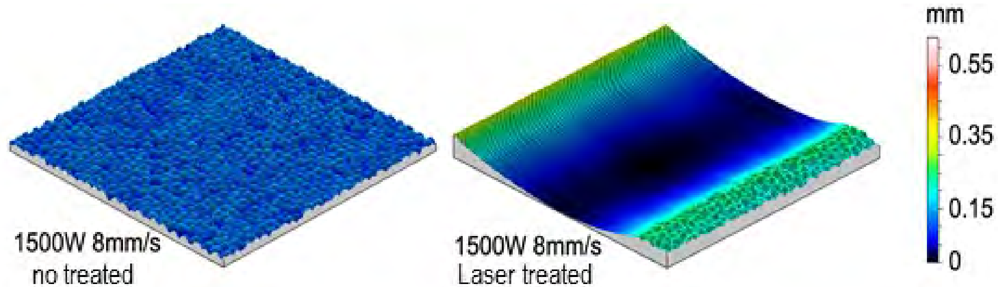


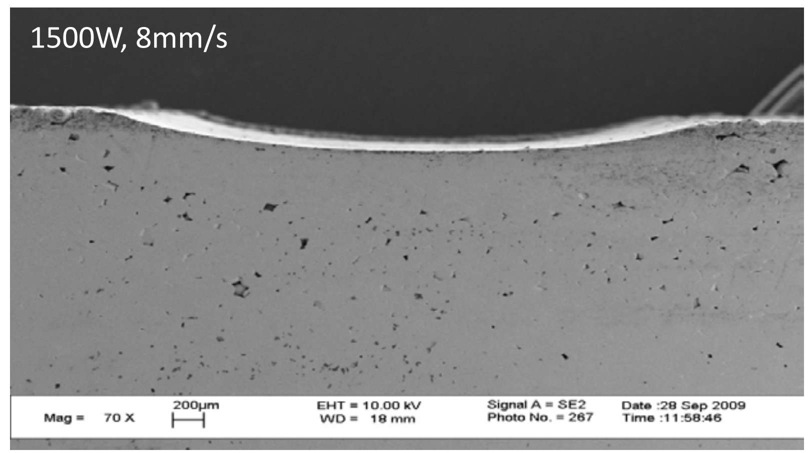
800 W 8 mm/s



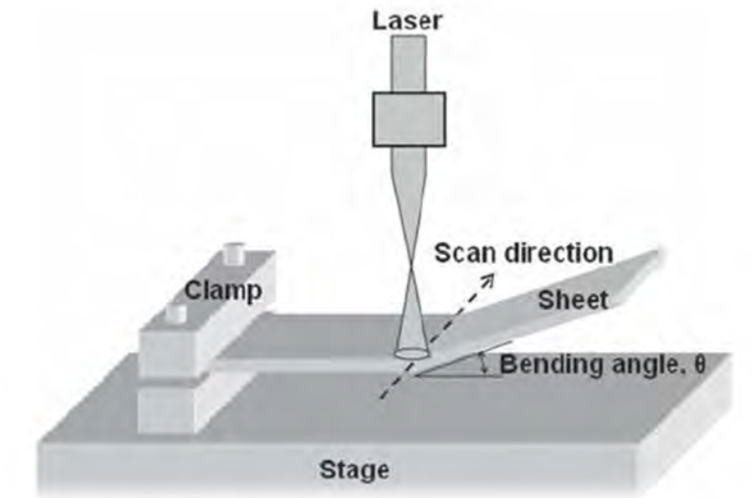
1500W 8mm/s







LASER BENDING

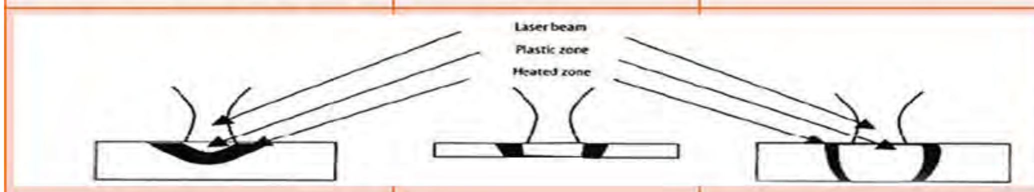


TGM
The side of the workpiece directly irradiated by laser is rapidly heated and approaches a higher temperature than the opposite side, thus expanding more. Tensile stress is generated inside the layers of material directly exposed to laser source, while, on the other side, compressive stress arises. On cooling off, the irradiated side contracts more and the workpiece bends toward the laser source because of the inversion of the residual stress fields, with the topmost layer being in compression and the down most in traction.

BM and UM occur at low scan speed of the laser beam, when temperature is fairly uniform across the thickness of the workpiece.

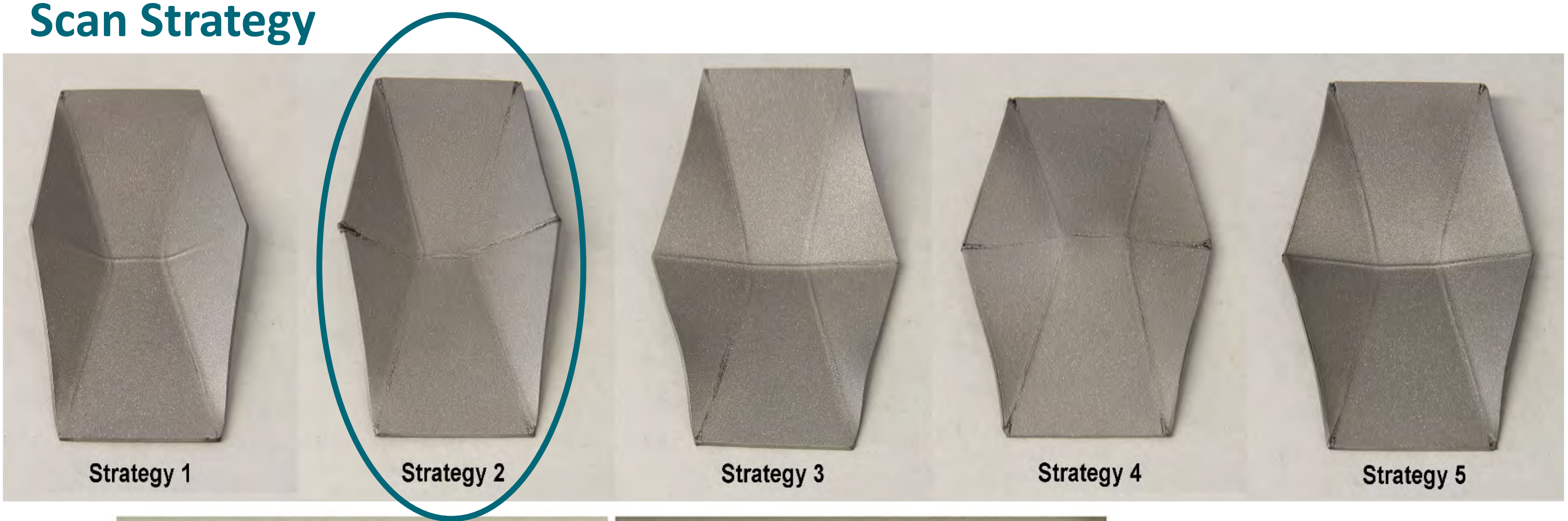
When the size of the laser beam is bigger than workpiece thickness, BM takes place, with the material being formed towards the same side of the irradiation.
When the size of the laser beam is closer to workpiece thickness, UM takes place, with the concurrent thickening of the irradiated portion of the material and bending by instability.

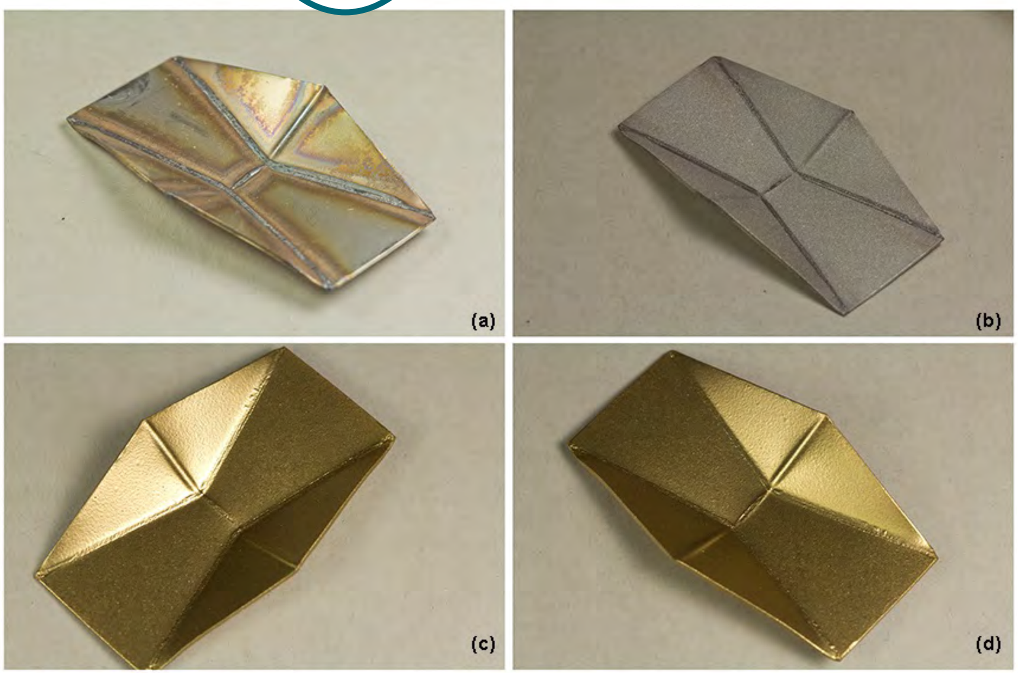
Temperature Gradient Mechanism (TGM)	**Buckling Mechanism (BM)**	**Upsetting Mechanism (UM)**

