

# 3-D PRINTING @ DSCTM-CNR

From imaging.....to modeling .....to processing.....to products

*Novel additive manufacturing processes 3D printing can offer benefits across the entire value chain from initial concept design to final manufacturing and all steps in between.*

*Different applications, from health to transportation, from design to cultural heritage, from construction to foods have unique opportunity to develop advanced products by choosing an appropriate 3D printer. Identifying the specific requirements within the entire design-to-manufacture process help to optimize the benefits of 3D printing: complex product geometry, processing of different materials including composites, customized products and devices, shorter time-to-market, improved product quality and performance.*

Contact persons:

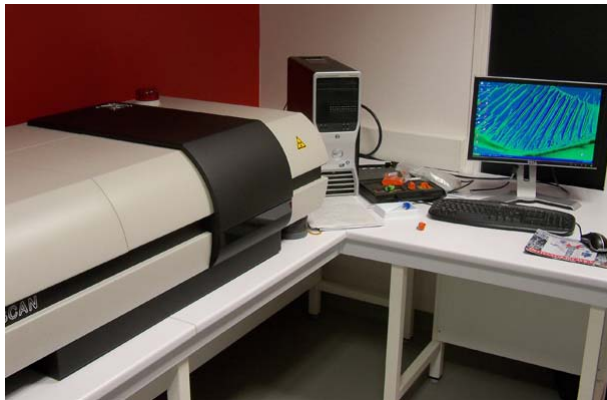
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# REVERSE ENGINEERING TOOLS

## Imaging

$\mu$ -CT



Skyscan 1082

3D Scanner



Cyberware 3D rapid digitizer



Polhemus Fast Scan

# MEASUREMENT & CONTROL



## Konica Minolta Range7

- Accuracy: 0.0015"
- Ideal for medium to large objects
- Scanning shiny surfaces without spray or darkroom
- Accuracy:  $\pm 40\mu\text{m}$



## Phasor XS

Ultrasonic non-destructive testing flaw detectors are used to detect and size subsurface defects and anomalies in many materials allows advanced inspections to be carried out in the field with greater speed and accuracy than ever before

# PRODUCT DESIGN

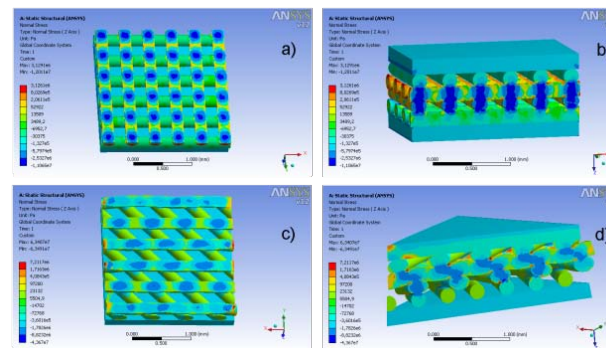
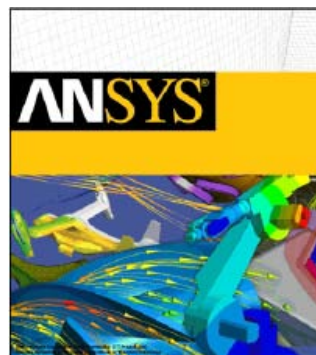
**SOLIDWORKS Premium:** create, simulate and virtual test to move quickly from idea to reality

**SOLIDWORKS**



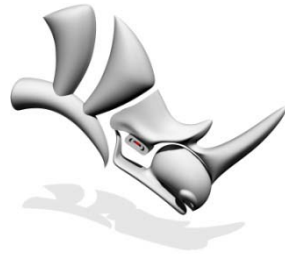
- Time-based Motion Analysis
- Linear Static Analysis for Parts and Assemblies
- Automated Tolerance Stack-Up Analysis (ToAnalyst)
- Routing of Pipes and Tubes
- Routing of Electrical Cabling and Wiring
- Reverse Engineering (Scanto3D)
- Linear Stress Analysis
- Thermal Structural Analysis
- Computational Fluid Dynamics
- Injection molding simulation

**MIMICS:** developed for the segmentation of 3D medical images (coming from CT, MRI, micro-CT, CBCT, 3D Ultrasound, Confocal Microscopy).

