Active surfaces, materials and tools for assembly

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Definition of the research scope

Active surfaces, materials and tools for assembly

- **Active:** the material is activated by chemical, mechanical, thermal processes. Its properties are radically different from those of unactivated areas.
- **Surfaces:** micro and nano texture, paintings, coatings over the surface can generate strong energy gradient that can be exploited for many purposes.
- **Materials:** SMA, SMP, EAP, PZT, but also super-elastic alloys, palladium, silicon, conductive polymers, etc.., rheopetic and tixotropic liquids generate new possibilities for assembly.
- **and tools for assembly:** IR cameras, high speed cameras, ionizers, etc.. can increase performances in assembly.

Rationale

- Possibility of manufacturing (and measuring) micro and nano textures on surfaces of different materials.
- Complex patterns and surface textures can be manufactured. It allows to confer different properties (even opposite) to areas bordering each other.
- Such surfaces can be active (chemically, electrostatically, Van der Waals, etc..) or actuated (piezoelectrically, mechanically, etc..) however they can be designed, manufactured and actuated at all scales.

- The characteristics of grasping/feeding surfaces often depend also on the layers beneath the surface itself.

Background for "Surfaces in Assembly"

Keynotes with potential impacts on research about active surfaces for assembly:

2011 - Replication of Micro and Nano Surface Geometries
H.N. Hansen (1), R.J. Hocken (1), G. Tosello

2011 - Biologically Inspired Design
L.H. Shu (2), K. Ueda (1), I. Chiu, H. Cheong

2009 - Cooperation of Human and Machines in Assembly Lines
J. Krüger (2), T.K. Lien (2), A. Verl (2)

2008 - Advances in engineered surfaces for functional performance

A.A.G. Bruzzone (2), H.L. Costa, P.M. Lonardo (1), D.A. Lucca (1)

2000 - Assembly of Micro-System

H. Van Brussel (1) , J. Peirs, D. Reynaerts, A. Delchambre, G. Reinhart (2) , N. Roth (2) , M. Weck (1), E. Zussman (2)

…

Feeders (1)

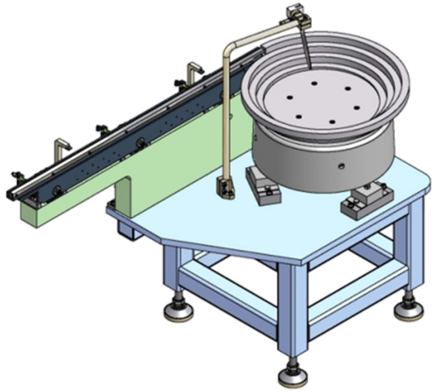
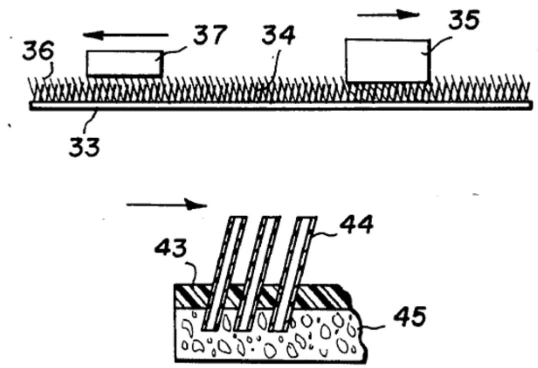
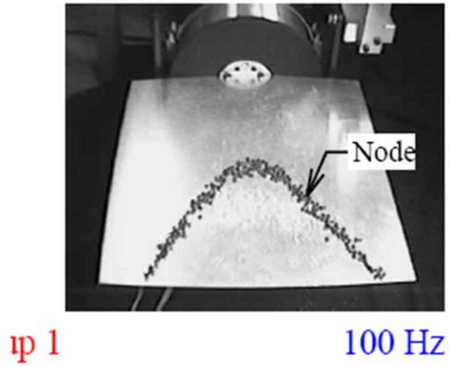
Active surfaces have been organised according to the physical principle they exploit for feeding.

Some of them work properly at the micro-meso scale while other also at the macroscale.

ACTIVE SURFACES for part feeding

Cilia	Nodal	Air Nozzles (programmable)	Hydrophillic Hydrophobic	Electrostatic	Gravitational
Friction					Bounce and fall
Brushes					Underwater

Some of the described feeders (2)

<table>
<tr><td>Bowl & linear feeder
(barely out of scope)</td><td>Brush feeder</td><td>Nodal lines - feeder</td></tr>
<tr><td></td><td>
</td><td>
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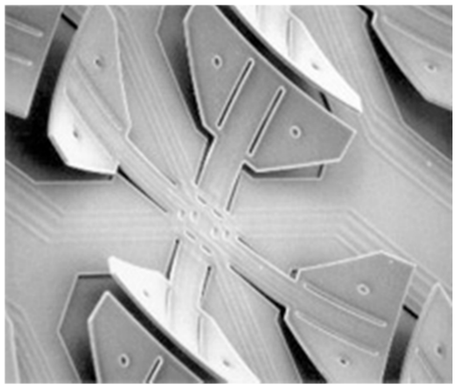
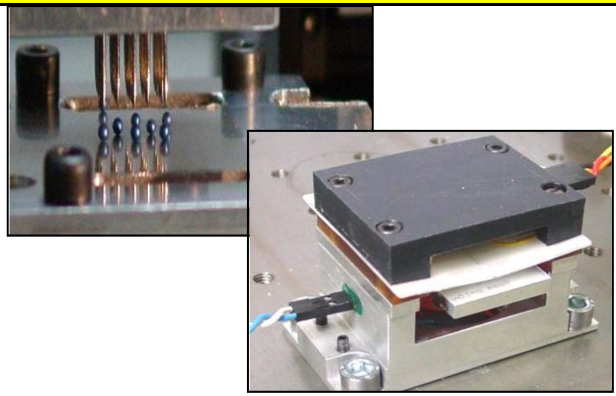
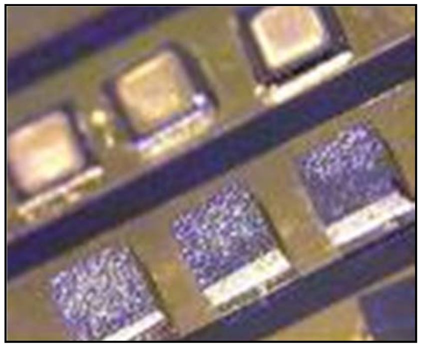
<tr><td>Feeder based on microcilia</td><td>Electrostatic feeder</td><td>Hydrophillic-Phobic Feeder</td></tr>
<tr><td></td><td></td><td></td></tr>
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Feeders (3)

Active surfaces	Active & Actuated surfaces	Actuated surfaces
Feeder based on hydrophillic and hydrophobic areas Electrostatic “permanent” traps and magazines Underwater traps and pockets	Electrostatically based feeders Brush feeder Microcilia Air feeder Externally-resonated micro vibromotor for microassembly	Nodal lines over vibrating plates Feeding by bouncing and falling Gravity traps Automated feeding of micro parts based on piezoelectric vibrations

