DOTTORATO IN INGEGNERIA DEI PRODOTTI E DEI PROCESSI INDUSTRIALI
Ciclo 37°

PhD scholarships on specific research themes

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Borsa CNR-ISTITUTO PER I POLIMERI, COMPOSITI E BIOMATERIALI	**RIGENERAZIONE DEL TESSUTO POLMONARE**
Borsa ASI - Agenzia Spaziale Italiana	**FLUID DYNAMICS OF COMPLEX MULTIPHASE MATERIALS THROUGH PYRO-ELECTROHYDRODYNAMIC EFFECT FOR MICROFLUIDC APPLICATIONS**

Borsa IIT 1

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Paolo A. Netti

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:
6 months abroad in a research laboratory for metabolomics studies.

MODELLING OF GASTRO-INTESTINAL DRUGS AND FOOD ADSORPTION

The oral route is the most common and practical way to administer food and drugs to the body; even if certain problems remain, especially for some treatments. Dealing with oral drugs administration, unfortunately, not all drugs are good candidates for this route. Solubility and permeability are generally used to determine whether a drug is a good candidate for oral administration which is generally related to chemical properties of drugs. They are ways, often empirically derived, to predict a good drug (or also food) absorption process, helping to reach a good bioavailability of the bioactive molecule that also correlates with reliability of the treatment since it reduces inter-individual variability. These positive indexes are coined in the term drugability, which reflects the fact that the drug is a good candidate for the oral route. Then, the active drug must be formulated to obtain an oral dosage form. In the early stages of drug development, in vitro and/or in vivo models are extensively used to determine the best formulation of the drug product. Ideally, those models must be easy to implement, relevant, simple, cost effective, accurate and compatible with high-throughput screening. Some of those features are difficult to obtain altogether. As a matter of fact, the complexity of the absorption process makes it impossible for the models to be relevant and to remain simple. These models must also be suitable to assess the absorption of new formulations such as nanomedicines. Besides predicting the extent of drugs absorbed, models are also used to explore the very different barriers to cross and the complex mechanisms of this transport process. Models are also used to study the stability and the behavior of the formulation. A lot is therefore expected of the absorption models, which is why many techniques are used to construct these models from in silico models, based on mathematical analysis and on chemistry properties, to in vivo models, often based on molecular imaging. In vitro models based are based on 3D tissue cultured in microfluidic devices are a good compromise between simplicity and relevance and are therefore represent a valuable tool to estimate the rate and degree of drug or food adsorption.
This project, using the physiology and molecular biology of the gastrointestinal tract, as a starting point seeks to elaborate a complete mathematical description of the drug and food adsorption taking into account the relevant role of human microbiota. The model will be validated in specific human-gut-microbiota on chip devices appositely designed for this project. Finally, the model will be used to predict the drugability of known and new drugs to assess its efficacy and reliability.

Borsa IIT 2

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Paolo A. Netti

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:

Collaboration with Prof. Carmine Settembre - TIGEM

6 months abroad in a research laboratory for cell studies.

CELL'S GYM ON CHIP

Cells, including eukaryotic one, are programmable/trainable entities which fate, stage and pattern can be potentially instructed a priori. A spectacular example of cell programming is offered by the advancement in genetic manipulation or editing. However, these technologies have still limited application in practical clinical context due to safety and ethical concerns along with their costs. There is an increasing evidence that cell microenvironment is also a potent regulator/modulator of the cell state and pattern (and conversely, dysfunction). Yet, the full potency of the microenvironmental conditions in dictating and guiding specific cell pattering is poorly exploited albeit it represents a viable and safer alternative to genetic approach. Part of the reason for this delay probably resides in the complexity of the arrays of microenvironmental signals, including biochemical and biophysical cues, and their redundancy along with the practical limitation to correctly recreate the multitude and time and space variation of signals that characterize the native cellular microenvironmental conditions. A step forward to explore cell-to-cell and cell-to microenvironment interactions has been possible with the advent of microfluidics. During these last two decades, accumulating findings show that is possible to re-create in vivo-like native biomolecular microenvironment with appropriate microfluidics. Most importantly, beside the relevant biochemical cues, it has also been possible to recapitulate the mechanical microenvironment of cell to mimic cardiovascular and respiratory systems. In general, with the use of microfluidic devices it has started a new era for the comprehension of the cellular activities at the base of physio-pathological cell states. There are also some examples on how emulating microenvironmental stimuli can be used to condition cell fate by either using biophysical stimulations, like mechanical reprogramming to rejuvenate cells that can be conveniently reproduced in microfluidics. However, the route of instructing cells by manipulating microenvironmental cues without operating directly on genes is still at its commencement.
This project aims to develop a cell training program on chip by developing a microfluidic platform able to provide different microenvironmental features to the cells -like a gym including different body fitness programs. The design of this multimodal microfluidic platform will allow for the analysis of the different outputs using state-of-the-art clustering algorithms and phenotype similarity measures. All in all, the project seeks to prove that "microenvironment conditioning" it is possible a cell programming strategy with important implications in the clinical setting. Thus, as proof of principle, this proposal aims to exploit the cell training on a chip approach to perform dynamic and multi-parametric modulations of cell microenvironment as new line of attack to identify conditions that selectively modulate somatic cell reprogramming. These innovative stimulation approaches characterized by thousands microenvironmental manipulations in a synchronized and asynchronized manner will be combined to last generation autophagy

