UNIVERSITÉ DE FRANCHE-COMTÉ

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Titre de la thèse/Thesis title : Soft Poly-Articulated Microrobots Embedding their Actuation for Force-Controlled Nanomanipulation

Laboratoire d'accueil / Host Laboratory : FEMTO-ST Institute, AS2M Department

Spécialité du doctorat préparé/Speciality : Robotics

Mots-clefs / Keywords : Design, modelling, control, soft and/or articulated robots, control robot-environment interactions, robotics at small scales, experimentation

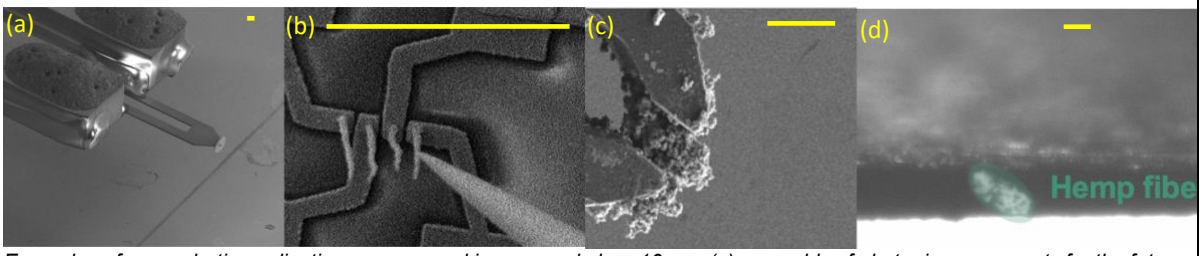
Descriptif détaillé de la thèse / Job description

Context of the PhD thesis:

The AS2M department at the FEMTO-ST Institute, University of Bourgogne Franche-Comté and Micro-Nano-Robotics Center, invites applications for a fully funded 3-year PhD position to design, model, develop Soft Poly-Articulated Microrobots and investigate their experimental behaviors specially to achieve force-controlled nanomanipulation tasks.

This thesis aims at contributing to the field of designing and controlling robots that can be soft or poly-articulated and their use to achieve manipulation tasks. The application field that is targeted is of robotic manipulation at small scales and more especially at the nanoscale, i.e. when components have at least one dimension smaller than 100 nm [1].

Robotic manipulation at small scales is emerging very fast because it is of interest for many application fields from material science, food industry, green technologies, communications technologies. At this scale, the so small size of components makes methods based on physics of chemical approaches of wide use. At this scale, robotics appears as a disruptive approach since this is the lonely solution that enables not only the creation of contacts between the robot and the object, but also the control of these contacts (dynamics, amplitudes, direction, etc.) [2][3][4]. Numerous proofs of concept have been demonstrated, such as the application of mechanical stimuli generating deformation or the realization of localized measurements by contact (temperature, electrical resistance...) [5][6] demonstrating the interest of robotic manipulation at small scales for most of UN sustainable developments goals (examples of works done at FEMTO-ST in the below Figure) [7][8]. Nevertheless, these works were made possible by the use of commercially available robots and required complex/time taking/dedicated modelling and advanced control algorithms because of by their huge size which especially unusual in the field of robotic manipulation (Robot/component size ratio 10^6).



Examples of nanorobotic applications we are working on, scale bar: 10 µm: (a) assembly of photonic components for the future of nanophotonic circuits, (b) electrical characterization of 3D industrial nano-electronic devices, (c) characterization of 3D MOS2 grains by robotic gripping to quantify the energy savings they can generate in mechanical friction, (d) mechanical characterization by instrumented robotics of single plant fibers for the deployment of bio-based composites.

Objectives of the PhD thesis: In this context, the AS2M department recently developed disruptive fabrication methods that opens to robots embedding their actuation as small as 100µm as typical dimension (Figure below, Scale bar = 50 µm). The first process is based on folded silica that are activated by light or electrical power [9], while the second process is based on 4D printing of soft materials that are activated by temperature or light [10].

Polyarticulated robotic structures based-on folded Silica | Soft robotic structures based-on 4D printing

Today, robots embedding their actuation are being studied together with their multi-physical modelling to predict their free motions i.e. when the robots move freely without external contact or force to be applied. The main objective of the thesis is to study, design and develop a new generation of robots capable of generating forces and to control them, typically to achieve manipulation or characterization tasks. Modelling will especially combine an analytical model and inverse identification methods based on FEM (Finite Element Modelling). IA based methods might also be considered. The prediction of the forces generated/induced by robots when interacting with their environment will be investigated by enriching existing models as a first step. A second step will consist in considering force sensing capabilities to be integrated such as force sensors [11], position/displacement sensing [12] or thermal sensing [13]. This study will conduct to specific design that will be investigated together with the fabrication, control and experimental characterization of the robots. Their application to demonstrate nanomanipulation tasks will also be investigated.

