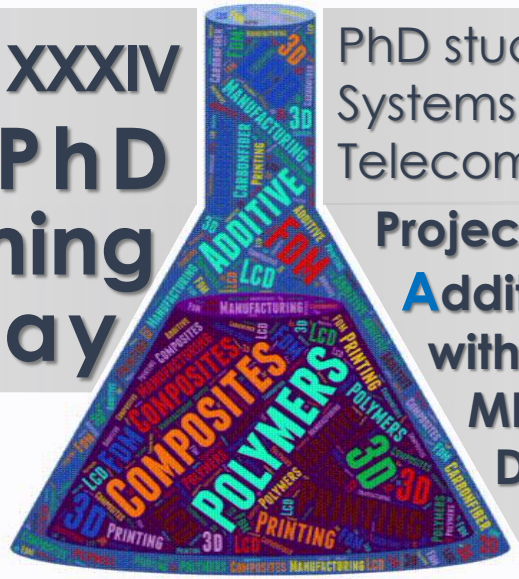
University of Catania
Department of Electric, Electronic and Computer Engineering

DIEEI

Claudio Tosto

XXXIV PhD Brainstorming Day



PhD student in
Systems, Energy, Computer and Telecommunication Engineering

Project "Advanced Material for Additive manufacturing" within the grant of MIUR PON 2014-2020 Dottorati Innovativi a Caratterizzazione Industriale

UNIONE EUROPEA
Fondo Sociale Europeo
Fondo Europeo di Sviluppo Regionale
Ministero dell'Istruzione, dell'Università e della Ricerca
PON RICERCA E INNOVAZIONE

Coordinator: Prof. Ing. Paolo Pietro Arena

Tutor: Prof. Ing. Gianluca Cicala

Formation Activity

Two work periods of study and research have been spent at:

- **Polymers and Composites Laboratory (DICAR) – 9 months**

- **Advanced Composites Solutions Srl (Tortoreto, TE) – 3 months (May-Aug 2019)**

The stage was supported by the Industrial PhD AMA (Advanced Materials by Additive manufacturing) funded by MIUR within the PON Ricerca e Innovazione 2014-2020 - Asse I "Investimenti in capitale umano" - Azione I.1 "Dottorati Innovativi con caratterizzazione industriale".

ACS is a company specialized in the design and production of innovative carbon fiber composite for the most important international automotive and racing brands

Dall'Acs di Tortoreto i pezzi "vincenti" di Porsche, Michelotto e Oreca

Source:https://www.cityrumors.it/notizie-teramo/cronaca-teramo/540357-dallacs-tortoreto-pezzi-vincenti-porsche-michelotto-oreca.html

Outline

Photocentric

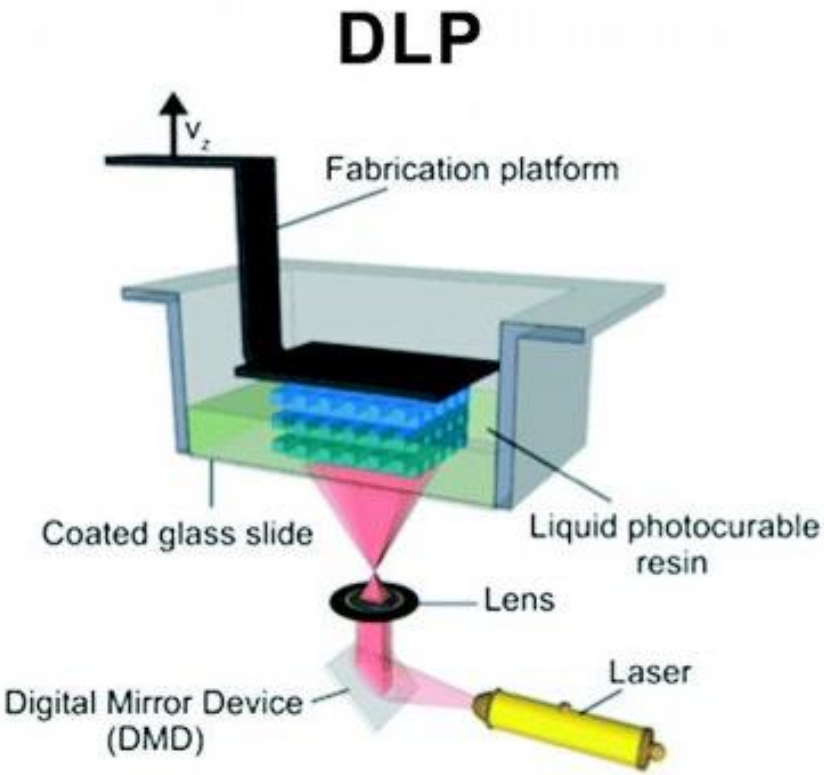
ACS ADVANCED COMPOSITES SOLUTIONS

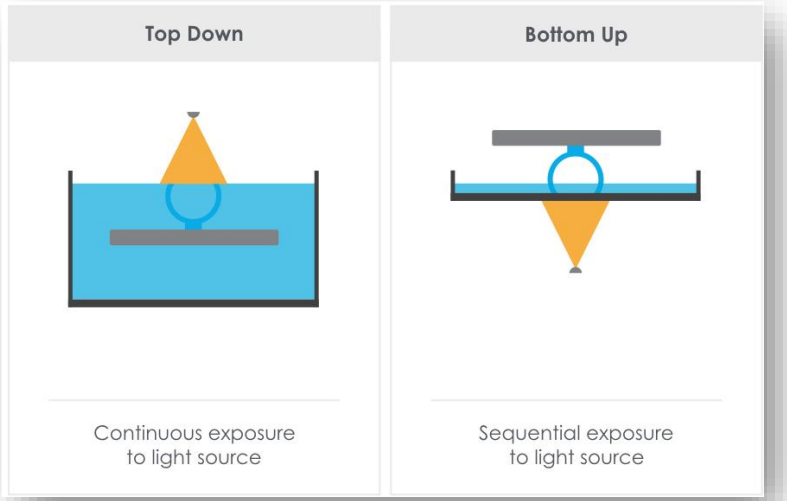
Production of carbon fiber composite components using Additive Manufacturing

Realization of innovative formulations based on Photocurable resins

Photocurable resin

Digital Light Processing



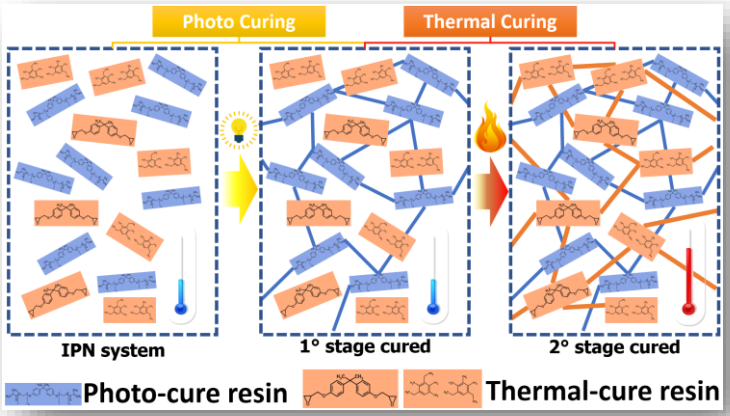


Photocurable resin

Materials

The **photocurable resin** used is named Cream Hard Daylight, a methacrylate-based system by Photocentric.