reporter assay to monitor how microenvironmental factors modulate specific gene expression.

Borsa IIT 3

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Paolo A. Netti

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:
Collaboration with Prof. Stefano Piccolo – Università di Padova

6 months abroad in a research laboratory for cell mechanotransduction.

PROGRAMMABLE CELL INSTRUCTIVE SURFACES

The main objective of this project is to produce materials that can instruct and guide in a deterministic manner complex cell operations such as morphogenesis, heterotypic organization, differentiation and reprogramming it is envisioned to encode regulator logics to dynamic displays matricellular signals. These activities will lead to an enormous enrichment of the basic understanding on how spatio-temporal occurrence of signals governs cell fate and functions and will empower the realization of the next generation of programmable materials able to instruct even complex and spatio-temporal orchestrated in vitro and in vivo cellular processes. To encode rapid and reversible switchable features in the materials, photoactive and/or electroactive polymers have already been tested and further development will be focused on the improvement of spatial resolution. The applications of these materials in vitro and in vivo are immense and include in vitro cell programming and diagnostic platforms, cell-fluidics systems for in vitro screening, selection, separations and diagnosis, in vitro stem cell niches, in vivo scaffolds for cell programming, recruitment and expansion.
The research project aims at deciphering the so called material-cytoskeleton-nuclear axis crosstalk to design bioactive surfaces able to instruct or program cells, in particular mesenchymal stem cell (hMSCs), by modulating their epigenetic state by morpho-physical confinement without using exogenous transfections. The main hypothesis behind the proposal consists in rewiring gene circuits by enabling mechanostrasduction pathways via focal adhesion (FA) patterning mediated by material signals.

Borsa IIT 4

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Paolo A. Netti

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:
Collaboration with Prof. A. Diaspro' group for super resolution quantitative fluorescence microscopy

6 months abroad in a research laboratory for single cell sequencing.

3D CONFORMATION OF DNA STRANDS WITHIN THE CELL NUCLEOUS

We are particularly interested to unravel the complex mechanism that regulates DNA transcription in undifferentiated and somatic cells. In fact, it's growing evidence that gene transcription is not a simply product of genome sequence since all cells of a given organism have essentially the same genetic content. Thus, features of the genome beyond its primary nucleotide sequence must contribute to specific transcriptional regulation that defines for specific cellular phenotype. In fact, albeit all cells of a given organism could potentially express all DNA sequences, a sophisticated mechanism of locking/unlocking entire specific sequences in the nuclear DNA ensures that cell retains a specific phenotype. Along these lines, the impact of 3D architecture of eukaryotic DNA on the regulation of gene expression is a fascinating field that has not been fully explored.

In this project, the successful candidate will investigate how DNA structural changes can activate specific transcriptional pattern into cell nucleus and how cellular phenotype is a direct consequence of such global chromatin composition and 3D distribution of nuclear DNA. The conformation and 3D assembly of chromatin fiber into the eukaryotic cell nucleus will be investigated with a multidisciplinary approach that combines optical electronic and super-resolution microscopy techniques with advanced live-cell imaging technology. Then, to study the molecular mechanisms whereby DNA 3D structure is shaped and orchestrated within cell nucleus, concepts from polymer physics will be investigated in order to provide a quantitative, predictive framework to explain the relationship existing between 3D conformation of the DNA and transcription pattern activation in eukaryotic cell nucleus

By addressing basic scientific questions as well as developing novel high-throughput engineered devices, the goal of the project is to develop an automatized system capable to "unlock" specific genomic domains and activate the transcription of DNA sequences residing in such domains.

Borsa IIT 5

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Paolo A. Netti

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:
Collaboration with
- CNR - Istituto Biostrutture e Bioimmagini
- CEINGE – Biotecnologie avanzate

6 months abroad in a research laboratory for tumor model in vivo studies.