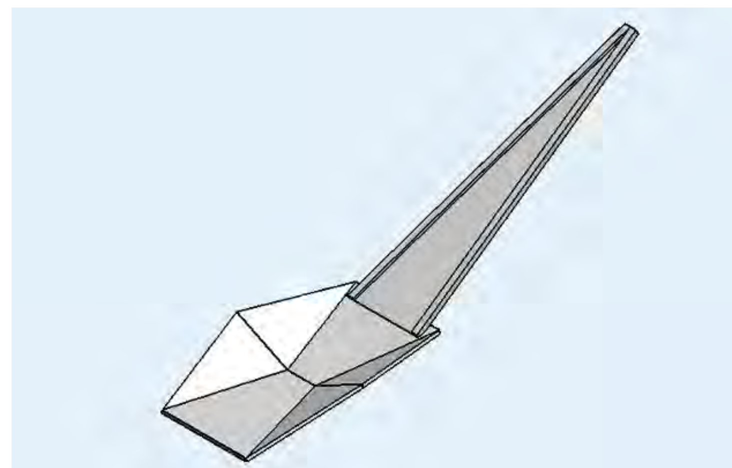


Manufacture of an ORIGAMI SPOON

Scan Strategy







3D LASER FORMING

Scan 4

Strategy 1

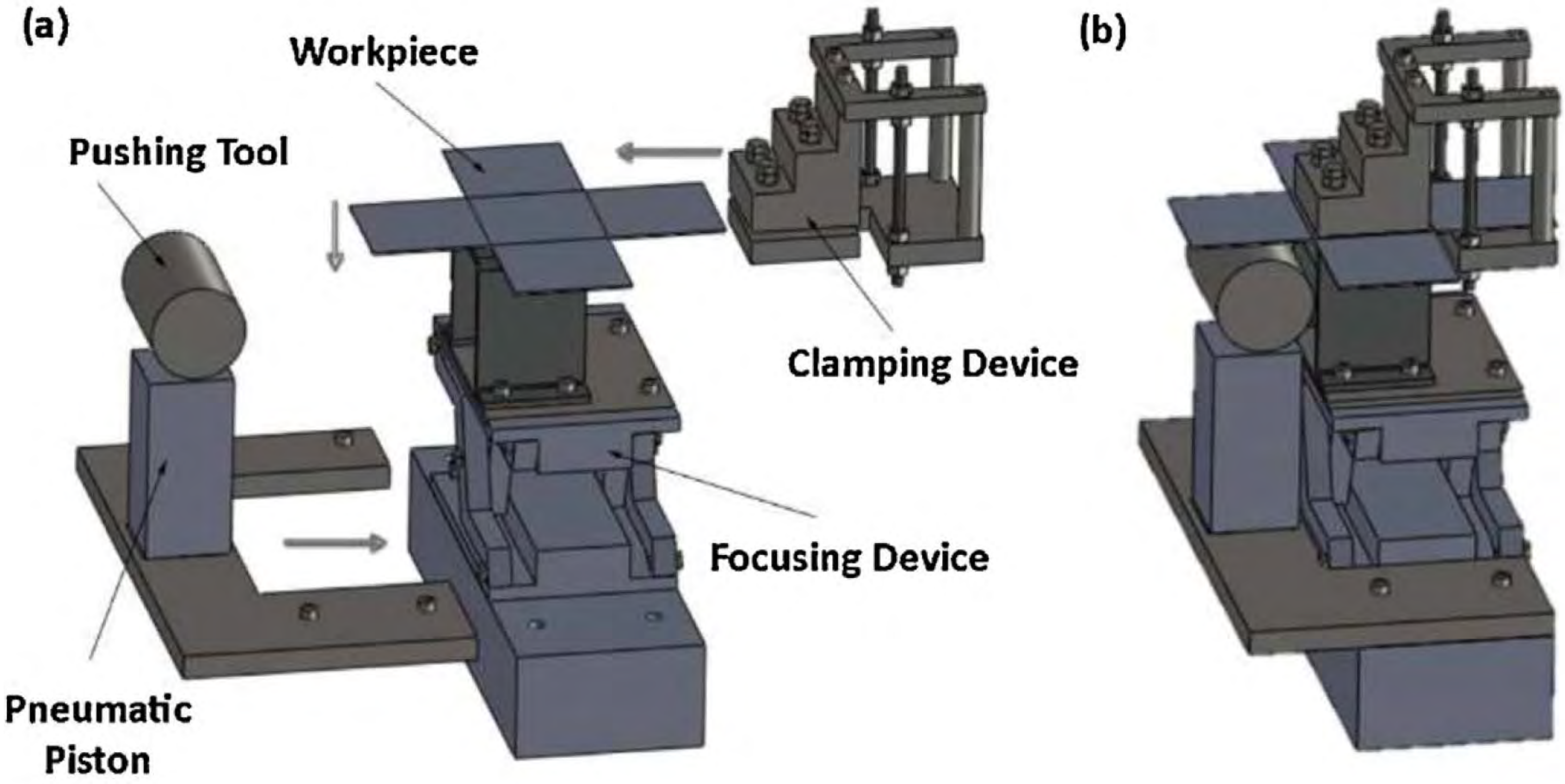
Strategy 3

Strategy 5

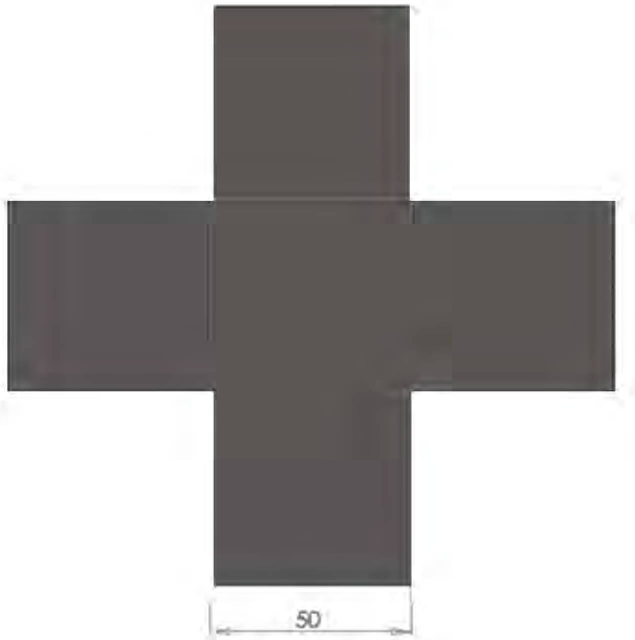
N° of Strategy	Scanning pattern	Power (W)		Scan speed		N° of circular passes
		Radial	Circular	Radial (mm/s)	Circular (m/min)	
1	1-2-3	/	900	/	5,5	6
2	4-5-6	300	/	8	/	/
3	4-5-6-1-2-3	300	900	8	5,5	6
4	3-2-1	/	900	/	5,5	6
5	6-5-4	300	/	8	/	/
6	6-5-4-1-2-3	300	900	8	5,5	6
7	4-5-6-1-2-3	300	700	8	5,5	3
8	6-5-4-1-2-3	300	700	8	5,5	3
9*	6-5-4	300	/	8	/	/

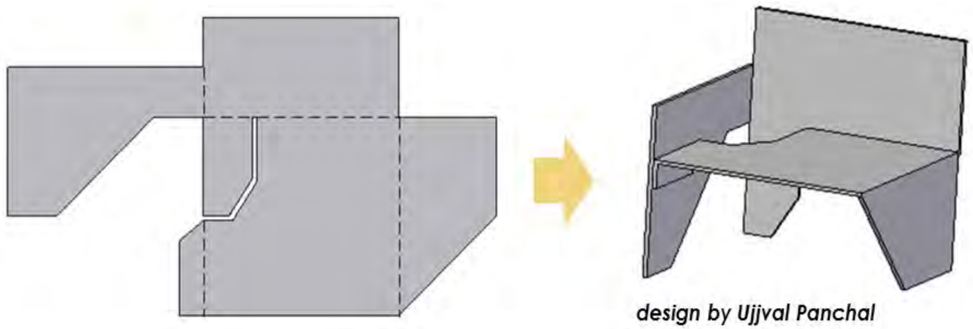
FREE SHAPES 3D FORMING BY COMBINATION OF CIRCULAR AND RADIAL SCANNING PATTERNS

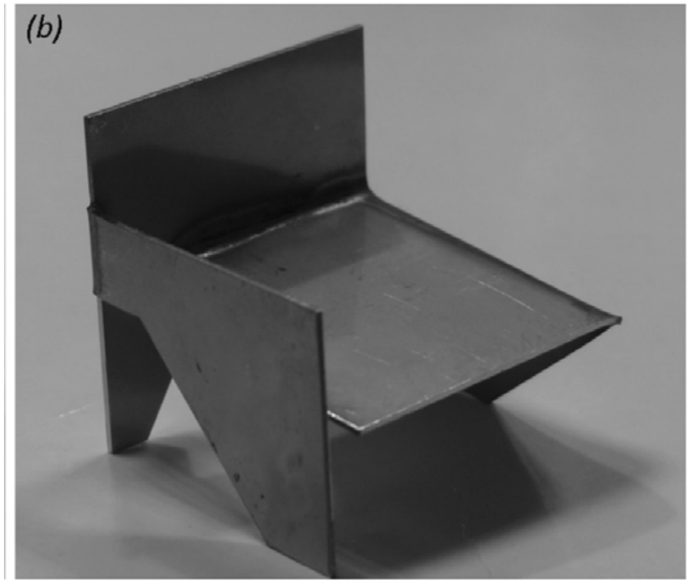
EXTERNAL FORCE-ASSISTED LASER-ORIGAMI BENDING (LO)