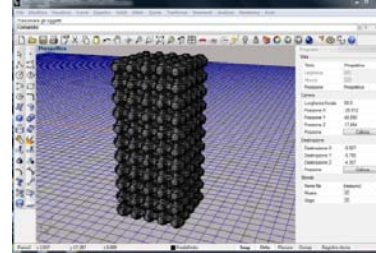


# PRODUCT DESIGN

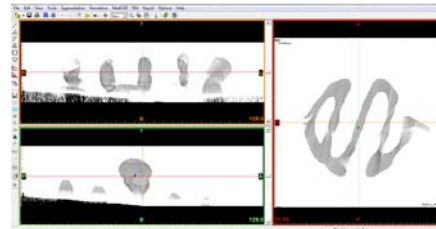
**RHINOCEROS 3.0:** a commercial 3D computer graphics and computer-aided design (CAD) application software that is based on NURBS mathematical model



**Rhino**ceros®  
NURBS modeling for Windows

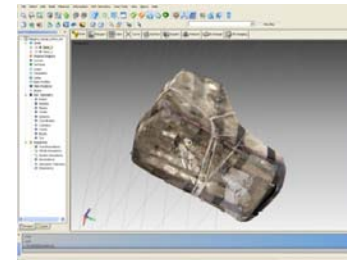


**MIMICS:** an image processing software to create 3D surface models from stacks of 2D image data.



**RAPIDFORM:** is the first software solution that allows users to go from 3D scan data to a fully parametric CAD model.

**RAPIDFORM**®  
™



# PROCESSING

## Acrylate/Fumarate Polyesters

- Polyethylene glycole diacrylate
- Polycaprolactone diacrylate
- Polycaprolactone Fumarate

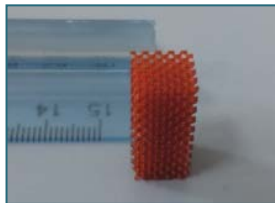
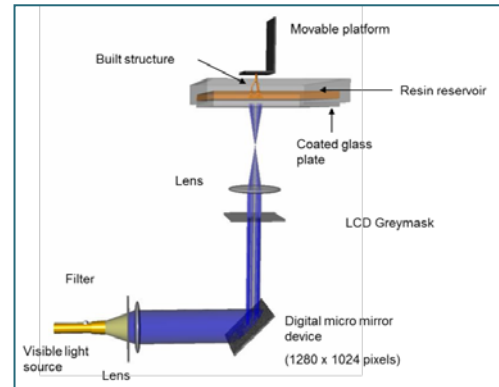
## Acrylate modified natural polymers

- Acrylate gelatin
- Acrylate collagen

## Polymer/nano particles composite

- Nano-hydroxyapatite
- $\text{Fe}_3\text{O}_4$
- $\text{MgO}$

Envisiontec®  
Perfactory Mini  
Multi lens



Mathematically defined  
biocompatible scaffolds



PDLLA/nano Hydroxyapatite  
composite scaffold

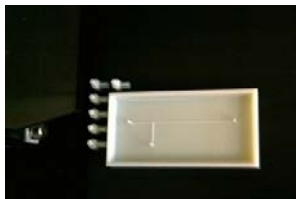
# PROCESSING

**Objet30**

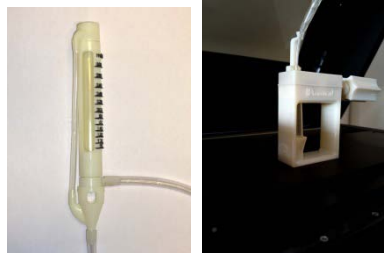


Roomy tray size of 300 × 200 × 150 mm  
(11.81 × 7.87 × 5.9 in.)

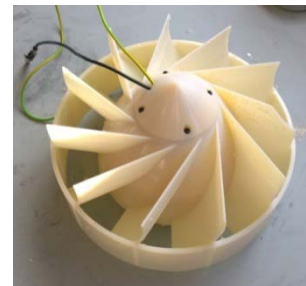
Layer thickness: 28 microns (0.0011 in.)  
Accuracy: 0.1 mm (0.0039 in.)



**Microfluidic devices**



**Medical devices**



**Wind turbine**



**Nokia 820 cover  
MWC 2013**

# PROCESSING

## Nano-size powder

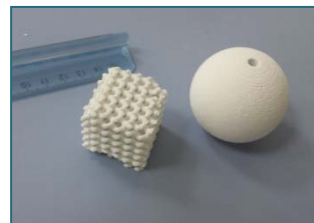
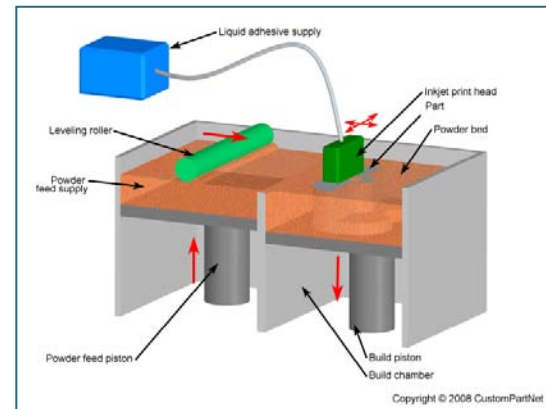
- Gelatin nano-powder
- zp<sup>®</sup>131-140
- Z<sup>®</sup>cast