Gripper to grasp (1)

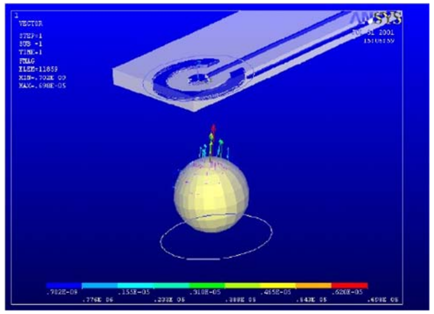
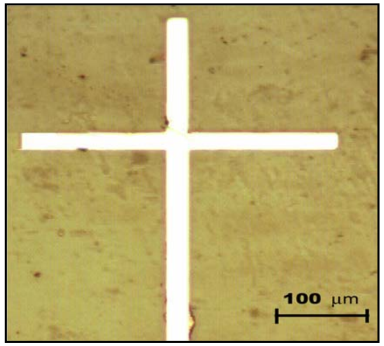
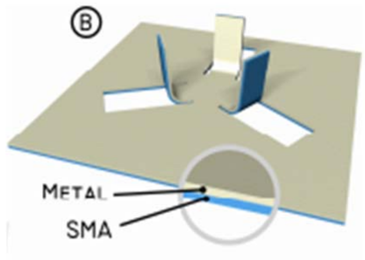
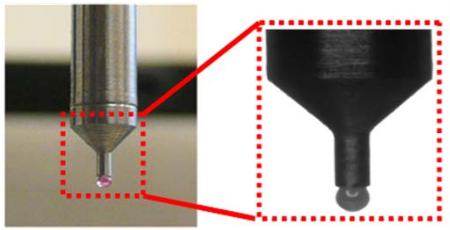
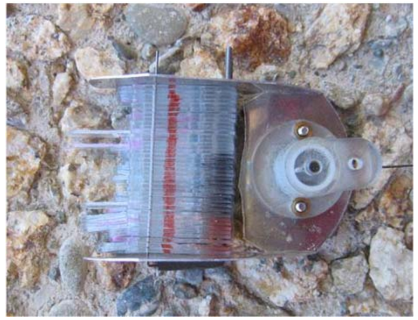
Active surfaces have been organised according to the physical principle they exploit for grasping.

Some of them work properly at the micro-meso scale while other also at the macroscale.

ACTIVE SURFACES AND MATERIALS for grasping

- …
- Van der Waals
  - Gecko
- Distributed friction
  - Universal Gripper
- Thermal Glue
- IR transp. gripper
- Wet adhesion
  - Frog
  - Hydrophillic Hydrophobic
  - Deform. membrane
  - EAP
  - 2 liquids
- Electrostatic

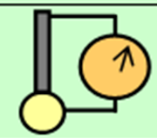
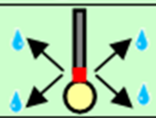
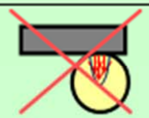
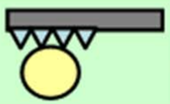
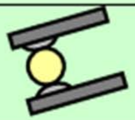
Gripper to grasp (2)

Electrostatic	Electrostatic	Gecko	Self centering SMA
 [Hesselbach]		 [Lanzetta]	 [Shu]
Flexible cups	**Capillary**	**Universal Gripper**	**Spini gripper**
[Dini]	 [Lambert]		 Squirrel [Cutkosky]

Gripper to grasp (3)

Active surfaces	Active & Actuated surfaces	Actuated surfaces
Liquid	Liquid+structured+actuated*	liquid+deformable membrane
Liquid-liquid manipulation*	Electrostatic	Centering
Gecko like	Electrowetted	Thermal glue
Electrostatic	UniversalGripper	Ultrasound
	Flexible vacuum cups	

Gripper to relase (1) at microscale

Type	Principle	Scheme	Description	Force↓
Gripper	Conductive material/coatings -*Grounded gripper*		Conductive materials or coatings (which do not form insulating oxides) reduce static charges. Grounded grippers prevent the charge storage [3, 5]	electrostatic
	Low difference of EV potential		Gripper and object made of materials with a small potential difference reduce "contact interaction" forces [5]	electrostatic
	Hydrophobic coating		Hydrophobic coating reduces surface tension effects: it prevents the adsorption of moisture [6]	surface tension
	Low Hamaker constant Coating		Low Hamaker constant coating reduces van der Waals forces [3]	van der Waals
	Hard materials		Contact pressure causes deformations, increasing the contact area between gripper and object: grippers made of hard material have to be preferred [5]	van der Waals; electrostatic
	Rough surface -*Micro pyramids*		The gripper roughness reduces the contact area and sharp edges induce the self discharge effect [5, 6]	van der Waals; electrostatic
	"Spherical" fingers		Spherical fingers reduce the contact area in comparison with planar ones [5]	van der Waals; surface tension

Gripper to relase (2) at microscale

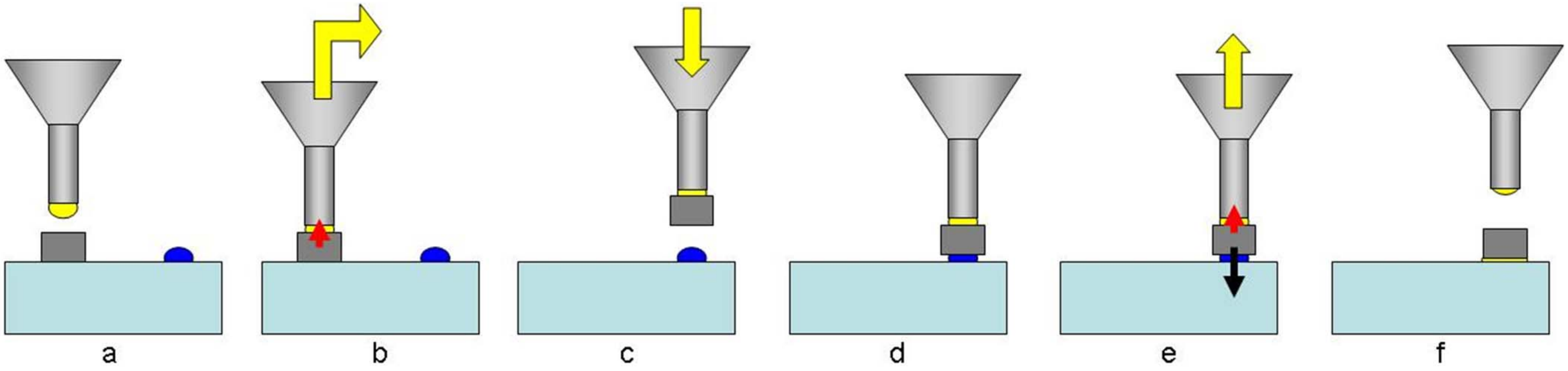
Active surfaces	Active & Actuated surfaces	Actuated surfaces
Conductive Coatings	Invert voltage	Micro heater
Hydrophobic Coatings	Liquid+structured+actuated*	Varying the gripper curvature
Superhydrophobic Coatings	EAP based Releasing	Tilting the gripper
Hard materials	Varying roughness by vibration	Acceleration or vibration
Rough surfaces		