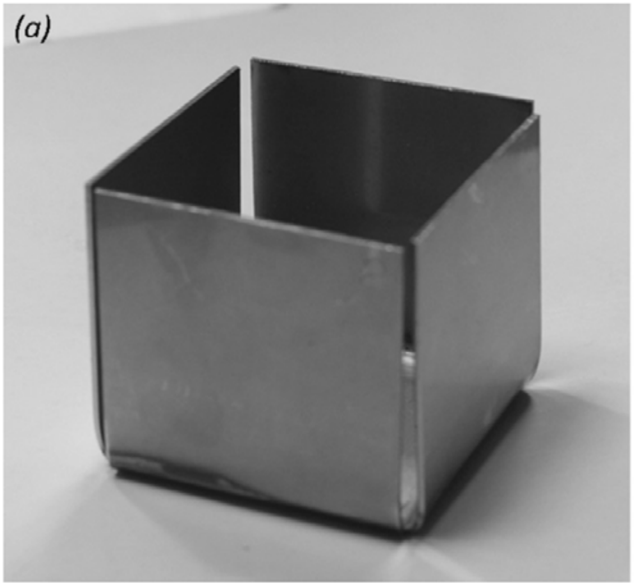


Shaping of 3D cubes and edge design of stainless steel chairs

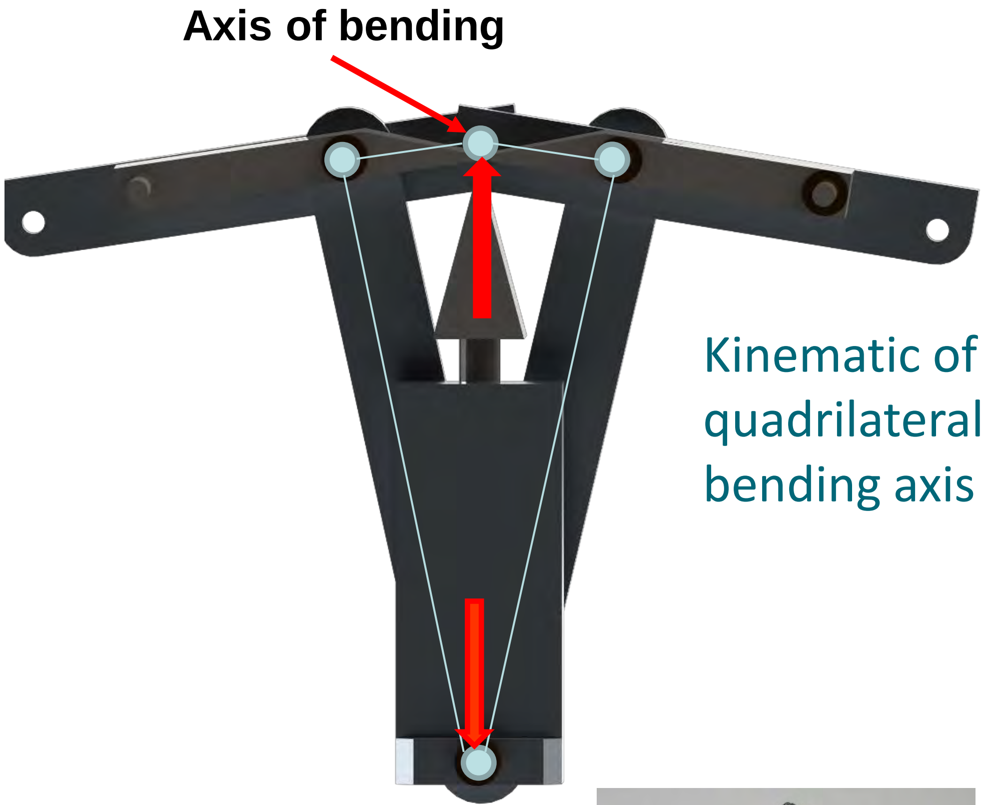




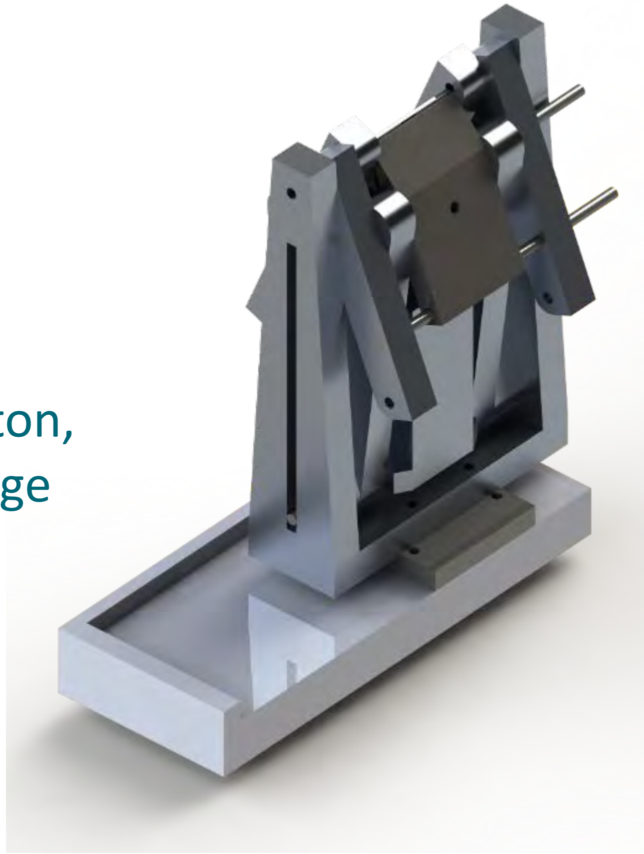


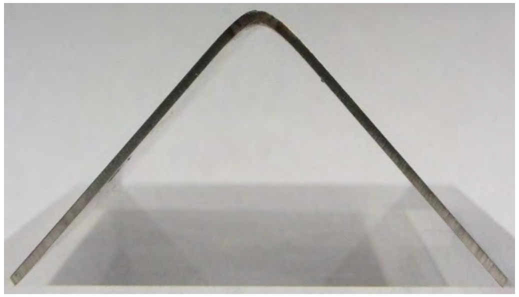


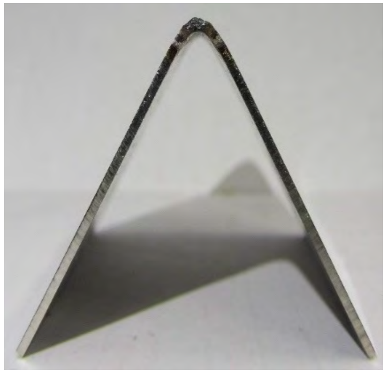
LASER ASSISTED BENDING OF SHARP ANGLES



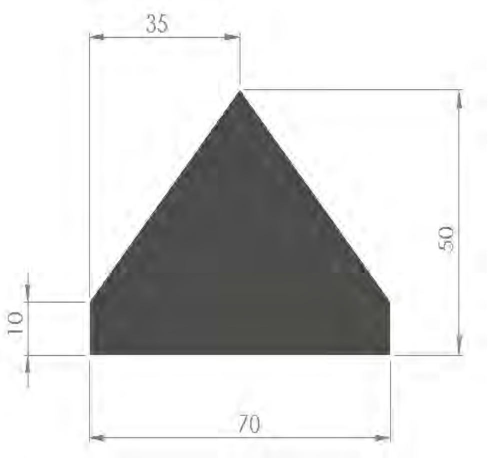
Kinematic of deformable quadrilateral, pneumatic piston, bending axis and bending edge