- Two different **epoxy resins** have been tried for the blends: the difunctional monomer diglycidyl ether of bisphenol-A (DGEBA), Araldite GY240;
- the trifunctional monomer triglycidyl-p-aminophenol (TGAP), MY0510.
- The curing agent used is Diethyltoluenediamine (DETDA). Different blends of daylight resin and epoxy resin have been prepared with weight ratio.



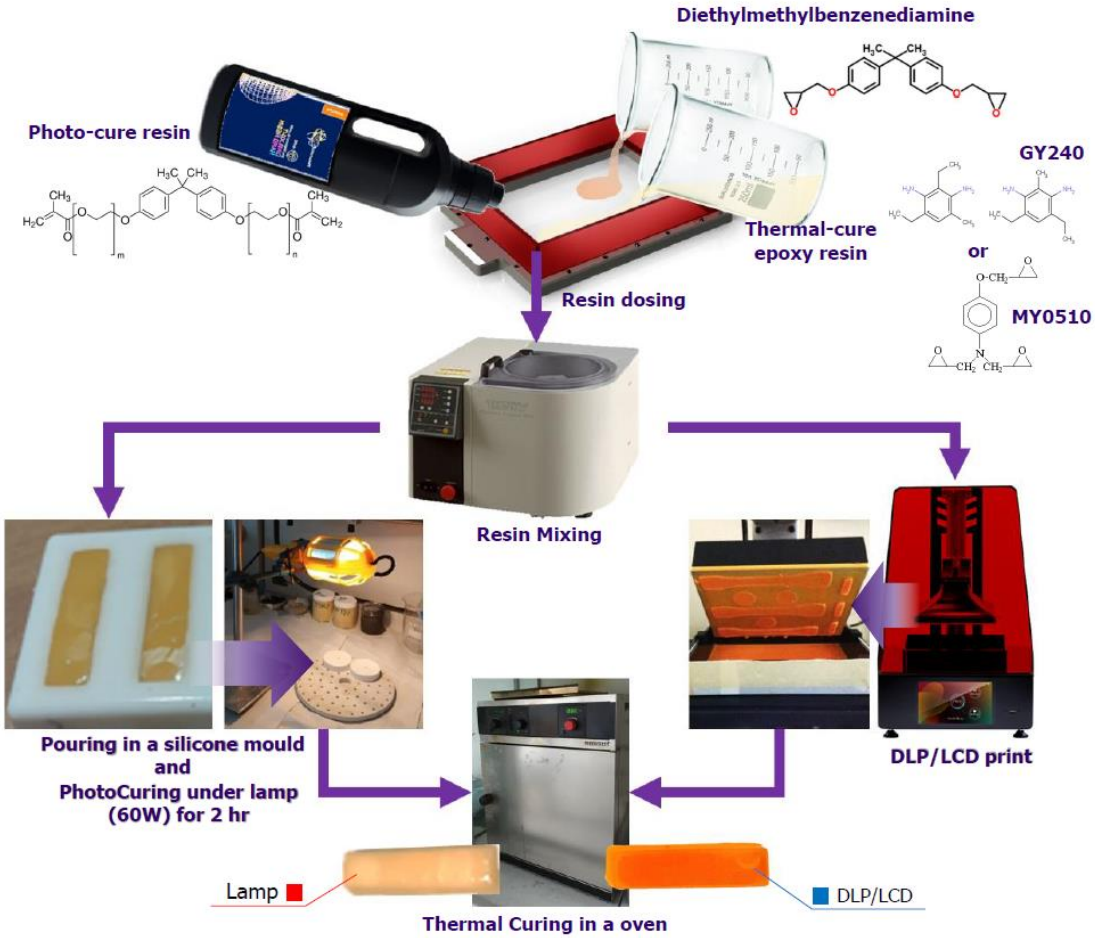
EPOXY BASED BLENDS

Sample	DayLight:Epoxy
Cream Hard	100:0
CE8020	80:20
CE7030	70:30
CE6040	60:40
CE5050	50:50
GY or MY-DETDA	0:100

Photocurable resin

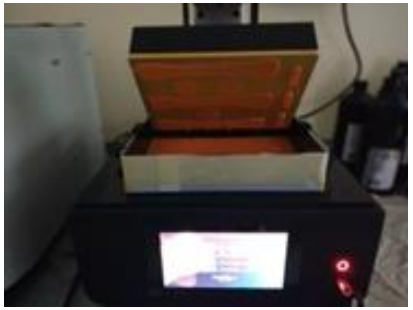
Experimental work

To speed up the resin testing most of the work was perfomed by photo curing **out of** the printer the formulations before testing them in the **LCHR2 printer.**
This experimental approach was tested on neat hard cream resin before testing it on the epoxy based blends.