Findings

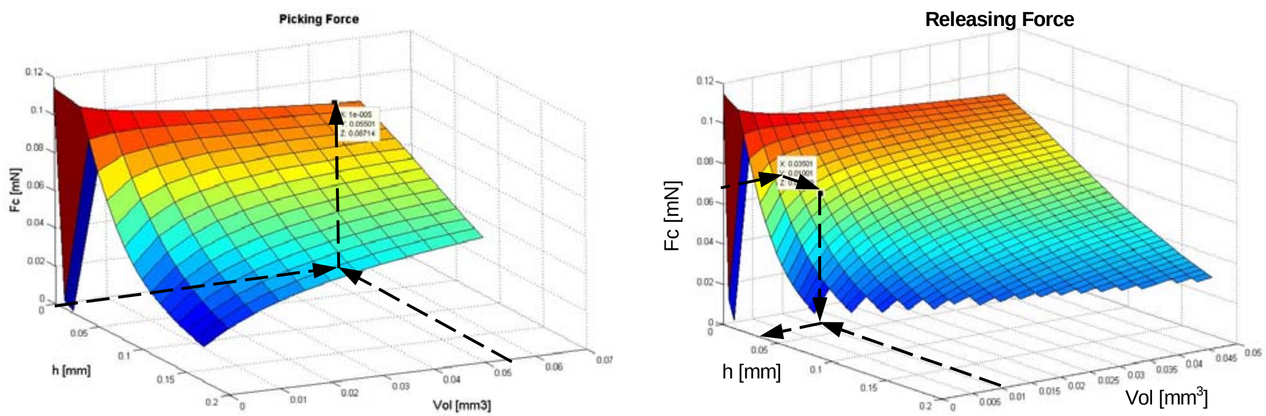
- New Devices for grasping and releasing microparts
  - At UNIPI
  - In collaboration with DTU

- New reseach opportunities

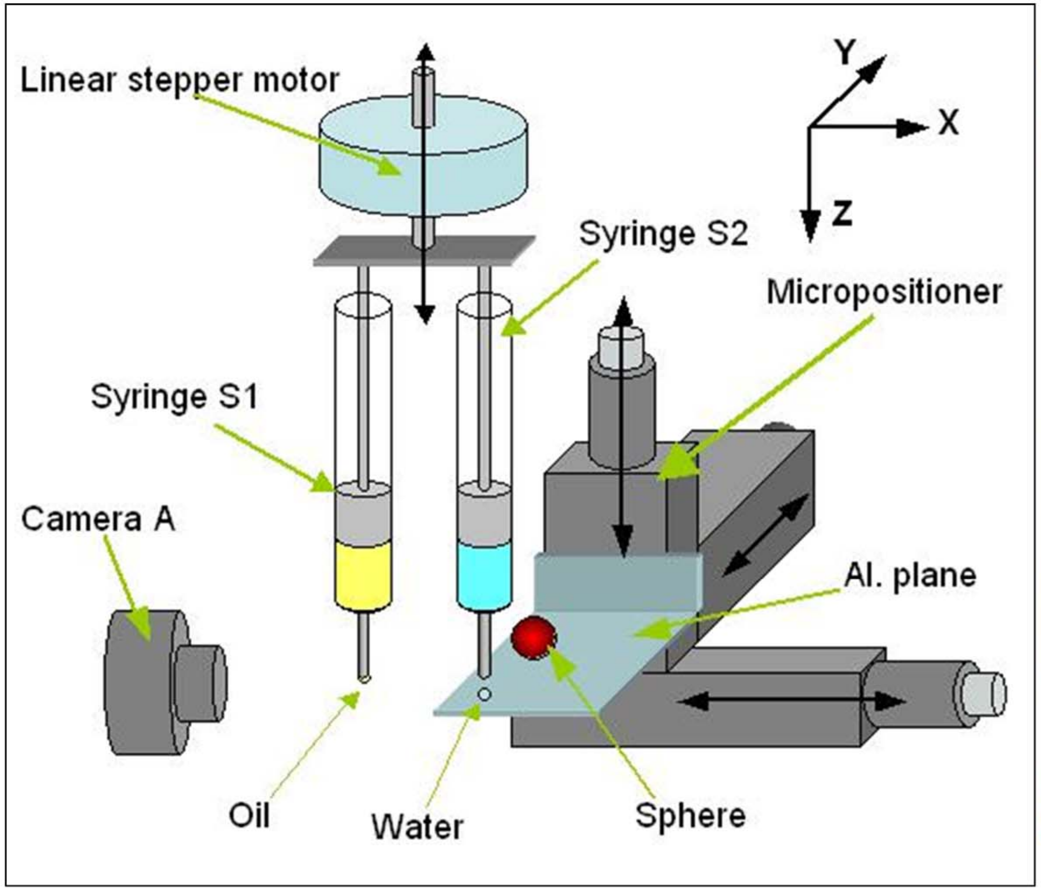
Grasping and releasing microparts exploiting liquids with different surface tensions

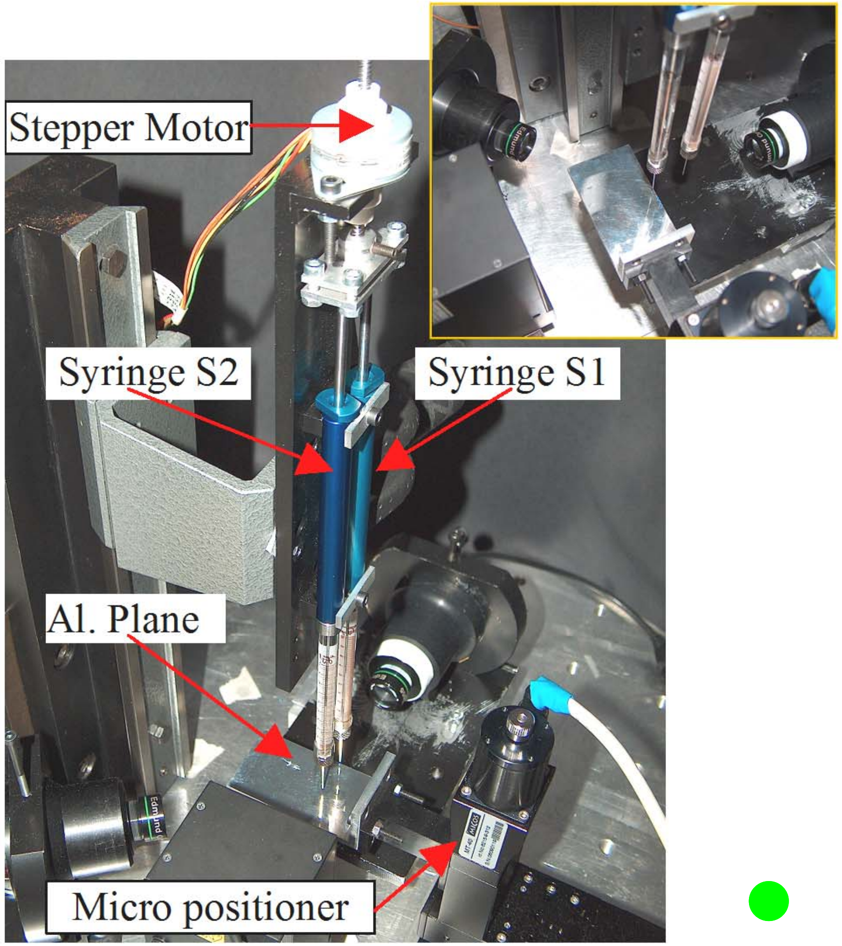


A novel grasping and releasing strategy for microparts exploiting liquids with different surface tensions
[Fantoni, Porta, Santochi]