+

## Liquid binder

- Water
- Z-bond
- Z-Max<sup>™</sup> Epoxy
- Wax

ZPrinter<sup>®</sup> 310





# PROCESSING

## Polyesters

- Polyethylene glycole
- Polycaprolactone

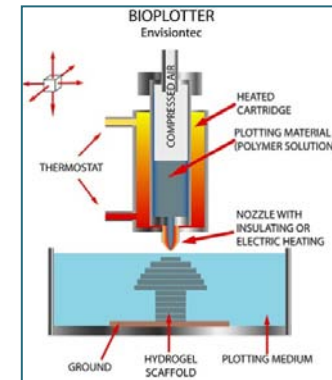
## Natural Polymers solution

- Collagen
- Gelatin
- Alginate

## Polymer/nano particles composite

- Nano-hydroxyapatite
- $\text{Fe}_3\text{O}_4$
- MgO

Envisiontec®  
Biplotter



PCL/HA nanocomposite scaffold for mandibular symphysis TE



PCL scaffold for Meniscus TE



Custom-made and gel-loaded IVD scaffold



Magnetic nano-composite scaffolds

# PROCESSING

## Polyesters

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- Polycaprolactone

## Natural Polymers solution

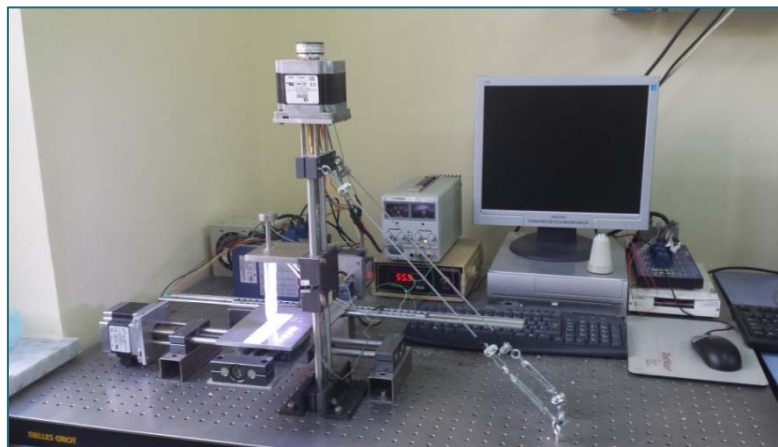
- Collagen
- Gelatin
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Homemade four axes printer  
(National Instrument™/Labview™)



Stereolithography/Bioplotter  
combined scaffolds

# PROCESSING

## Natural Polymer solution

- Collagen
- Gelatin
- Alginate

+

## Cells

- hMSCs
- Fibroblast

## CAD-CAM Gel/Cells deposition

Spraybase®



Cell -loaded nucleus/annulus substitute  
at 5 days after cell seeding

# REFERENCES

1. Gloria, T. Russo, R. De Santis, L. Ambrosio. "3D fiber deposition technique to make multifunctional and tailor-made scaffolds for tissue engineering applications". *Journal of Applied Biomaterials & Biomechanics*. 2009; 7:141-52.
2. R. De Santis, A. Gloria, T. Russo, U. D'Amora, S. Zeppetelli, A. Tampieri, T. Herrmannsdörfer, L. Ambrosio, "A route toward the development of 3D magnetic scaffolds with tailored mechanical and morphological properties for hard tissue regeneration: preliminary study". *Virtual and Physical Prototyping*, 6(4), 189-195, 2011.
3. R. De Santis, A. Gloria, T. Russo, U. D'Amora, V. D'Antò, F. Bollino, M. Catauro, F. Mollica, S. Rengo, L. Ambrosio, "Advanced composites for hard-tissue engineering based on PCL/organic-inorganic hybrid fillers: From the design of 2D substrates to 3D rapid prototyped scaffolds". *Polymer Composites*, 34, 1413-1417, 2013.
4. Domingos M, Intranuovo F, Russo T, De Santis R, Gloria A, Ambrosio L, Ciurana J, Bartolo P., "The first systematic analysis of 3D rapid prototyped poly( $\epsilon$ -caprolactone) scaffolds manufactured through BioCell printing: the effect of pore size and geometry on compressive mechanical behaviour and in vitro hMSC viability". *Biofabrication*, 5 (4), 045004 (13 pp), 2013.
5. Roberto De Santis, Antonio Gloria, Teresa Russo, Angelo Varriale, Mario Veltri, Piero Balleri, Francesco Mollica, Francesco Riccitiello, Luigi Ambrosio, "Reverse engineering of mandible and prosthetic framework: Effect of Titanium implants in conjunction with Titanium milled full arch bridge prostheses on the biomechanics of mandible". *Journal of Biomechanics*, 47,16, 3825-3829. 2014.
6. Ronca A , L. Ambrosio, D.W. Grijpma, Preparation of designed poly(d,l-lactide)/nanosized hydroxyapatite composite structures by stereolithography .*Acta Biomater.* 9, 5989-5996, 2013.