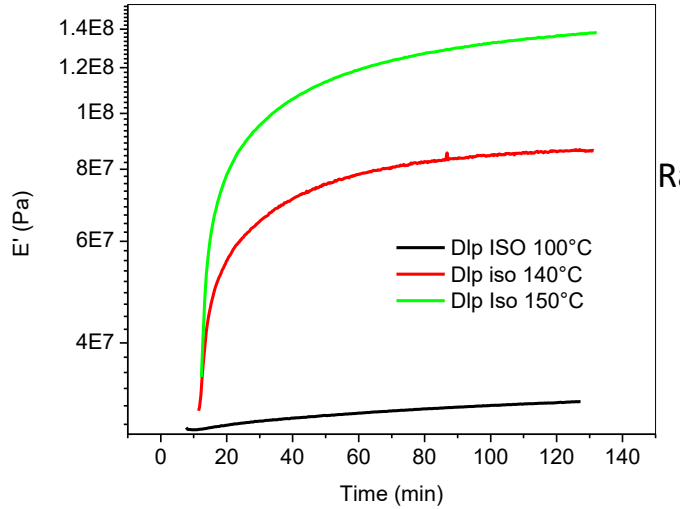


Photocurable resin

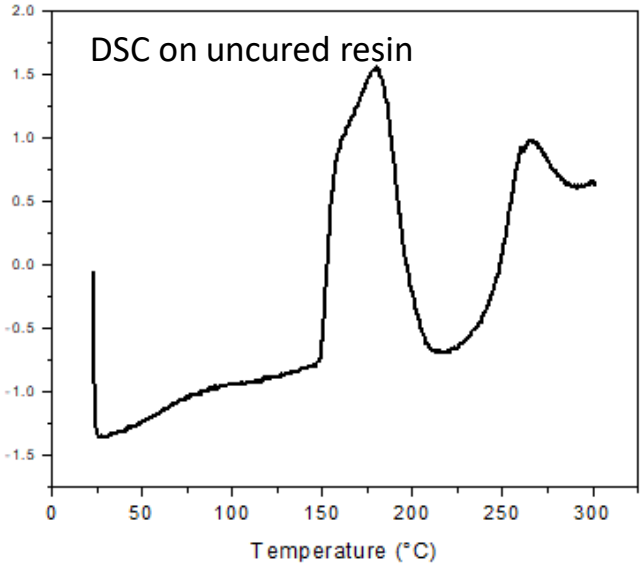
Isotherm curing within DMA instrument: Cream Hard