Grasping and releasing microparts exploiting liquids with different surface tensions

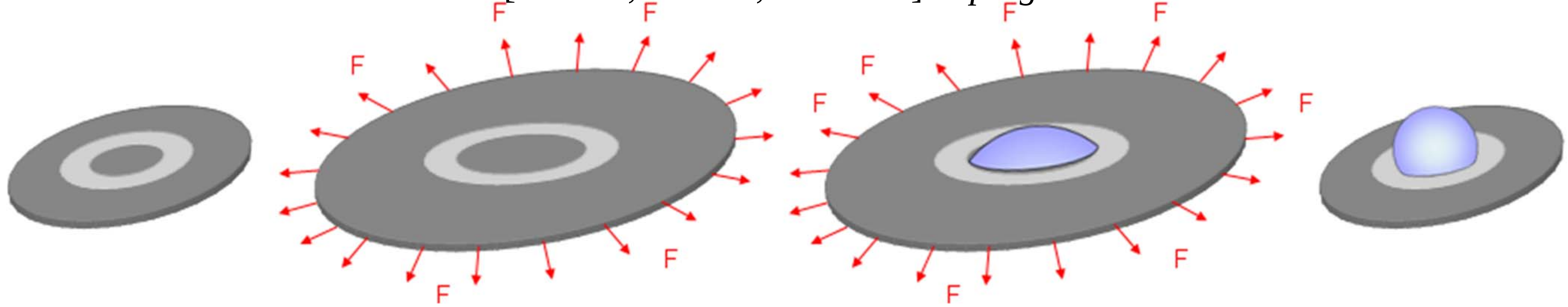




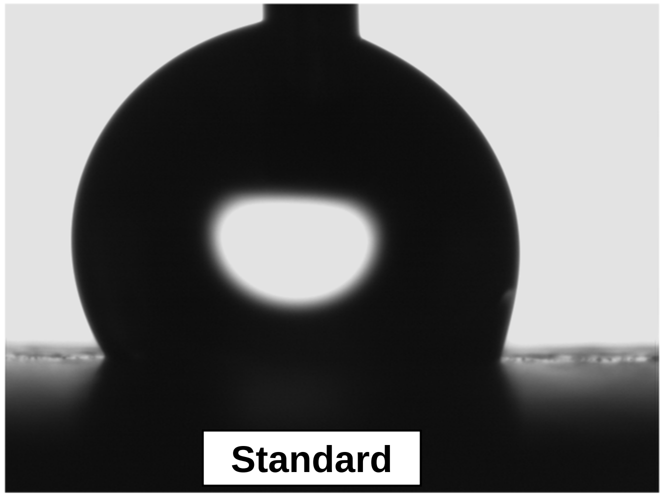
Active surfaces for grasping and releasing of microparts

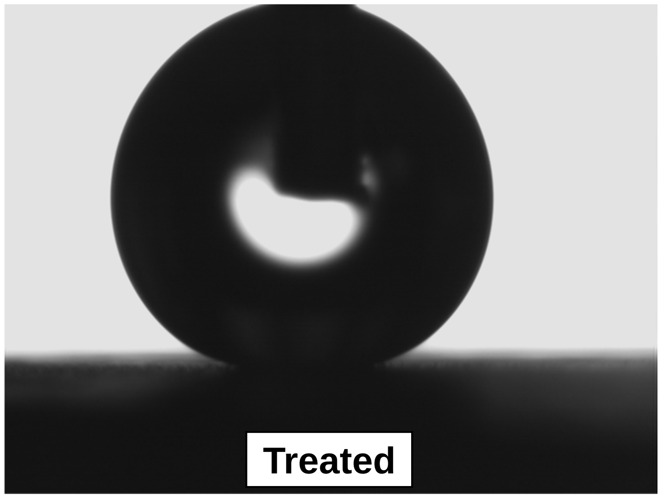
Grasping and releasing of microparts by using active hydrophillic-phobic surfaces