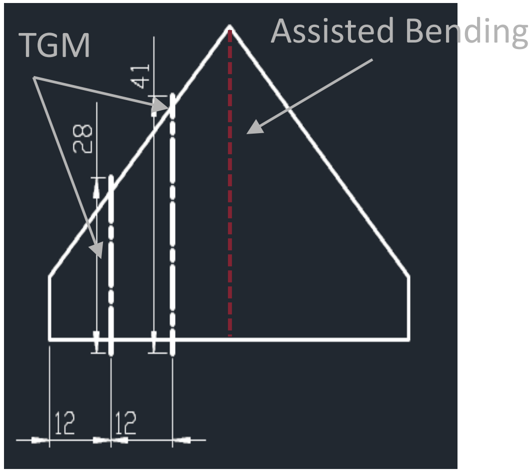




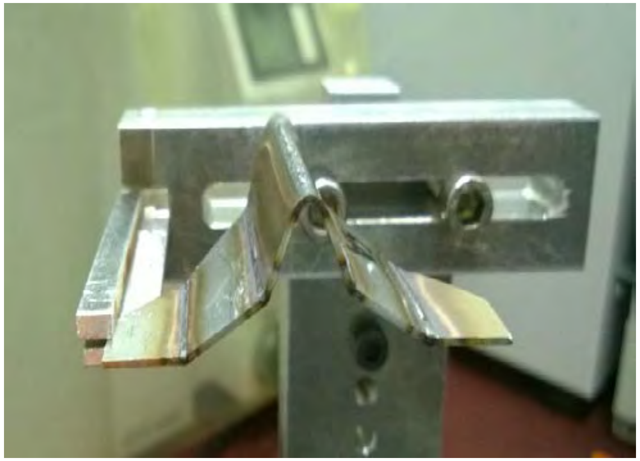


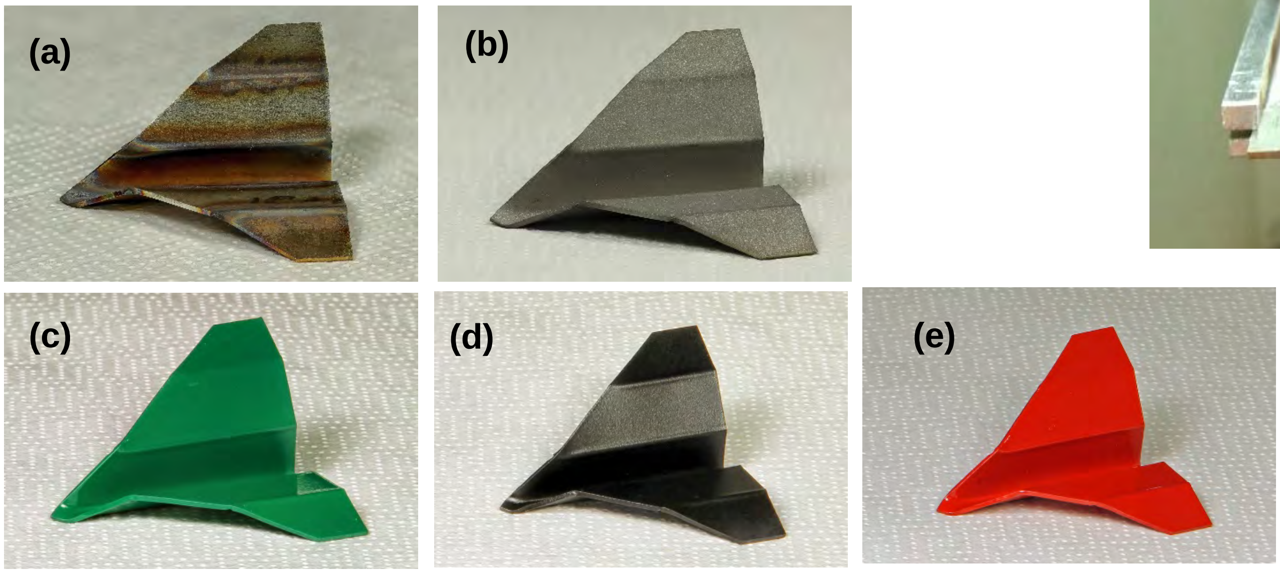
Manufacture of an AIRCRAFT PROTOTYPE





Path	Power [W]	Speed [mm/s]	N° of pass
Central bending	155	1,5	15
Bending of wings	200	6	12

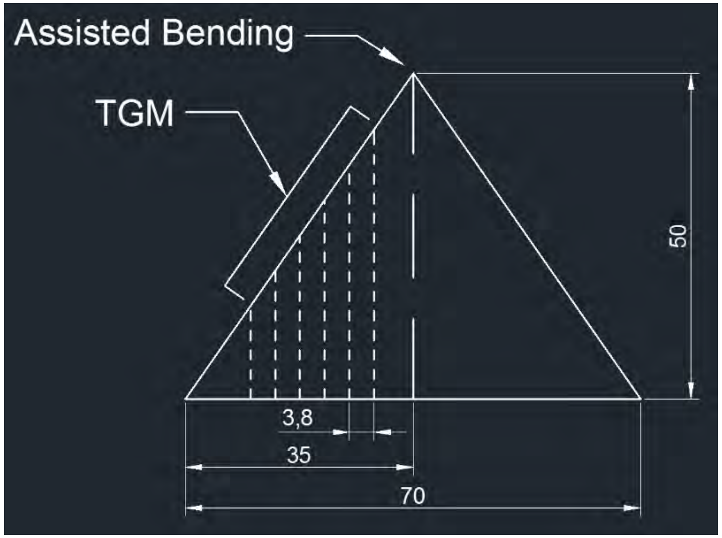


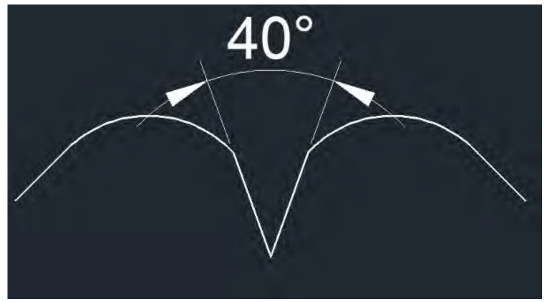


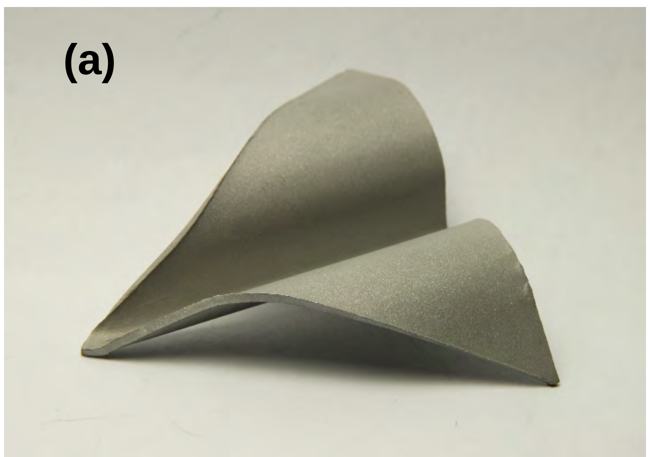
a) Laser treated b) Sand Blasted c-d-e) Painted

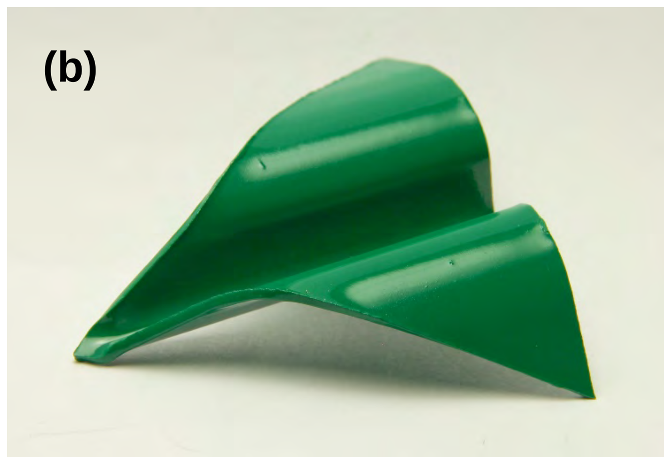
Manufacture of a GULL-WING

Path	Power [W]	Speed [mm/s]	N° of pass
Central bending	450	10	12
Bending of wings	240	12	18