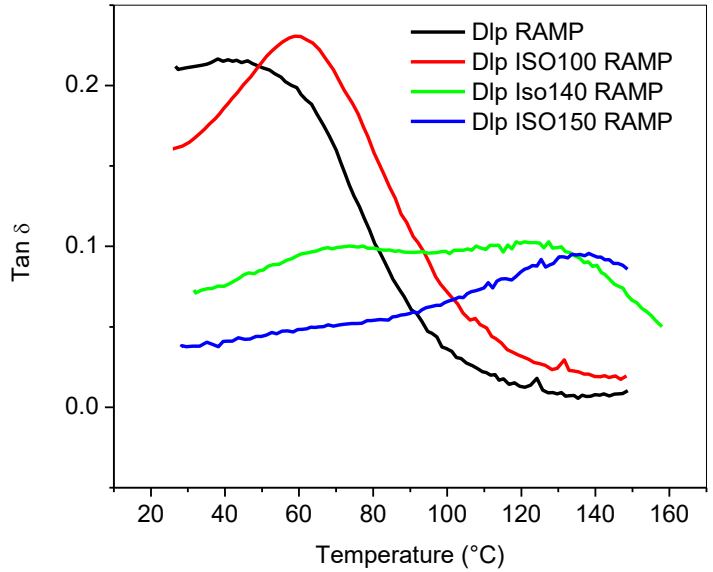


DLP Cured



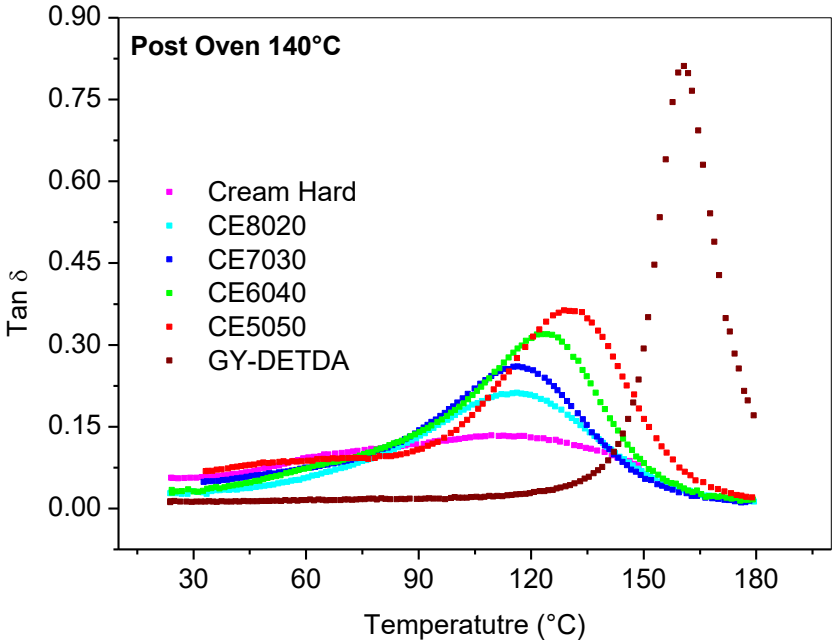
Ramp after Isothermal curing

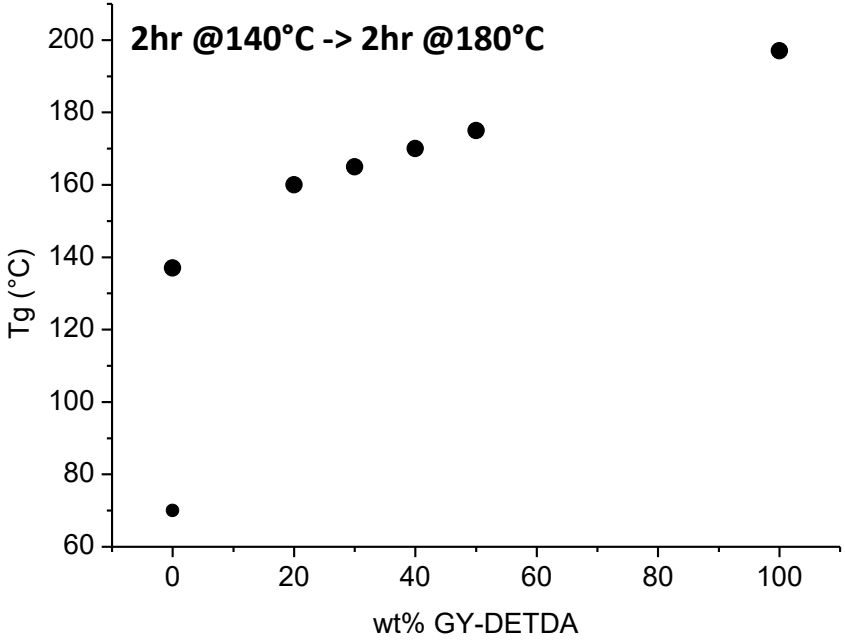




Photocurable resin

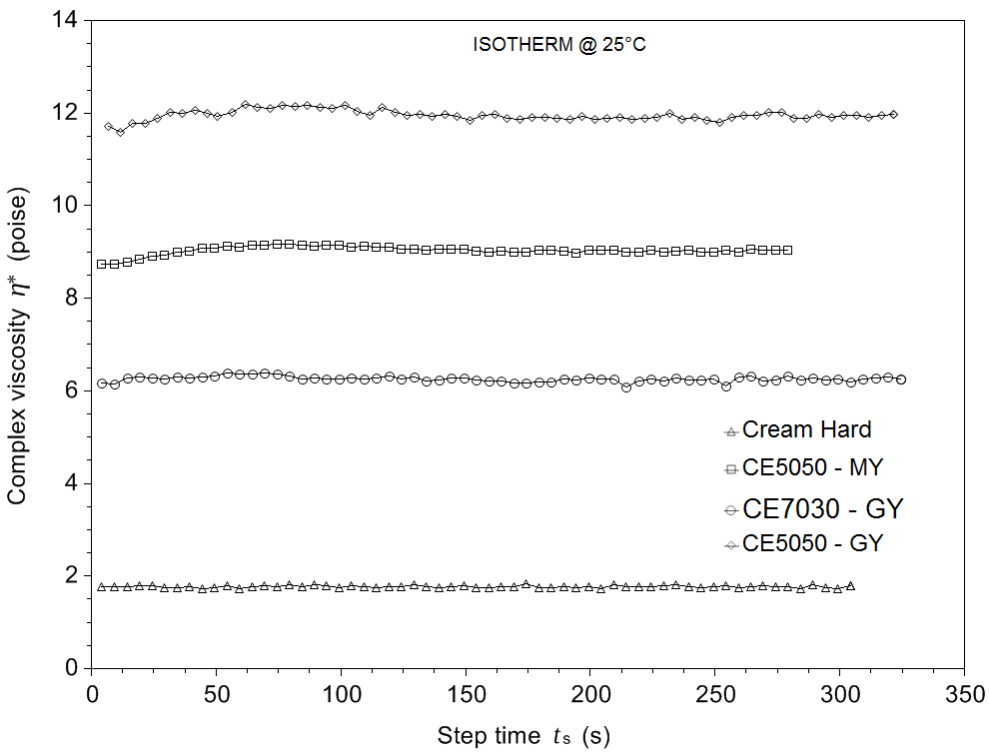
DMA Testing on dual cured samples: Effect of Epoxy Blending - GY

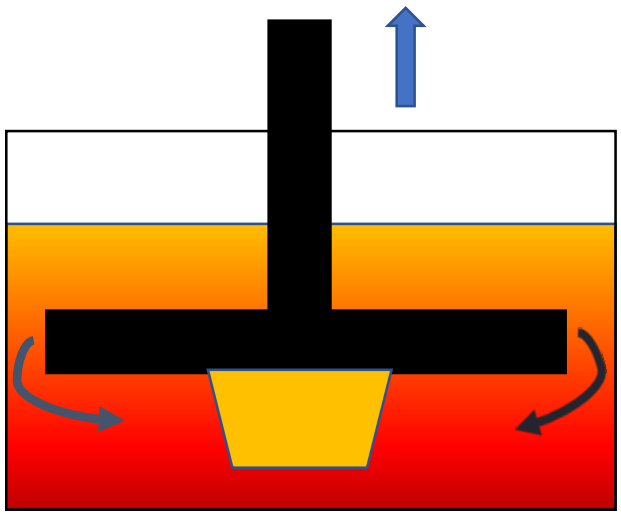




Photocurable resin

Isothermal rheometry on uncured blends





Resin Flow when the platform is lifted up

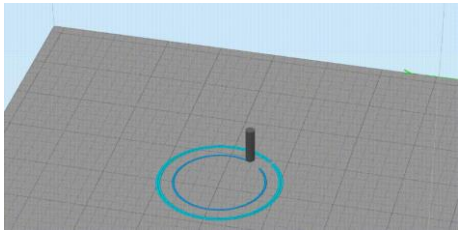
Viscosity limit for Photocentric printing : 100 Poise

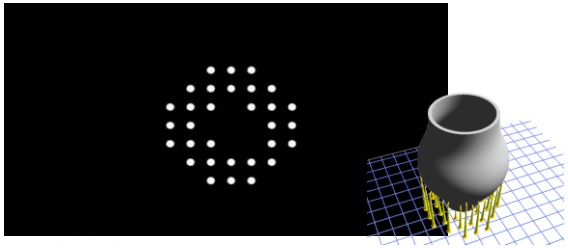
Tooling for composites

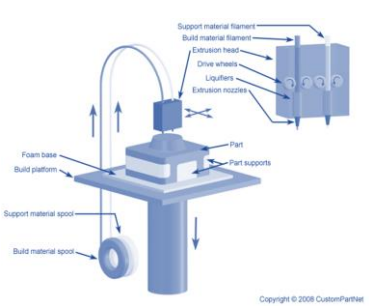
Experimental work

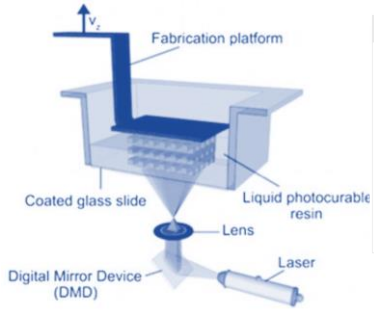
Building of AM sacrificial mandrel

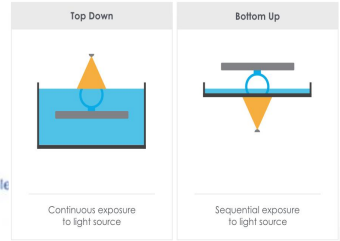
FDM	DLP
Soluble support SR100	Breakway DLP resin