[Fantoni, Hansen, Santochi] *in progress*

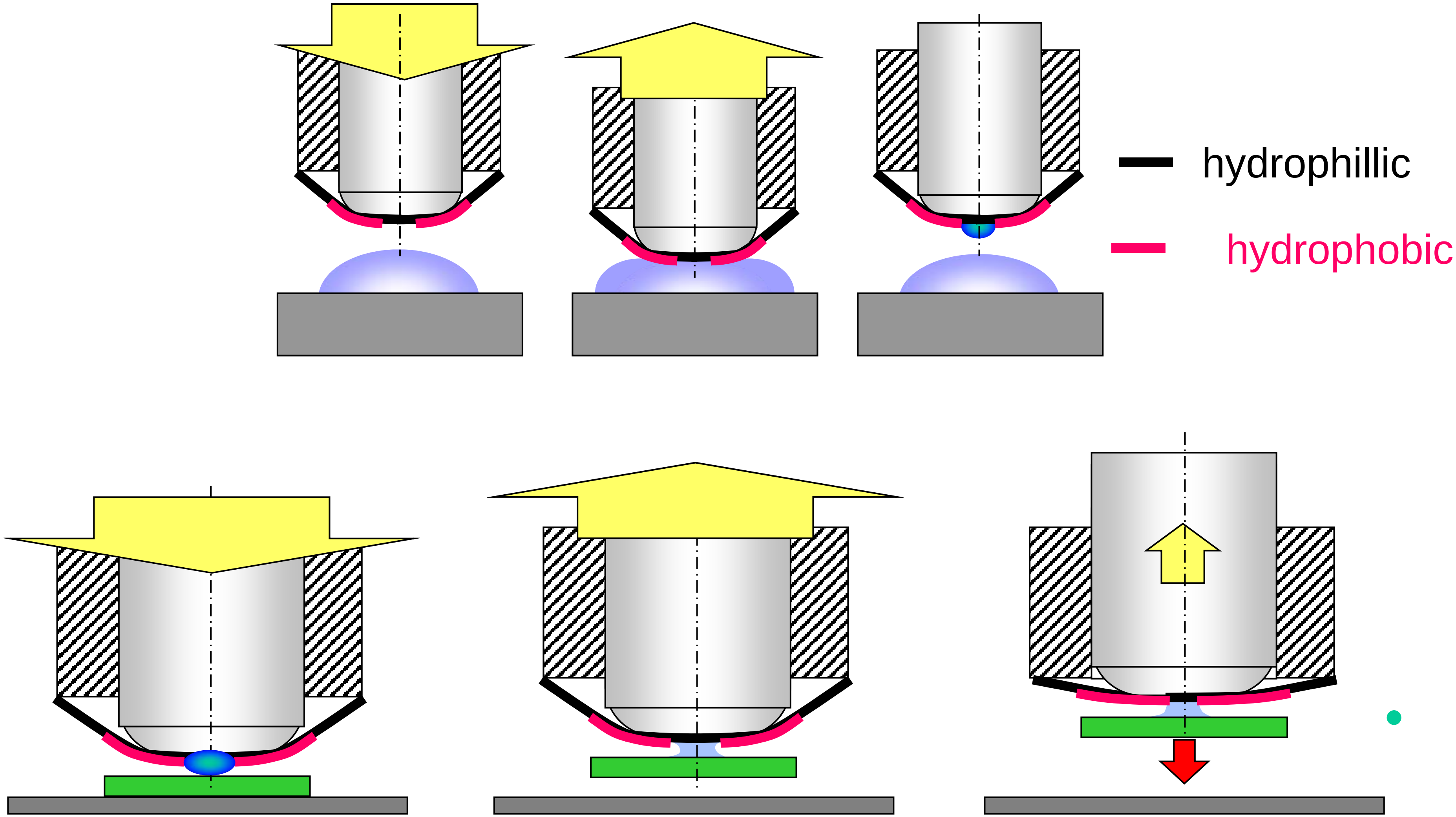


Programmable hydrophobic surfaces [Fantoni, Zang, Tosello, Hansen] *in progress*

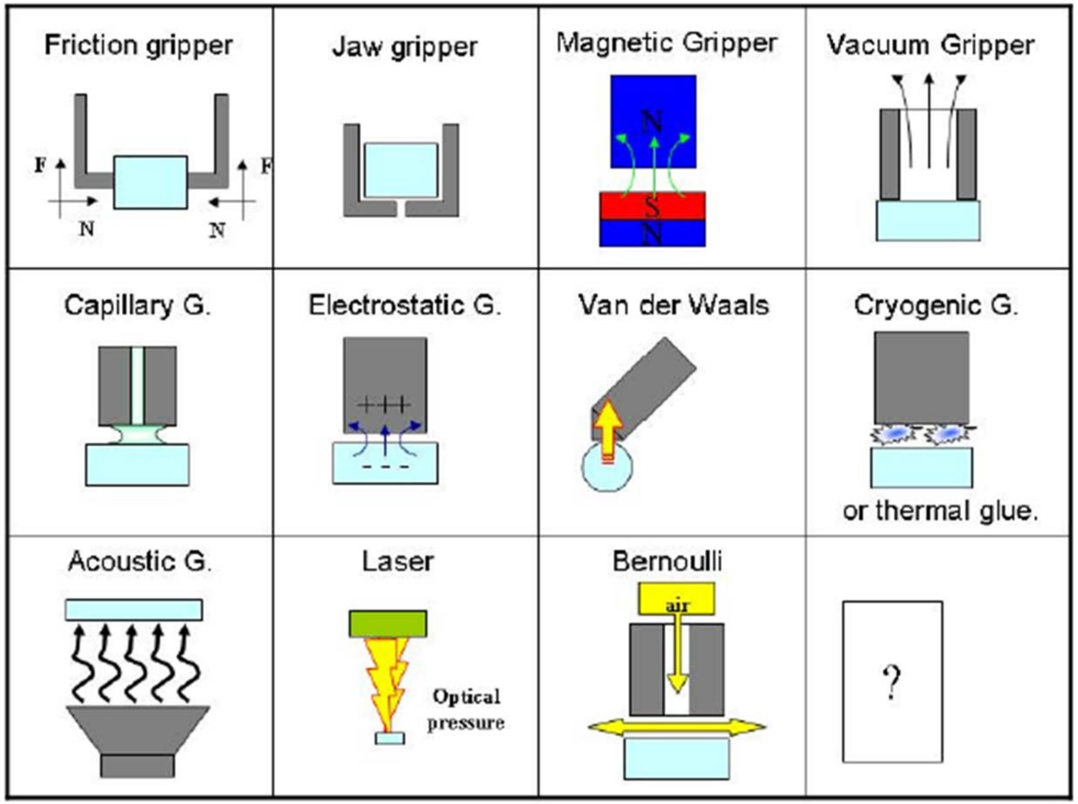


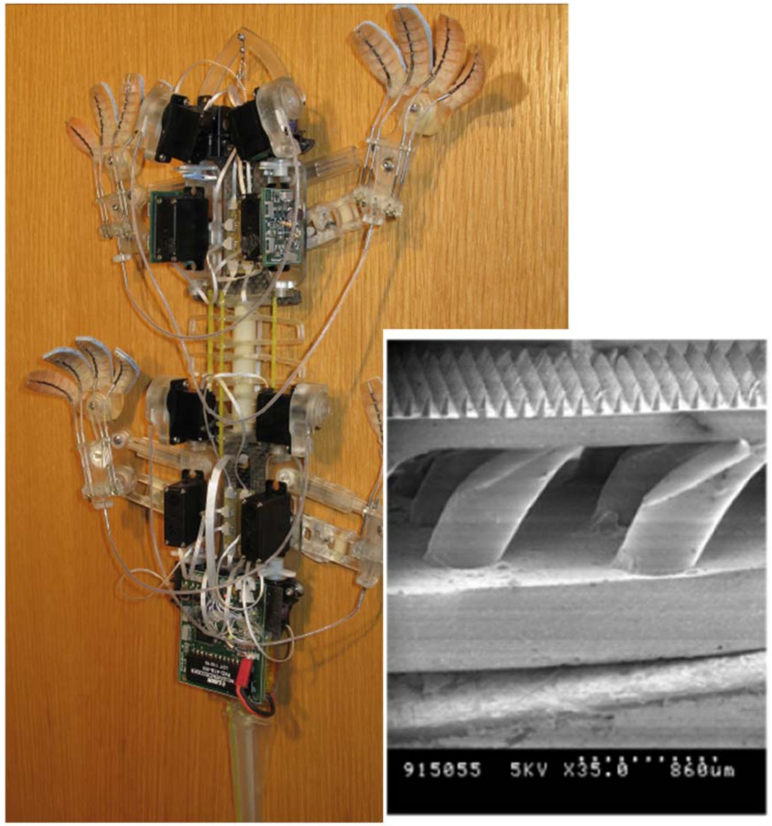


Active surfaces for grasping and releasing of microparts



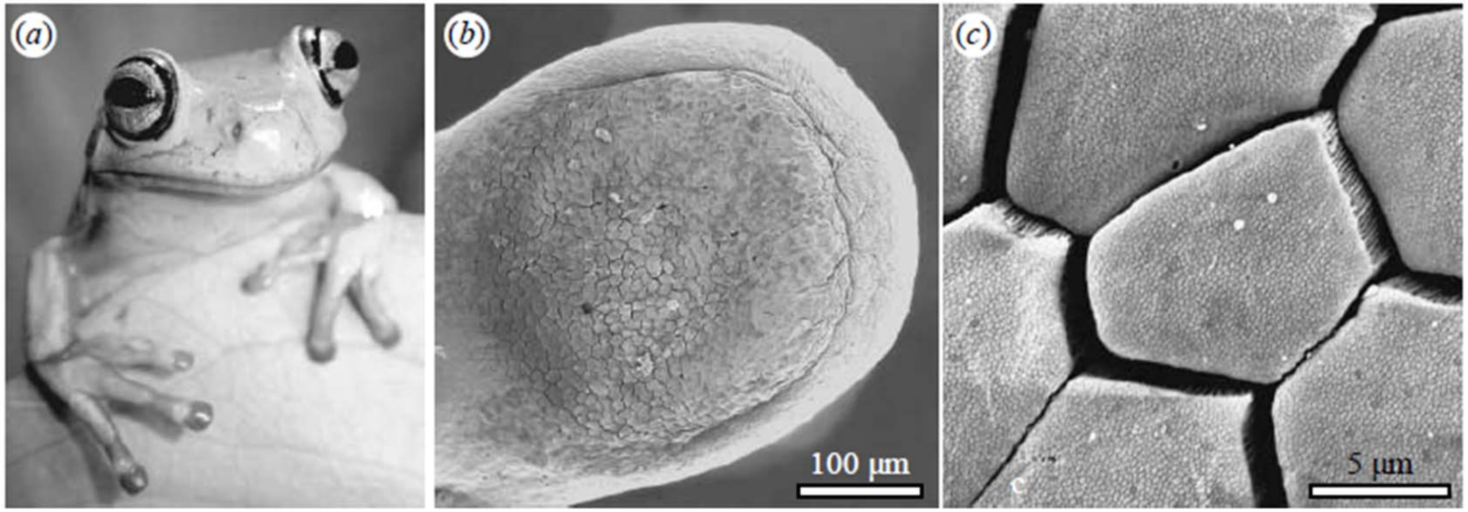
Research opportunities: from micro to macro



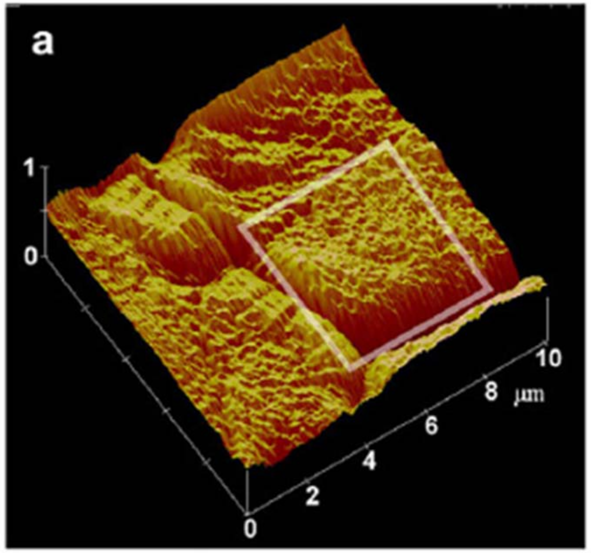