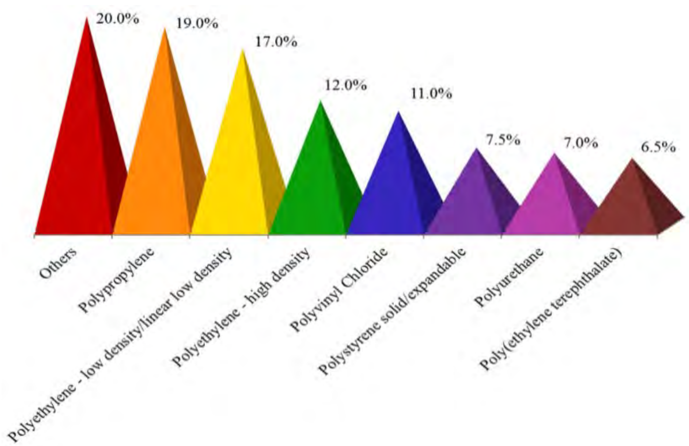


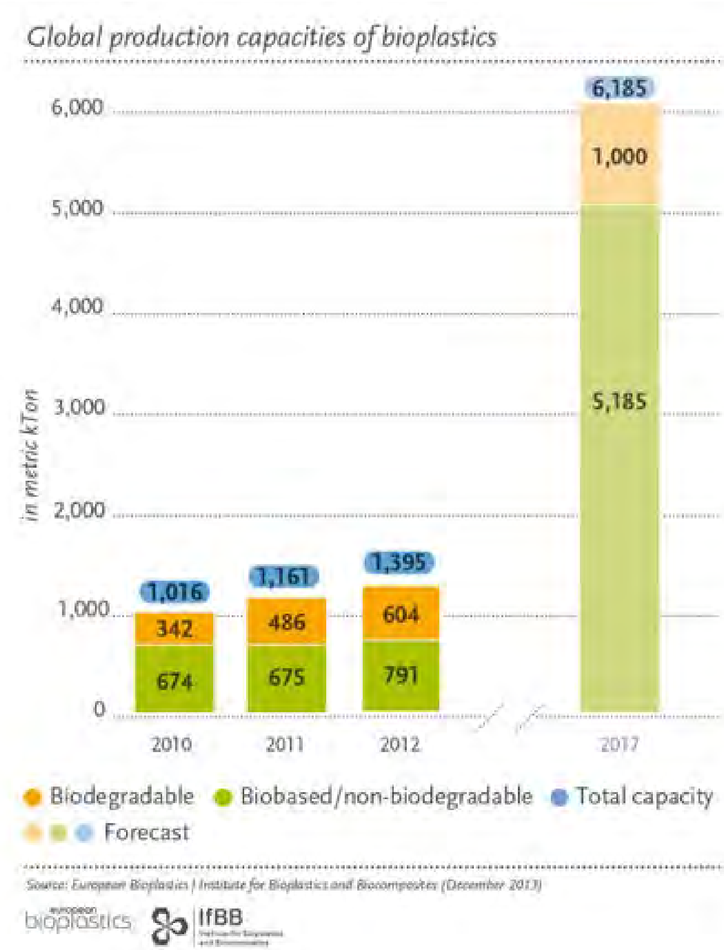
a) Sand Blasted; b) Painted

LASER TRANSMISSION WELDING (LTW)

Lasers in the Packaging Industry

Poly(Ethylene Terephthalate) (PET)



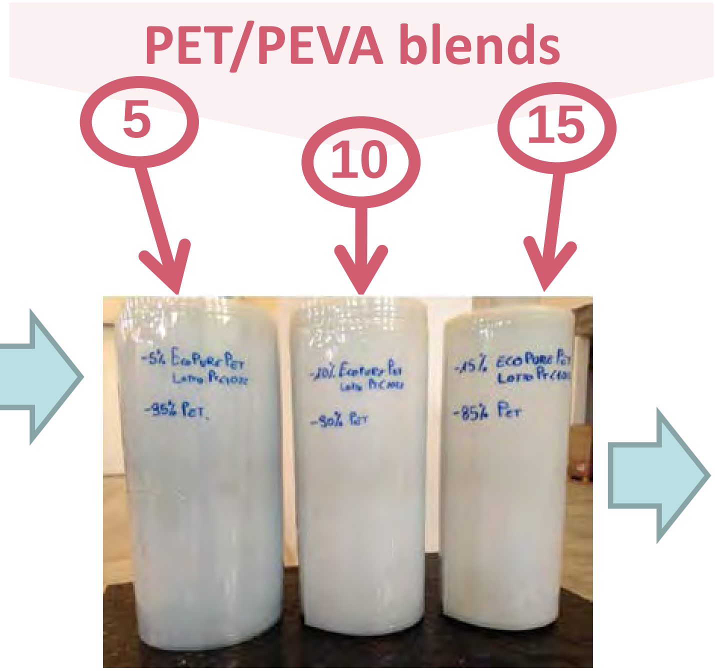


6,5 % share of the global plastics market

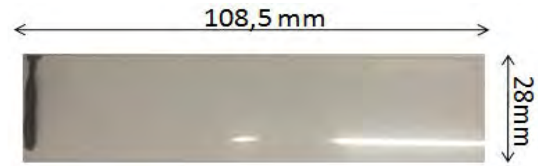
Environmental requirements: PET can be recycled [*Europ. Polym. J. 41 (2005) 1453-1477*], but, unfortunately, it is not biodegradable or compostable [*Polymers 5 (2013) 1-18*)].

Laser Transmission Welding (LTW) of PET and biodegradable PETs

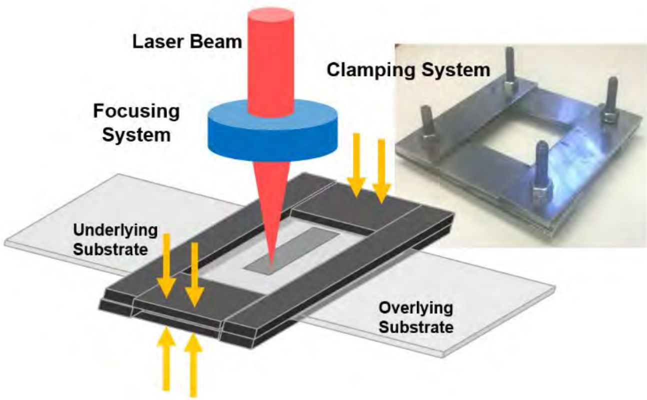
Co-rotating twin-screw extruder with a screw diameter of 27 mm and L/D = 36, screw speed of 320 rpm and 255 < T (ºC) < 270

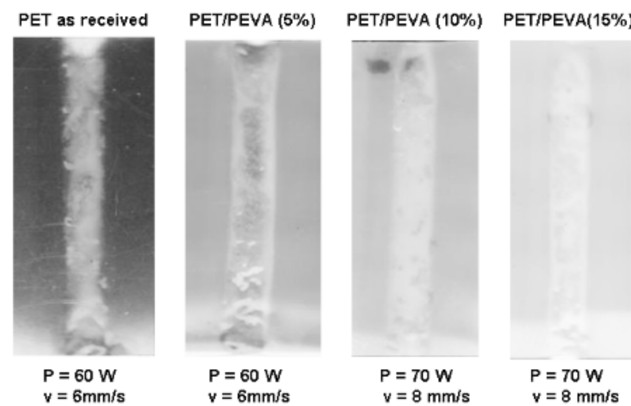


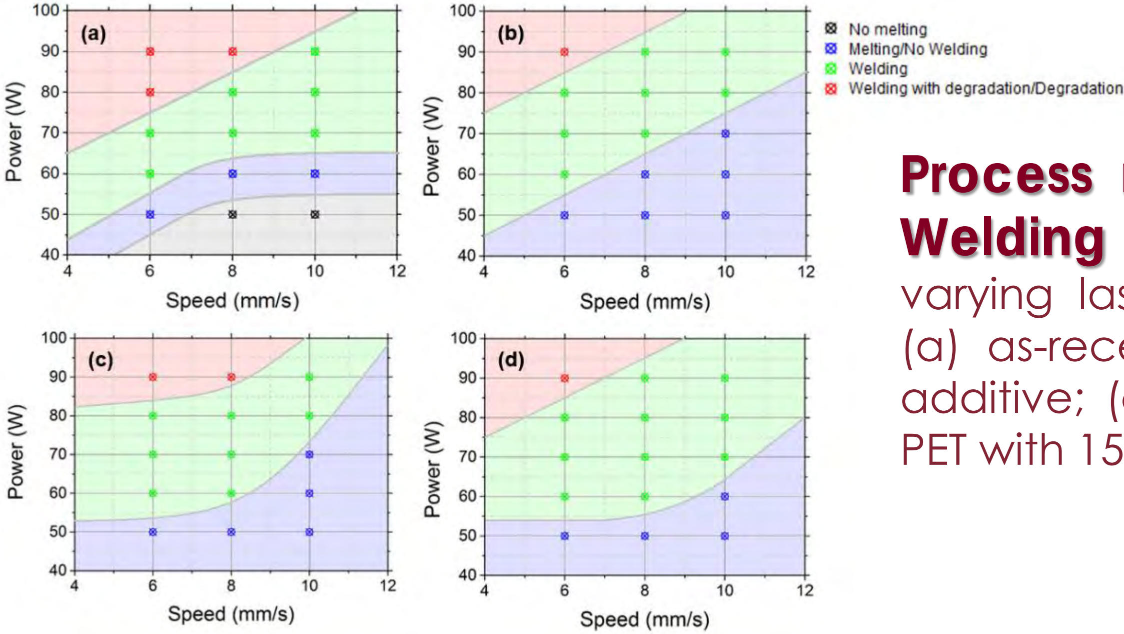
52 mm single-screw extruder for sheets, 350 mm wide and 330 mm thick. T of 255 to 270 ºC with a three-roll hauling off device at 60 ºC