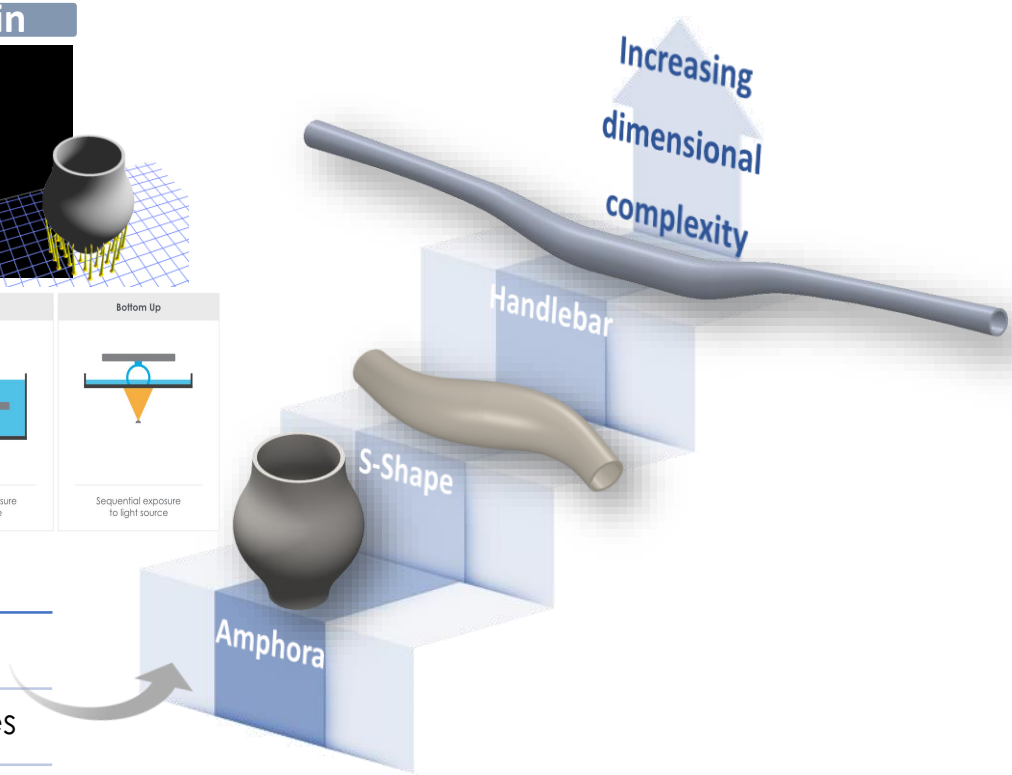






Build plan based on:

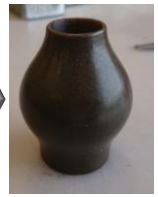
- Dimensional complexity
- Optimizing production/test times



Tooling for composites

FDM-Amphora test

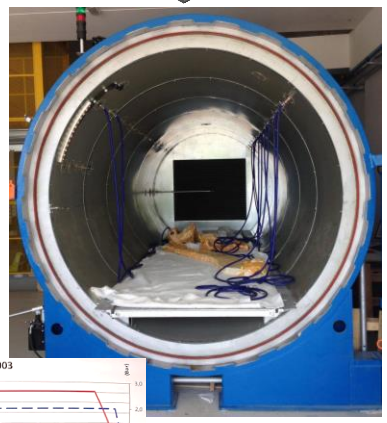
FDM Part



Preparing

Lay-up prepreg

Vacuum bagging

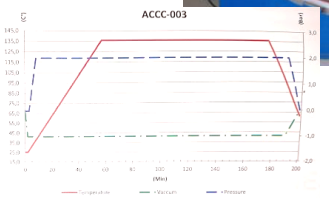


Autoclave

FDM sacrificial tooling easily washes out in a detergent solution.

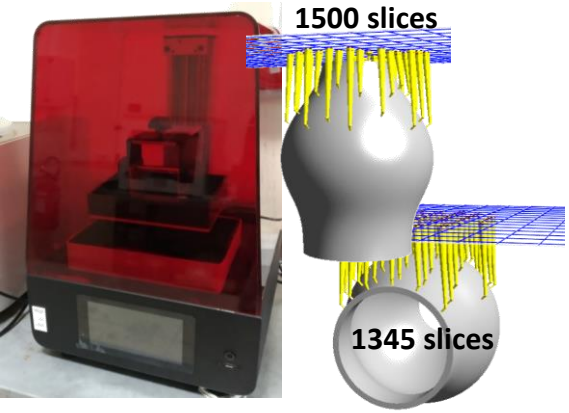
FDM sacrificial tools are compatible with most epoxy resin systems. However, the solution that dissolves the tool can attack and weaken certain polyester resins.

CURE CYCLE	
Temperature	135 °C
Pressure	5 bar
Dwell time	120 min
Process time	200 min



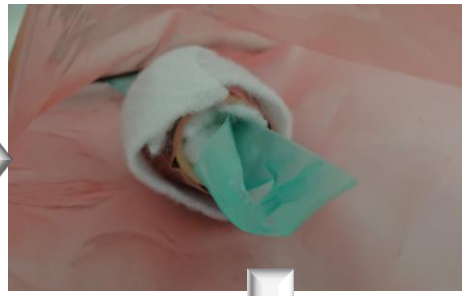
Tooling for composites

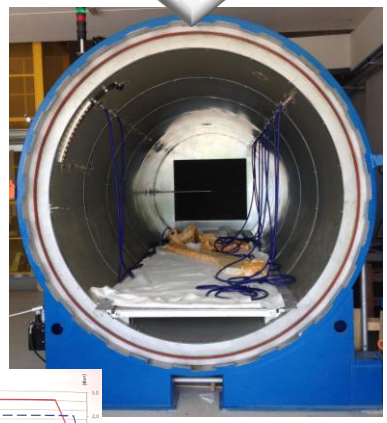
LCD-Amphora test



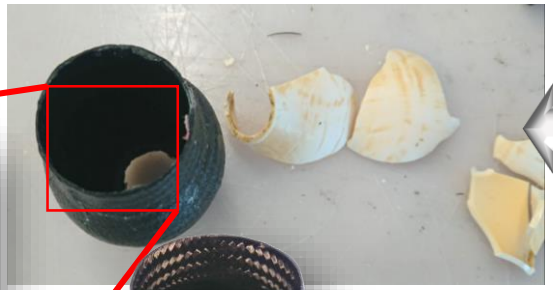
DLP resin: Precision Hard White

ID Prepreg: DT121 (200 g/mq)





Autoclave



CURE CYCLE	
Temperature	135 °C
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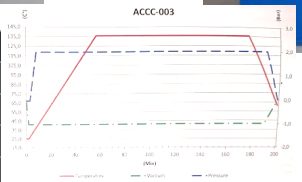
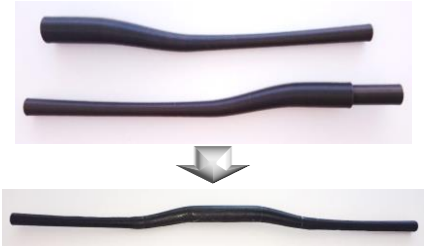


Tooling for composites

Application to manufacture of a bike handle bar (135g final part)