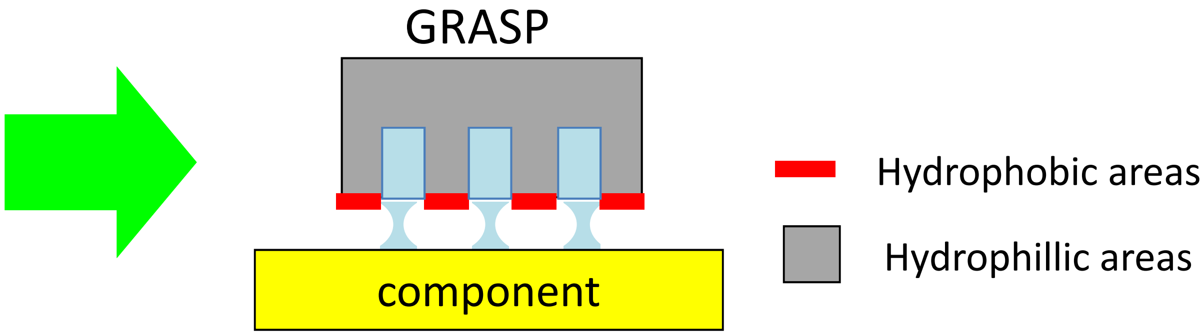
M. Lanzetta, M.R. Cutkosky, Shape Deposition Manufacturing of Biologically Inspired Hierarchical Microstructures, CIRP Annals of Manufacturing Technology, 2008

Toward a new adhesive gripper

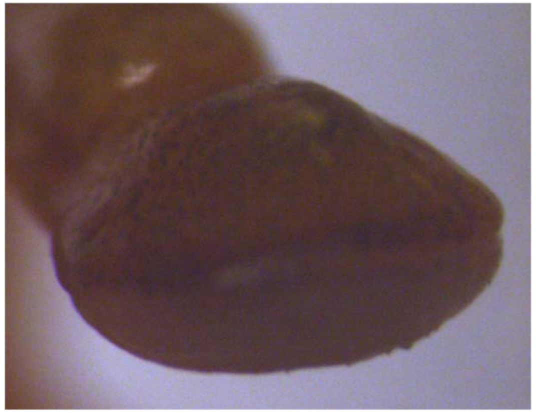


W Federle, W.J.P Barnes, W Baumgartner, P Drechsler and J.M Smith, **Wet but not slippery: boundary friction in tree frog adhesivetoe pads** *J. R. Soc. Interface* 2006 **3**, 689-697