Cutting by fine blanking



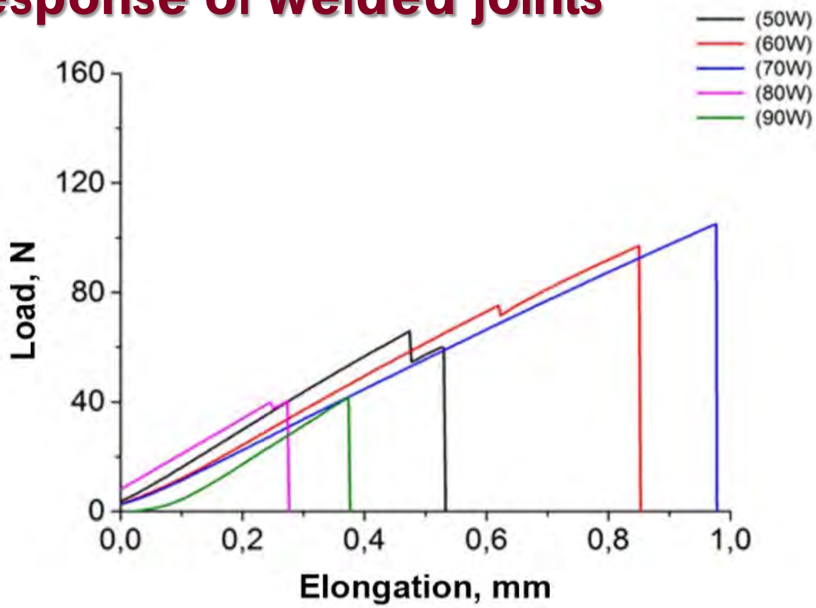




Process maps of Laser Transmission Welding (LTW)

varying laser power and scanning speed: (a) as-received PET; (b) PET with 5 wt. % additive; (c) PET with10 wt. % additive; (d) PET with 15 wt. % additive

Mechanical response of welded joints



Rupture at break	
PET	110.4 N
PET/PEVA 5%	90.4 N
PET/PEVA 10%	98.6 N
PET/PEVA 15%	102.8 N

LASER PM JOINING (PLASTIC and METAL)

ADHESIVE JOINTS

- ✓ no additional material
- ✓ much faster
- ✓ the same flexibility in design but without contaminant risks

MECHANICAL JOINTS

- ✓ no additional assembly parts
- ✓ much faster
- ✓ higher process flexibility

OTHER THERMAL JOINTS

- ✓ precise control of the laser energy in the focal spot gives a good localised material processing
- ✓ minimum heat affected area
- ✓ very small and accurately joint seams

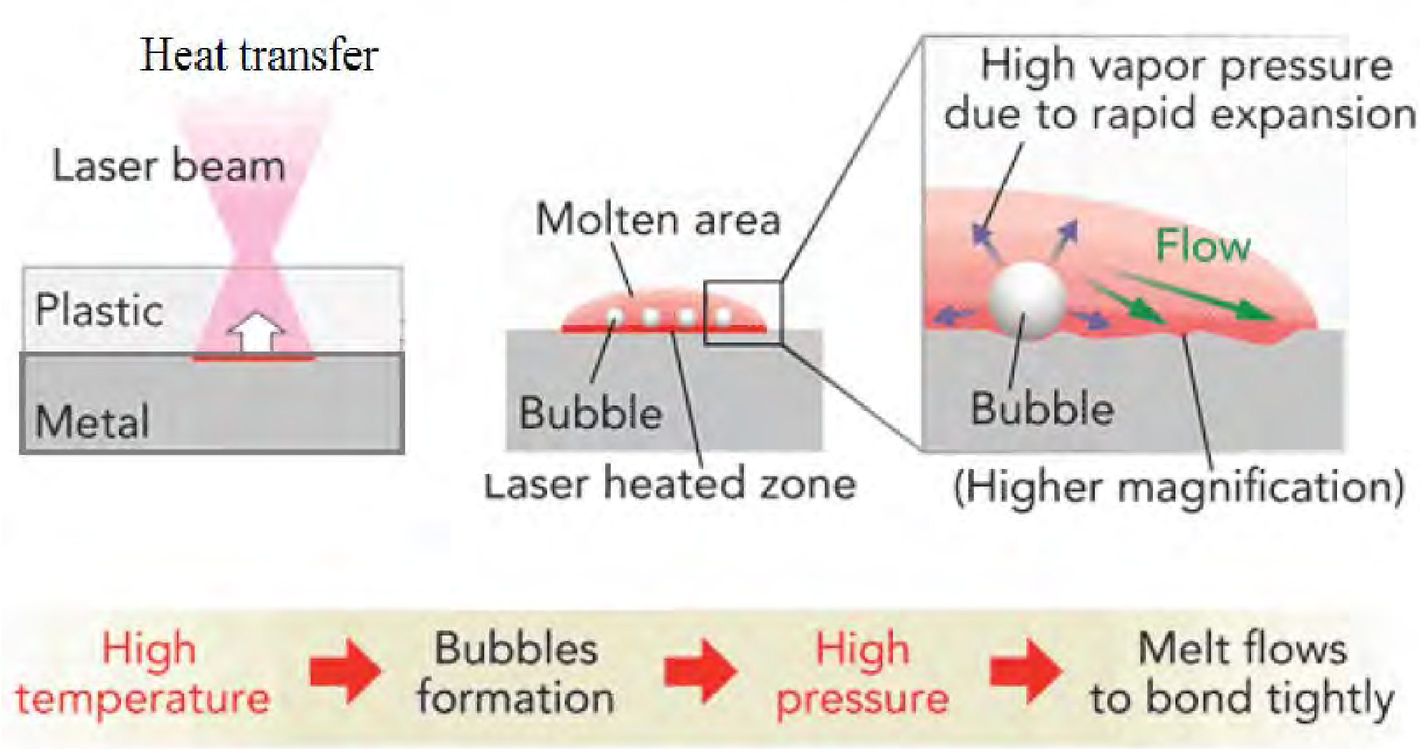
Automotive Industry

Medical device Industry

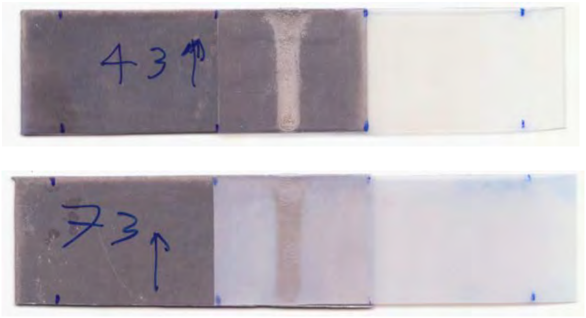
Packaging Industry

Joining of PET or biodegradable PETs with Metal (Al 7075 T6, NiTi, aluminum foil)

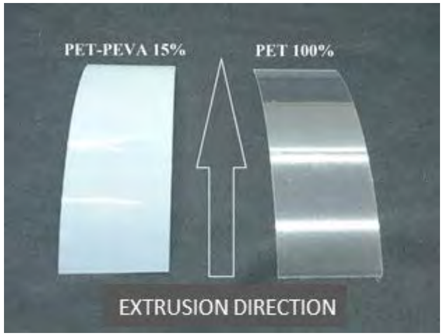
JOINING MECHANISM



(Source: S. Katayama, Osaka University)