Mandrel Assembled

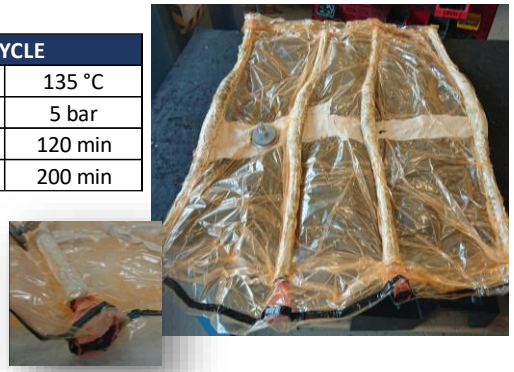
- FDM Material: SR100 (soluble support for PC)
- Laminate: DT121 (200 g/mq)

Mandrel wrapped with CF prepreg

Part ready for the autoclave

Cured parts

CURE CYCLE	
Temperature	135 °C
Pressure	5 bar
Dwell time	120 min
Process time	200 min



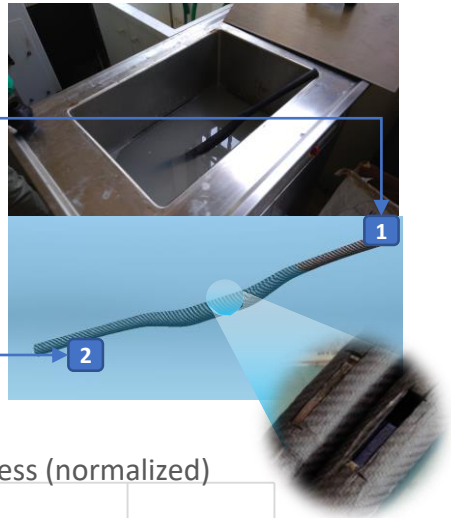
Tooling for composites

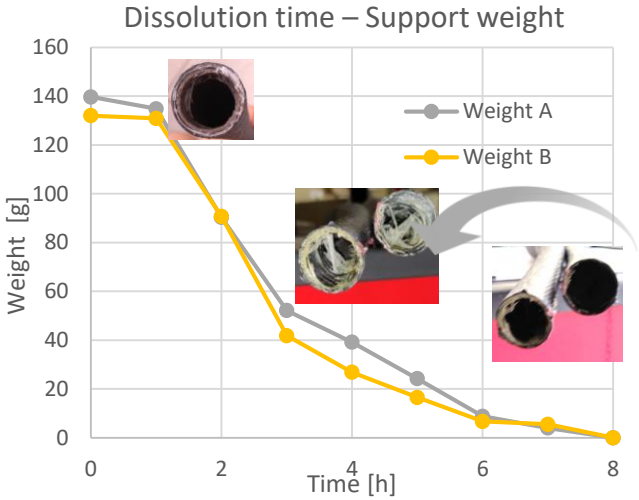
Application to manufacture of a bike handle bar

Mandrel removal

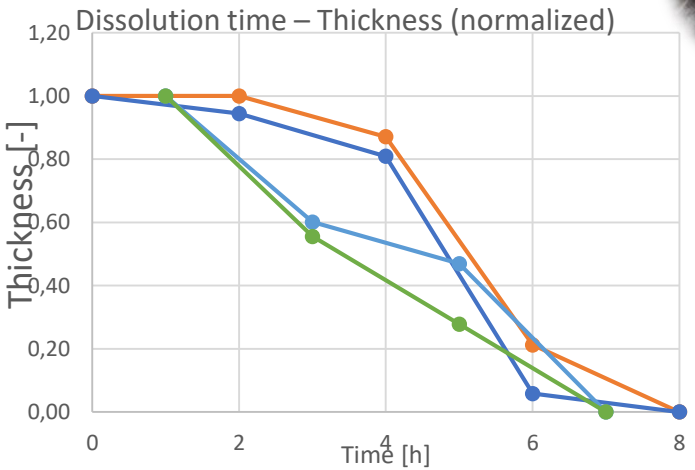
h	Weight [g]					
	A			B		
	Raw	Differences	Normalized	Raw	Differences	Normalized
0	202,97	131,97	1,00	205,52	139,62	1,00
1	201,84	130,84	0,99	200,7	134,8	0,97
2	161,7	90,7	0,69	156,2	90,3	0,65
3	112,8	41,8	0,32	118	52,1	0,37
4	97,8	26,8	0,20	105	39,1	0,28
5	87,5	16,5	0,13	90,1	24,2	0,17
6	77,7	6,7	0,05	74,7	8,8	0,06
7	76,5	5,5	0,04	69,9	4	0,03
8	71	0	0,00	65,9	0	0,00

	A1			B1		
h	Raw	Differences	Normalized	Raw	Differences	Normalized
0	15,71	5,19	1,00	15,51	5,19	1,00
2	15,71	5,19	1,00	15,80	4,90	0,94
4	16,38	4,52	0,87	16,50	4,20	0,81
6	19,80	1,10	0,21	20,40	0,30	0,06
8	20,90	0,00	0,00	20,70	0,00	0,00
	A2			B2		
h	Raw	Differences	Normalized	Raw	Differences	Normalized
1	17,19	3,41	1,00	16,40	3,60	1,00
3	18,55	2,05	0,60	18,00	2,00	0,56
5	19,00	1,60	0,47	19,00	1,00	0,28
7	20,60	0,00	0,00	20,00	0,00	0,00