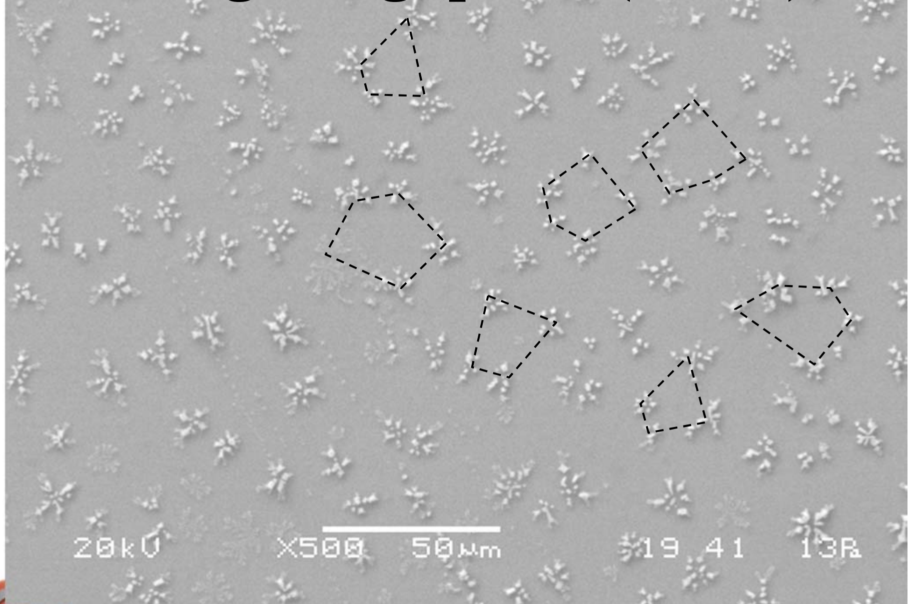




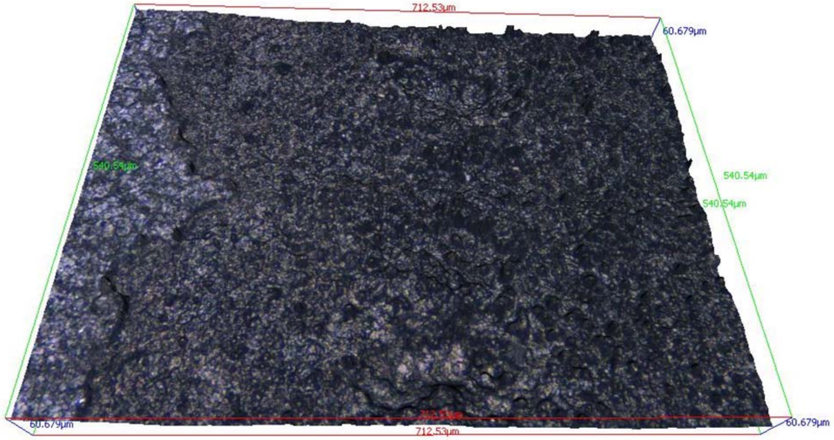
Toward a new adhesive gripper: skin and pulp

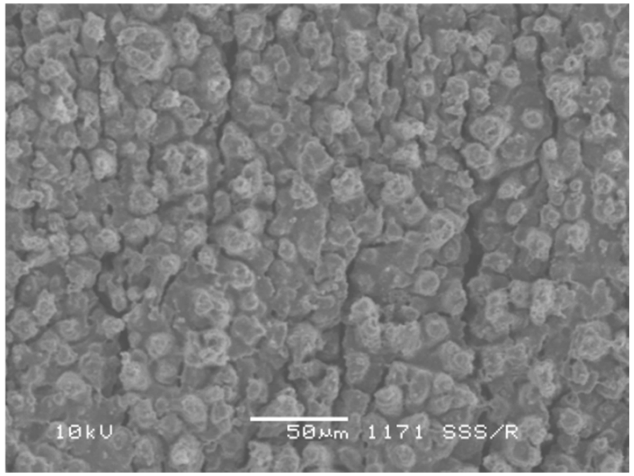


Frog Fingerprint (SEM)



Supehydrophobic surface





Conclusions

- Research activities
  - RobLog (7° EU project)
  - MicroGrippers expoliting structured surfaces
  - Extension of the grasping principles from micro to macro
  - Continue the research on compliant, actuated, hyerarchical surfaces
- Search for partners for joint projects and exchange of students
- Keynote paper on “Grasping and handling devices and methods in assembly”??

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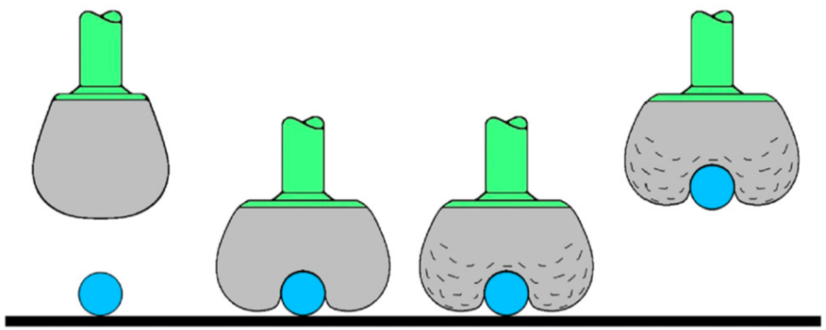
Research opportunities (2): NOT only a surface problem

- The problem is in part more complex, actually the underskin structure plays a key role in mating
- Hyerarchical structures are a solution:
  - Compliant Spines (insects) → Independent and adaptable structures
  - Tree structures (gecko) → Beam-plate structures (Lanzetta, Cutkosky)
- Transition from flexible to rigid is another solution



But we can exploit also non newtonian fluids.
Ie. Rheopectic/ Thixotropic liquids increase/decrease in viscosity as stress over time increases.

Toward a new adhesive gripper

- Functions of the skin and side channels:
  - Roughness of the skin → to exert lateral friction
  - Roughness of the skin → supehydrophobic?
  - Side channels → collect, feed and remove water in order to avoid waterplaning
  - Side channels → hydrophillic areas quickly retract water to use it during climbing

- Functions of the pillars:
  - Supply the skin with additional dof in order to mate the pulp with the surface roughness (meso) also in case of corners, sharp edges etc..

- Functions of the pulp:
  - Mate the pulp with the surface roughness (micro)