Références bibliographiques / Bibliography [purple color = articles by us]

[1] Nelson, B., J., & Dong, L., Nanorobotics, Bhushan, B. (Ed.). (2017). Springer handbook of nanotechnology. Springer.
[2] Hou, B., Zhang, T., Yang, H., Han, X., Liu, L., Li, L., ... & Wang, Y. (2023). Advances in probing single biomolecules: From DNA bases to glycans. Interdisciplinary Materials, 2(4), 511-528.
[3] N. Pavliček et al. Generation, manipulation and characterization of molecules by atomic force microscopy. Nature Reviews Chemistry, 1, 0005 (2017)
[4] Grandgeorge, P., et al. (2018). Capillarity induced folds fuel extreme shape changes in thin wicked membranes. Science, 360(6386), 296-299.
[5] Shi, C et al. (2016). Recent advances in nanorobotic manipulation inside scanning electron microscopes. Microsystems & nanoengineering, 2(1), 1-16.
[6] J. Liddle et al. "Nanomanufacturing: a perspective." ACS nano 10.3 (2016).
[7] Bettahar, H., Lehmann, O., Clévy, C., Courjal, N., & Lutz, P. (2020). 6-dof full robotic calibration based on 1-d interferometric measurements for microscale and nanoscale applications. IEEE Trans. on Autom. Science and Engineering, 19(1), 348-359.
[8] André, A. N., et al. (2022). Automating Robotic Micro-Assembly of Fluidic Chips and Single Fiber Compression Tests Based-on XY θ Visual Measurement With High-Precision Fiducial Markers. IEEE Trans. on Autom. Science and Engineering.
[9] Benouhiba, A., Wurtz, L., Rauch, J. Y., Agnus, J., Rabenorosoa, K., & Clévy, C. (2021). NanoRobotic Structures with Embedded Actuation via Ion Induced Folding. *Advanced Materials*, *33*(45), 2103371.
[10] Adam, G., Benouhiba, A., Rabenorosoa, K., Clévy, C., & Cappelleri, D. J. (2021). 4D printing: Enabling technology for microrobotics applications. Advanced Intelligent Systems, 3(5), 2000216.
[11] Adam, G., Boudaoud, M., Reynaud, V., Agnus, J., Cappelleri, D. J., & Clévy, C. (2024). An Overview of Microrobotic Systems for Microforce Sensing. Annual Review of Control, Robotics, and Autonomous Systems, 7.
[12] Bettahar, H., Clévy, C., Courjal, N., & Lutz, P. (2020). Force-position photo-robotic approach for the high-accurate micro-assembly of photonic devices. IEEE Robotics and Automation Letters, 5(4), 6396-6402.
[13] Thiery, L., Rauch, J. Y., & Lei, Y. (2024). High resolution surface contact temperature measurements by means of micro-thermocouples in vacuum conditions. International Journal of Thermal Sciences, 195, 108663.

Profil demandé / Applicant profile

We are seeking a highly motivated, a team player, an open mind, and result-oriented candidate.
The candidates are expected to have the following skills:

- Master degree in mechanical, mechatronics, robotics engineering or equivalent with distinction.
- Strong background in modelling of multi-physical systems, control, robotics, soft materials, robotics, and manufacturing (micromachining).
- Familiar with Matlab, Python or C++, CAD software and Finite Element Methods.
- Interest/experience on experimental investigations/validations.
- Additional skills on computer vision and optics (lasers) might be appreciated
- Candidates must be fluent in English. French would be an advantage but not necessary.

Financement/Funding : MESRI Etablissement

Application deadline**: as soon as possible, the selection process in ongoing and will last until the position is filled.**
Beginning of the contract: 1st October 2024
Gross monthly salary: 2100€. The position is fully funded for a 3 years duration. Additional teaching activities might be available in case of interest.

Direction de la thèse:/ **Thesis Supervisor**
CLEVY Cédric / cclevy@femto-st.fr

Encadrement de la thèse : **co-directeur(s) et co-encadrant(s)**
RAUCH Jean-Yves / co-encadrant

Applicants are invited to submit their application to the PhD supervisors, including a CV, Cover letter including research statement, last year's marks and at least 1 reference letter.