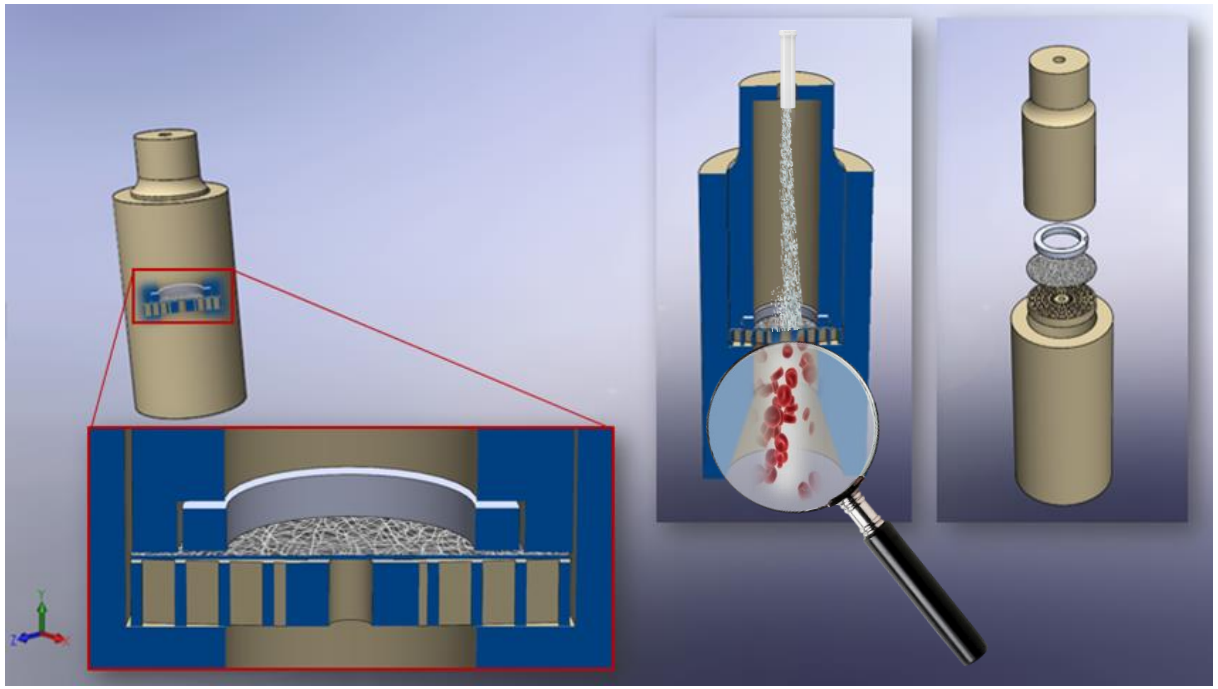
After 3 hours in the dissolution bath **70% of the mass is dissolved**



After 7-8 hours the mandrel is **completely dissolved**.

Applications

Device for Cell Growth and Counting

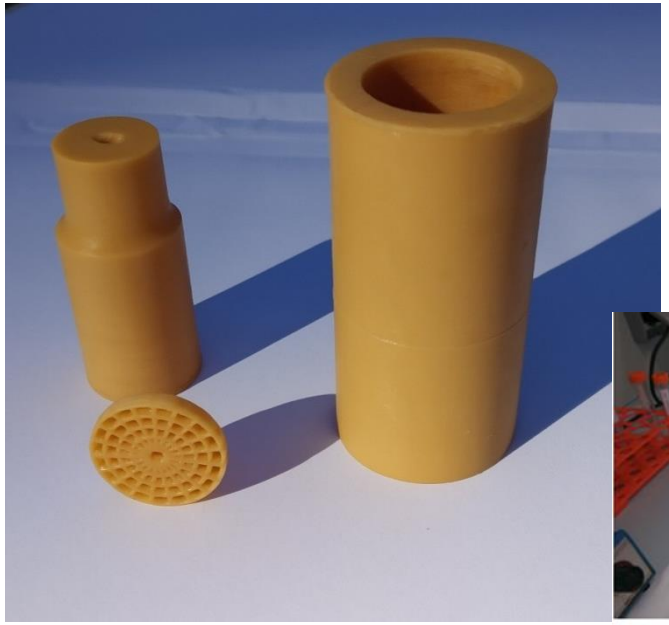


Characteristics required:

- Good mechanical properties;
- Resistance to temperatures higher than 100°C for sterilization.