Feeder (4): References

- Karl Böhringer, K, Bhatt, V, Goldberg, K, 1995, Sensorless Manipulation Using Transverse Vibrations of a Plate, IEEE International Conference on Robotics and Automation
- U. Gengenbach, J. Boole, "Electrostatic feeder for contactless transport of miniature and Microparts", *Microrobotics and Micro-manipulation, Proceeding of SPIE*, 2000, pp. 75-81.
- Gan-Mor, S., Law, E.,. "Frequency and Phase -Lag Effects on Transport of Particulates by an AC Electric Field", *IEEE Transactions on Industry Applications*, Vol. 28, 1992, pp.317-322.
- Moesner, F. M., Higuchi, T., "Electrostatic Devices for Particle Microhandling", *IEEE Transactions on Industry Applications*, Vol. 35, No. 3, 1999, pp.530-536
- Böringer, K.F., Cohn M., Goldberg K., Howe R., Pisano A.,. "Parallel microassembly with electrostatic force fields", *Proceedings of IEEE International Conference on Robotics and Automation*, 1998, pp. 1204-1211.
- del Corral, C., Zhou, Q., Albut, A., Chang, B., Franssila, S., Tuomikoski, S., Koivo, H.N., 2003, Droplet Based Self-Assembly of SU-8 Microparts, 2nd VDE World Microtechnologies Congress, Munich, Germany, 293-298.
- Böhringer, K. F., Srinivasan, U., Howe, R. T., 2001, Modeling of capillary forces and binding sites for fluidic self-assembly, The International Conference on Micro Electro Mechanical Systems, 369-374.
- Hesselbach, J., Büttgenbach, S., Wrege, J., Bütefisch, S., Graf, C., 2001, Centering electrostatic microgripper and magazines for microassembly tasks, Microrobotics and Microassembly 3, Proc. of SPIE, vol. 4568, Newton, USA.
- J. Hesselbach, J. Wrege, A. Raatz, 2007, Micro Handling Devices Supported by Electrostatic Forces, Annals of the CIRP, vol 56/1, pp. 45-48
- Fantoni, G., Santochi, M., 2005, A modular contactless feeder for microparts, Annals of the CIRP, vol.54/1, pp. 23-26.
- Fantoni, G.; Porta, M. Santochi, M., 2007, An electrostatic sorting device for microparts, Annals of the CIRP, vol.56/2, pp. 21-24.
- Fantoni, G.; Santochi, M., 2010, "Development and testing of a brush feeder", *Annals of the CIRP, vol.59/2*
- Van Brussel, H., Peirs, J., Reynaerts, D., Delchambre, A., Reinhart, G., Roth, N., Weck, M., Zussman, E., 2000, Assembly of Microsystems, Annals of the CIRP, vol. 49/2.
- Kru¨ ger J, Lien TK, Verl A 2009, Cooperation of Human and Machines in Assembly Lines. CIRP Annals-Manufacturing Technology 58(2):628–646.
- Reinhart G, Loy M, 2008, Flexible Feeding of Complex Parts. 2nd CIRP Conference on Assembly Technologies and Systems, Toronto, Canada.
- Boothroyd, G. and Dewhurst, P. (1983). Design for Assembly { A Designers Handbook. Department of Mechanical Engineering, University of Massachusetts, Amherst, Mass
- *Trap Design for Vibratory Part Feeders.* R-P. Berretty, K. Goldberg, M. Overmars, F. Van der Stappen. International Journal of Robotics Research. 20(11), November 2001.
- Mike Brokowski, Michael Peshkin Ken Goldberg, 1993, Curved fences for part alignment, IEEE International Conference on Robotics and Automation
- Michele Turitto, Yves-André Chapius and Svetan Ratchev , 2006, Pneumatic Contactless Feeder for Microassembly, Precision assembly technologies for mini and micro products, IFIP International Federation for Information Processing, Volume 198/2006, 53-62, DOI: 10.1007/0-387-31277-3_6
- Kazuhiro Saitou*a* and Soungjin J. Wou, 1998, Externally-resonated linear micro vibromotor for microassembly, Proc. SPIE Microrobotics and Micromanipulation 3519, 128 (1998); doi:10.1117/12.325733, Boston, MA, USA
- Fully Programmable MEMS Ciliary Actuator Arrays for Micromanipulation Tasks, (with J. Suh, R. B. Darling, K.-F. Böhringer, H. Baltes, and G.Kovacs), the *IEEE International Conference on Robotics and Automation (ICRA)* San Francisco (April, 2000) pp. 1101-1108.

Gripper to grasp (5): References

- L.H. Shu, T.A. Lenau, H.N. Hansen, L. Alting, Biomimetics Applied to Centering in Microassembly, Annals of the CIRP Vol. 52/1/2003
- Sven Rathmann, Annika Raatz, Jürgen Hesselbach: Concepts for Hybrid Micro Assembly Using Hot Melt Joining. IPAS 2008: 161-169
- Hesselbach, Jürgen; Wrege, Jan; Raatz, Annika, 2007, Micro Handling Devices Supported by Electrostatic Forces, CIRP Annals - Manufacturing Technology , Elsevier Vol. 56/1, 45-48
- G. Reinhart, J. Hoeppner, Non-Contact Handling Using High-Intensity Ultrasonics, CIRP Annals - Manufacturing Technology, Volume 49, Issue 1, 2000, Pages 5-8
- Reinhart, G.; Höppner, J.: The Use of AcousticLevitation Technologies for Non-Contact HandlingPurposes. In: Annals of the German Academic Society for Production Engineering VIII(2001)1
- Pagano, C., Ferraris, E., Malosio, M., Fassi, I., 2003, Micro-handling of parts in presence of adhesive forces, CIRP Seminar on Micro and Nano Technology 2003, Copenhagen, November 13-14, pp. 81-84.
- Biganzoli, F., Pagano, C., Fassi, I., (2005), Development of a gripping system based on capillary force, The 6th IEEE International Symposium on Assembly and Task Planning: From Nano to Macro Assembly and Manufacturing, 2005. (ISATP 2005).
- Koyano, K., Sato, T., 1996, Micro object handling system with concentrated visual fields and new handling skills, Proc. of the IEEE Int. Conference on Robotics and Automation, pp. 2541-2548.
- Autumn, K., Liang, Y. A., Hsieh, S. T., Zesch, W., Pang Chan, W., Kenny, T. W., Fearing, R., Full, R. J., (2000), Adhesive force of a single gecko foot-hair, Letter to Nature, NATURE, Vol 405.
- Enikov, E.T., Lazarov, K.V., 2001, Optically transparent gripper for microassembly, SPIE, vol. 4568, pp. 40-49.
- Monkman, G.J., 2003, Electroadhesive Microgrippers, Assembly Automation vol. 24/1, MCB University Press.

Gripper to relase (3) at microscale

- A.A.G. Bruzzone (2), H.L. Costa, P.M. Lonardo (1), D.A. Lucca (1), 2008, Advances in engineered surfaces for functional performance, Annals of the CIRP
- H. Van Brussel (1) , J. Peirs, D. Reynaerts, A. Delchambre, G. Reinhart (2) , N. Roth (2) , M. Weck (1), E. Zussman (2), 2000, Assembly of Micro-System, Annals of the CIRP
- Arai, F., Andou, D., Fukuda, T., Nonoda, Y., Oota T., 1995, Micro Manipulation Based on Micro Physics -Strategy Based on Attractive Force Reduction and Stress Measurement-, Proc. of IEEE/RSJ Conf. on Robots and Intelligent Systems 2, pp. 236-241.
- Fearing, R.S., (1995), Survey of Sticking Effects for Micro Parts Handling, Proc. IROS ’95, IEEE/RSJ Int. Conf on Intelligent Robots and System, 2:236-241
- Tichem, M., Lang, D., Karpuschewski, B, (2003), A classification scheme for quantitative analysis of micro-grip principles, Proc. of the Int. Precision Assembly Semininar, Bad Hofgastein, Austria.
- Gegeckaite A, Hansen HN, De Chiffre L, Pocius P (2007) Handling of Micro Objects: Investigation of Mechanical Gripper unctional Surfaces. Proceedings of 7th EUSPEN International Conference, Bremen, 185–188.

Please, find further references in

- Fantoni, G., Porta, M., 2008, A critical review of releasing strategies in microparts handling, Proceeding of the 6th Int. Precision assembly seminar (IPAS’2008), 17-19 March, Bad Hofgastein, Austria.