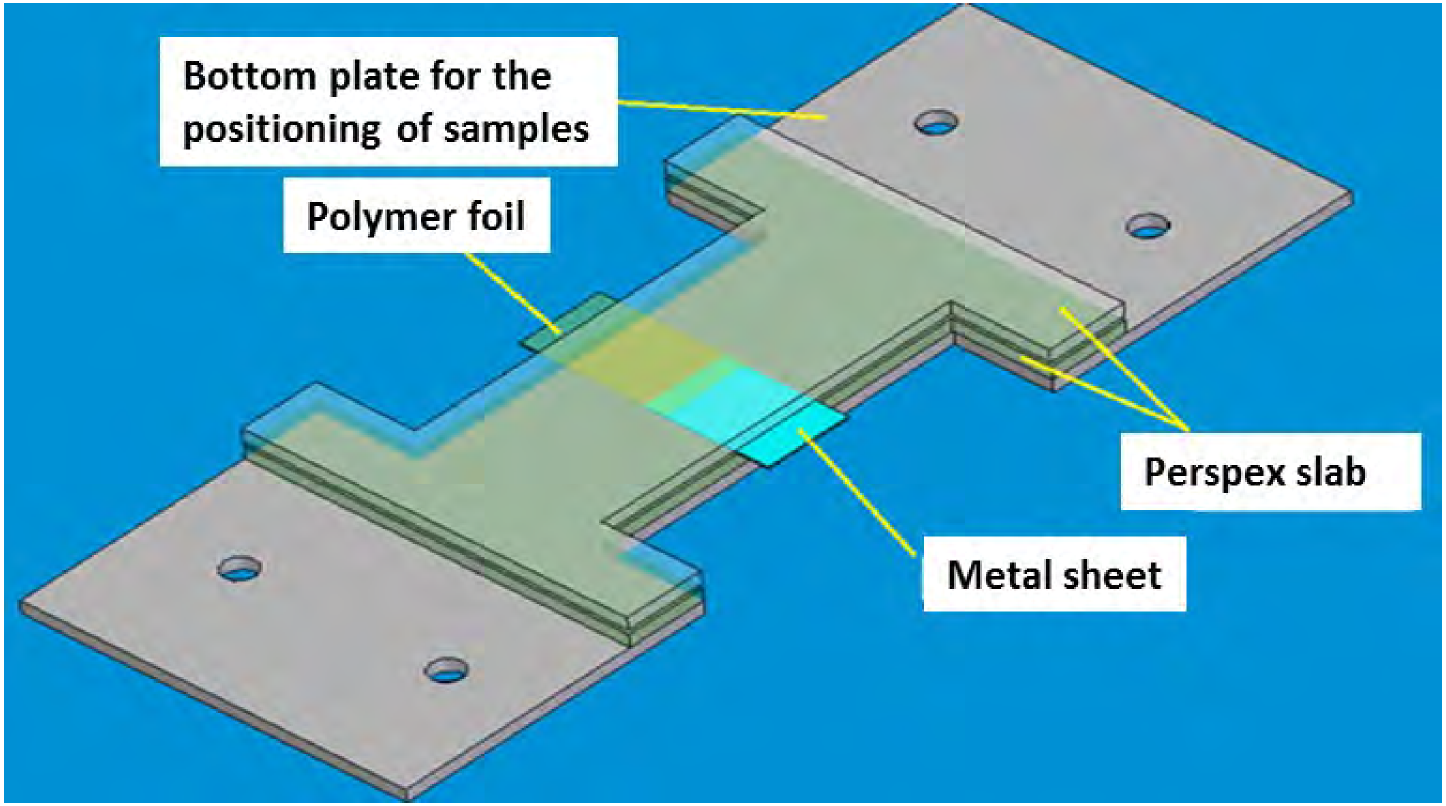


PLASTIC

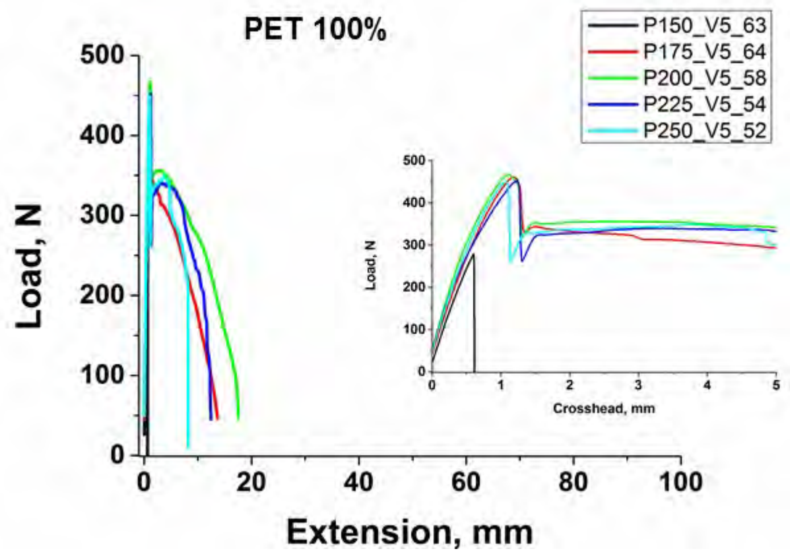


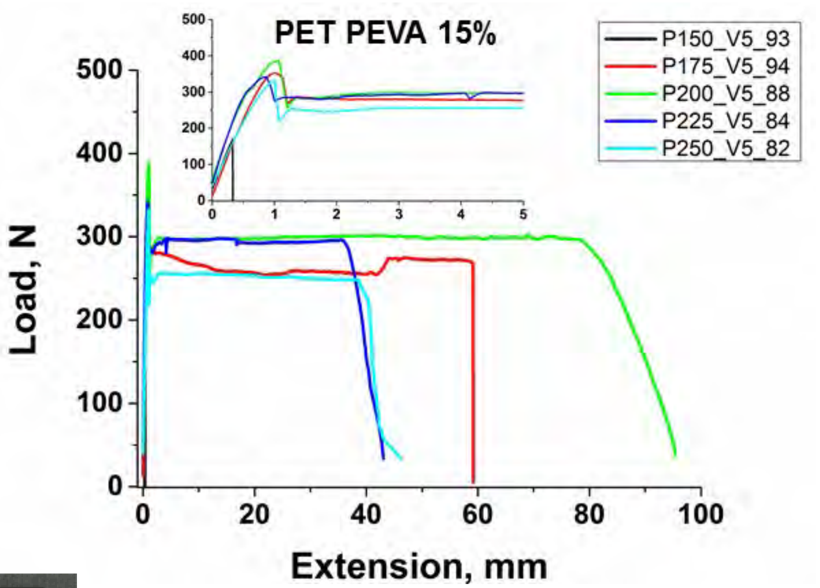
METAL

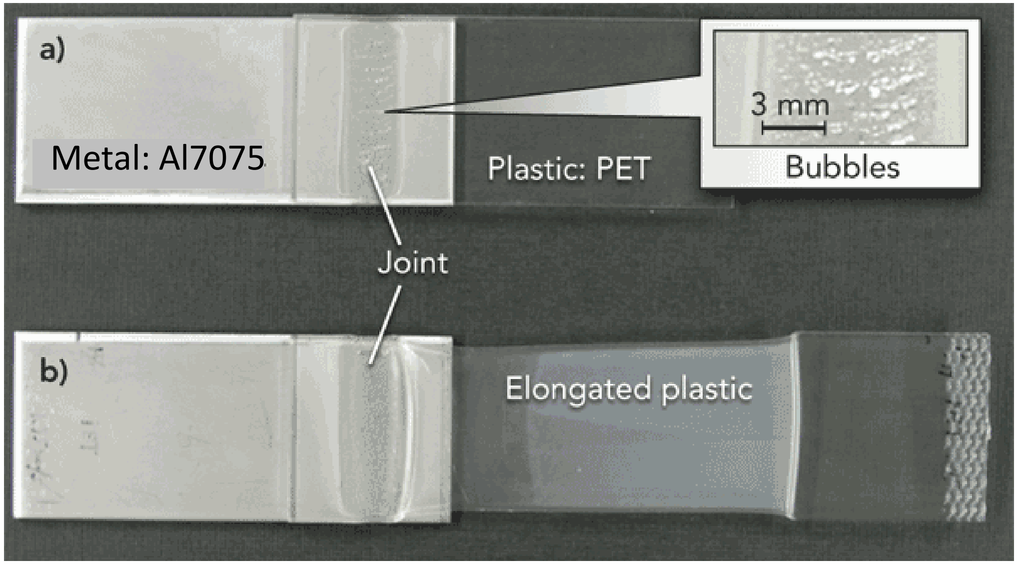
Clamping system



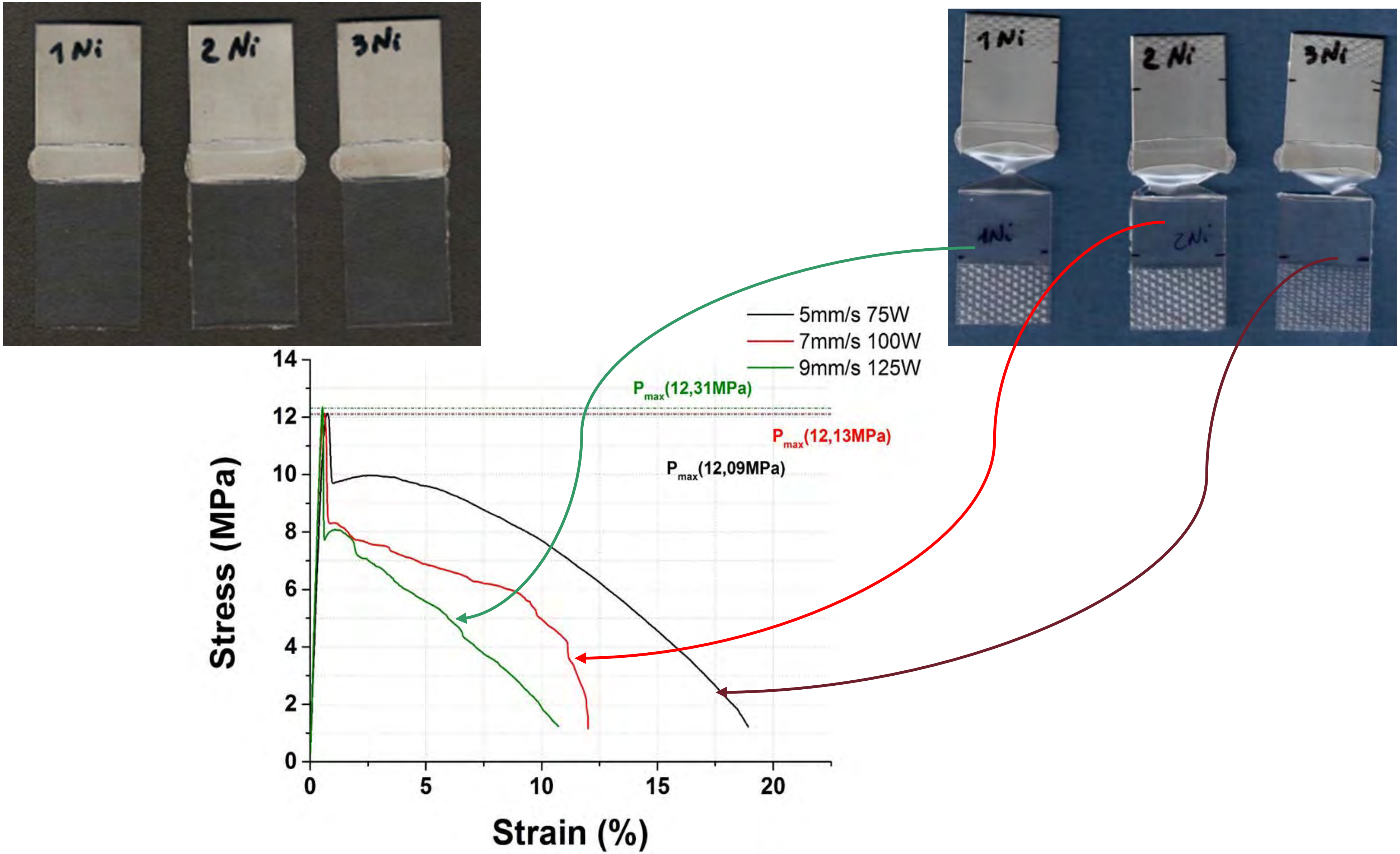
Laser PM Joining of PET or biodegradable PETs and Al 7075