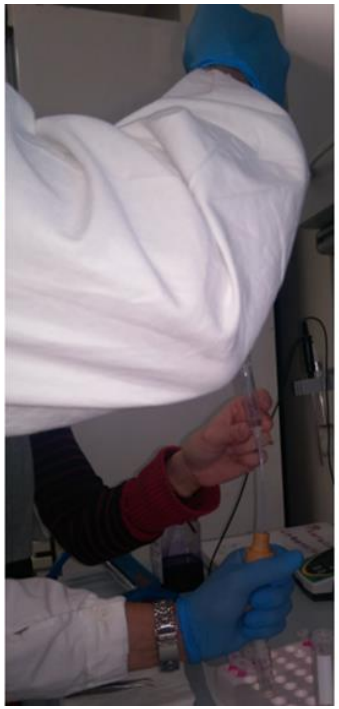
Applications

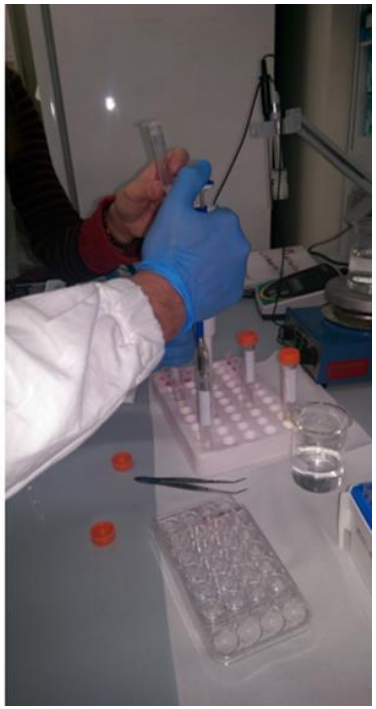
Device for Cell Growth and Counting



Filtration system after printing

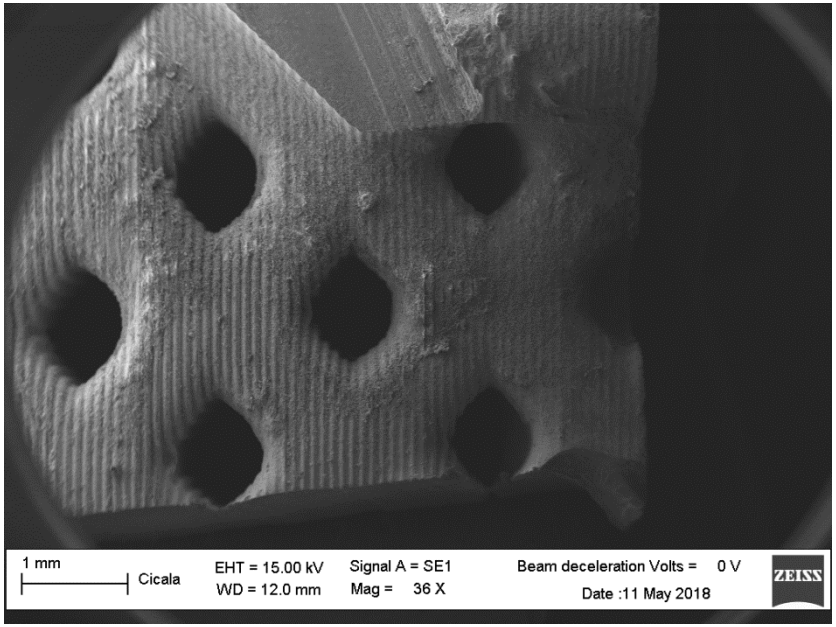
Filtration system during a run test

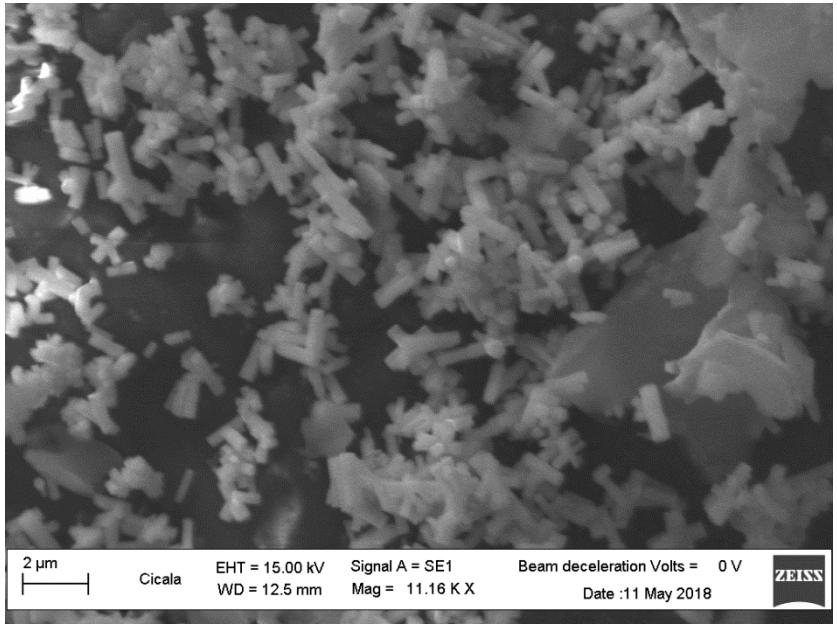




Applications

Surface functionalization with ZnO nanorods





List of Publications

International journals:

1. C. Tosto, A. Latteri, E. Pergolizzi, D. Giordano, G. Abramo, R. Catenaro, N. Pignotti, G. Cicala (2019) Additive Manufacturing of Plastics: an efficient approach for composites tooling - Macromolecular Symposia - Macromolecular Symposia Wiley-VCH.

International conferences:

1. C. Tosto, A. Latteri, E. Pergolizzi, D. Giordano, G. Abramo, R. Catenaro, N. Pignotti, G. Cicala (2019) Additive Manufacturing of Plastics: an efficient approach for composites tooling - Macromolecular Symposia - POLCOM 10-13 October 2019, Bucharest.
2. G. Ognibene, C. Tosto, L. Saitta, G. Cicala, M.E. Fragalà, G. Li Volti (2019) Coatings with antibacterial properties for electrospun materials and additive manufacturing - Materials in the next decade 2019, 18-20 September 2019 Favignana (TP).
3. G. Ognibene, I. Blanco, L. Saitta, C. Tosto, G. Cicala (2019) The use of thermo-mechanical technique to support the development of novel materials for additive manufacturing - CEEC-TAC5 & Medicta2019 - 27-30 August 2019 Roma.
4. C. Tosto, E. Pergolizzi, I. Blanco, G. Cicala (2019) Thermomechanical properties of mandrels manufactured by 3D printing for the production of hollow FRP parts - CEEC-TAC5 & Medicta2019 - 27-30 August 2019 Roma ("Best Poster Award").
5. S. Oliva, C. Tosto, A. Latteri, I. Blanco, G. Recca, G.Cicala (2019) Polymer Blends for Day-Light curing: application to DLP 3D printing - Eurofillers Polymer Blends 2019, Palermo, 23-26 April 2019.
6. G. Ognibene, M.E. Fragalà, C.Tosto, A. Di Stefano, G. Li Volti, G.Cicala (2019) Electrospun Polyethersulfone nanofibers as cells scaffold - Eurofillers Polymer Blends 2019, Palermo, 23-26 April 2019.

National conferences:

1. C. Tosto, G. Ognibene, L. Saitta, G. Recca, G. Cicala (2019) Epoxy blending for resins used in advanced manufacturing by DLP printing - XII INSTM CONFERENCE-XV AIMAT CONFERENCE, July 21-24, 2019 Ischia (NA).
2. C. Tosto, G. Ognibene, L. Saitta, R. Catenaro, G. Cicala (2019) Additive manufacturing for tooling of plastics and fiber reinforced composites - XII INSTM CONFERENCE-XV AIMAT CONFERENCE, July 21-24, 2019 Ischia (NA).
3. G. Ognibene, C. Tosto, G. Li Volti, M.E. Fragalà, L. Saitta, G. Cicala (2019) Functional electrospun veils: application from wound healing to frp composites - XII INSTM CONFERENCE-XV AIMAT CONFERENCE, July 21-24, 2019 Ischia (NA).

Attendance to conferences/events

International conferences/events:

1. Formnext 2018, 13-15 November 2018, Frankfurt (GE). The leading exhibition and conference dedicated to additive manufacturing and all of its upstream and downstream processes.
2. 5th Central and Eastern European Conference on Thermal Analysis and Calorimetry & 14th Mediterranean Conference on Calorimetry and Thermal Analysis. 27-30 August 2019, Rome, Italy.
3. 5th Short Summer School on Thermal Analysis and Calorimetry & 1st International Conference for Young Researchers and Students on Thermal Analysis and Calorimetry. 27 August 2019, Rome, Italy.

National seminars:

1. Strumenti di accesso al mercato del lavoro / Contratto di apprendistato di alta formazione e ricerca Il valore del linguaggio verbale e non verbale nella comunicazione efficace. Ph.D. Days 2018/19 IV Ed. – Per una ricerca di qualità, COFP, 8 November 2019, Catania, Italy.
2. Diffondere la ricerca scientifica con I social media. Ph.D. Days 2018/19 IV Ed. – Per una ricerca di qualità, COFP, 28 November 2019, Catania, Italy.
3. La valutazione della ricerca. Ph.D. Days 2018/19 IV Ed. – Per una ricerca di qualità, COFP, 11 December 2019, Catania, Italy.
4. Dal Ph. D alla Start Up. Ph.D. Days 2018/19 IV Ed. – Per una ricerca di qualità, COFP, 19 February 2019, Catania, Italy.
5. Le proprietà intellettuali dei ricercatori universitari: invenzioni e diritto d'autore. Ph.D. Days 2018/19 IV Ed. – Per una ricerca di qualità, COFP, 16 April 2019, Catania, Italy.

Contacts

For further informations
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