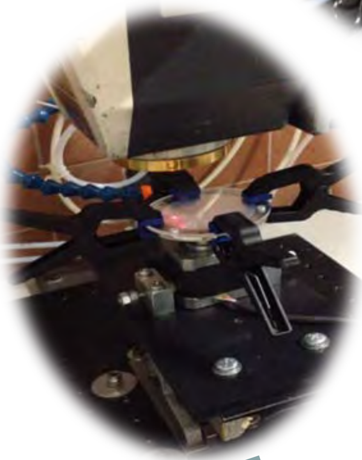


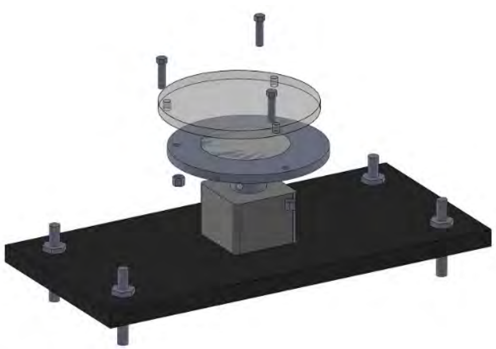


Laser PM Joining of PET or biodegradable PETs and NiTi



Laser PM Joining of PET or biodegradable PETs with Aluminum foil

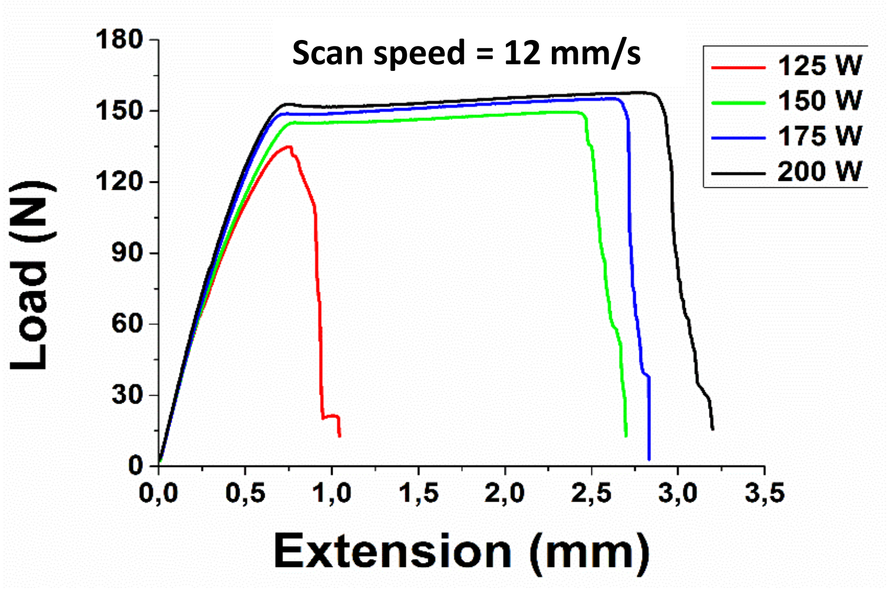




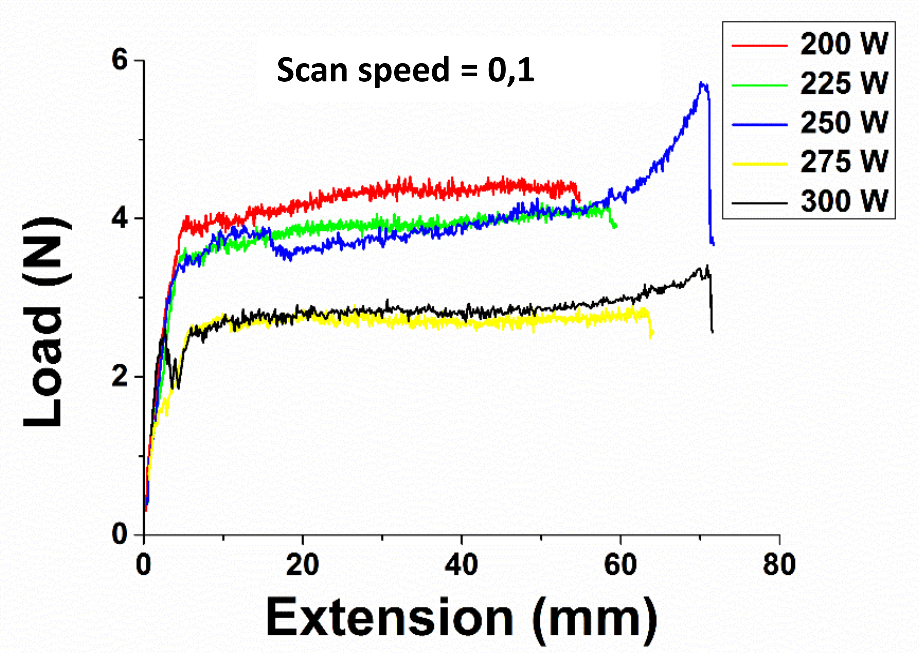
Mechanical response of welded joints

Tensile test

Rupture at break	
v=4 mm/s	80 N
v=8 mm/s	151 N
v=12 mm/s	122 N



Peel-off test



Challenge: 12 billions coffee capsules to landfill

Viable alternatives to conventional materials for fabrication of coffee capsules

Bio-based materials cost lots more

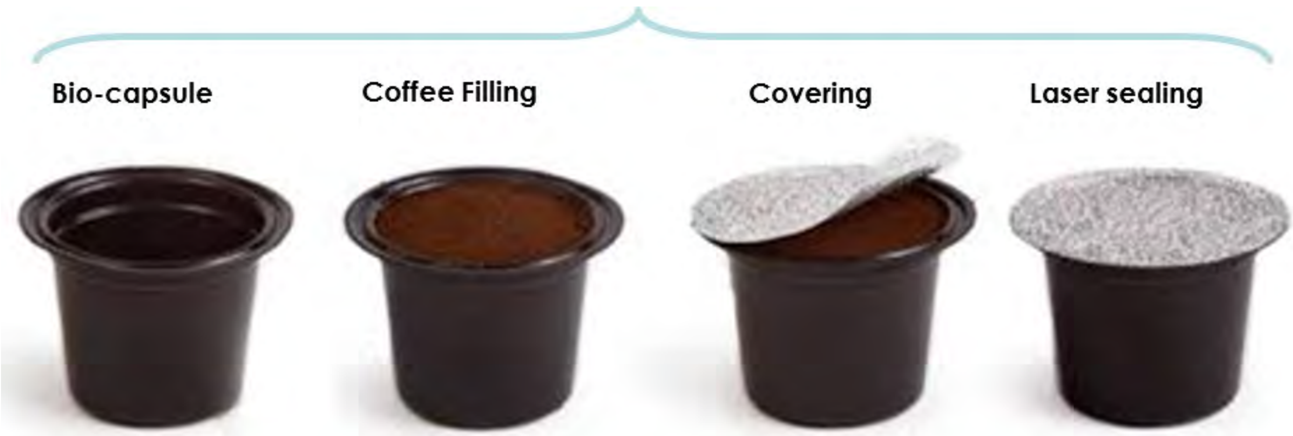
Rationale manufacturing of coffee capsules can contain the final costs

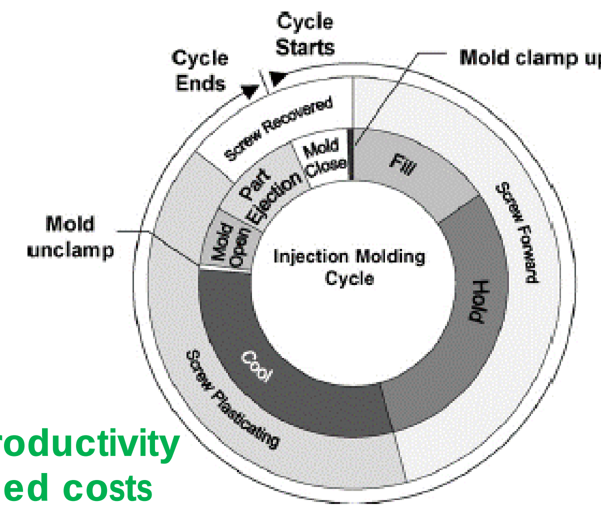
Bio-based Polymer (PLA)

Tailor-made PLA

Laser speeds up filling and sealing operations of coffee capsules

Compostable Coffee Capsules





Higher productivity for reduced costs