MULTIFUNCTIONAL NANOVECTORS FOR ADVANCED THERANOSTIC

La prospettiva della teranostica è quella di effettuare contemporaneamente diagnosi e cura, individuando le singole particelle tumorali. Ciò è possibile grazie a nanoparticelle multifunzionali trasportate sul sito patologico mediante un targeting attivo e capaci di rilasciare in maniera mirata l'agente diagnostico e/o terapeutico. In particolare, per quanto riguarda la diagnosi possono essere utilizzate come agenti nella risonanza magnetica nucleare per aumentare il contrasto dell'immagine e consentire una migliore rilevazione del tumore.
Questo progetto di dottorato riguarderà lo sviluppo di nanovettori biopolimerici multifunzionali da utilizzare come nuovi agenti di imaging da utilizzare per la diagnosi precoce ed accurata di patologie tumorali, cardiovascolari e neurodegenerative. Lo studio riguarderà anche la possibilità di sviluppare nuovi strumenti che garantiscano una terapia mirata e forniscano simultaneamente valutazioni in-loco degli effetti della terapia stessa.

Borsa IIT 6

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Francesca Santoro

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:
Collaboration with Stanford University (Dept. of Materials Science)

6 months abroad in a research laboratory.

3D PLATFORMS FOR CELL COUPLING AND IN VITRO ELECTROPHYSIOLOGY

The interface between biological cells and non-biological materials has profound influences on cellular activities, chronic tissue responses, and ultimately the success of medical implants and bioelectronic devices. The optimal coupling between cells, i.e. neurons, and materials is mainly based on surface interaction, electrical communication and sensing.
In the last years, many efforts have been devoted to engineer materials which recapitulate both the environment (i.e. dimensionality, curvature, dynamicity) and the functionalities (i.e. long and short term plasticity) of the neuronal tissue to ensure a better integration of the bioelectronic platform and cells.
In this project, we aim to fabricate 3D organic platforms (MEAs, OFET, neuromorphics) for the coupling with primary neuronal cells in order to record action potentials/neurotransmitter release from a large network population and investigate the physical interaction between the device and cells by mean of microscopy.

Borsa IIT 7

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Francesca Santoro

Financial support by:
Istituto Italiano di Tecnologia (IIT)

Supporting information:

ADVANCED ELECTROPHYSIOLOGY SIGNAL PROCESSING THROUGH MACHINE LEARNING APPROACHES

Electrical signals from cells such as action potentials indicate the communication level within a complex network. Neuronal cell base their short and long term plasticity on the action potential transmission through neurotransmitters at synaptic level and key connections are created. These hubs regulate the network behavior being topological and electrical conjunctions. In order to enlighten the formation of hubs as well as secondary connectivity links within dissociated neuronal networks, we aim to characterize primary cortical neuronal networks through electrical recordings with high-density MEAs. Recorded electrical signals and high resolution images will be processed and analysed through machine learning algorithms (coding) and correlated to identify functional neuronal network areas. Advanced data filtering and conditioning is required to handle the large number of traces provided by the recording unit. In addition, theoretical modelling based on artificial neuronal network computing is envisioned to further investigate the predictive behaviour of the biological system.

Borsa DICMAPI

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Antonio Abate
Prof. Ernesto Di Maio

Financial support by:
DICMAPI Prof. Abate

Supporting information:
Collaboration with :
- Istituto per i Polimeri, Compositi e Biomateriali (IPCB) - Consiglio Nazionale delle Ricerche
- Istituto di Scienze e Tecnologie Chimiche "Giulio Natta" (SCITEC) - Consiglio Nazionale delle Ricerche.

A stay of 6-12months at Stuttgart University in the lab of Prof. Michael Saliba

POLYMER-TEMPLATED NUCLEATION AND CRYSTAL GROWTH OF PEROVSKITE FILMS FOR SOLAR CELLS

Organic–inorganic halide perovskites are attractive materials for solar cells, because of their ease of fabrication, panchromatic absorption of sunlight and long carrier diffusion length. The control over both morphological and electronic properties of the perovskite films is crucial to achieve high-performance perovskite devices. Electronic trap states resulting from pinholes or crystal defects and grain boundaries enhance non-radiative recombination, severely reducing the charge carrier lifetime and the photoluminescence (PL) yield. This in turn entails a loss in open-circuit voltage and overall conversion efficiency. The morphology of solution-processed perovskite film is mainly governed by nucleation and crystal growth. Generally, inducing rapid nucleation and slowing down the crystal growth are promising ways to obtain perovskite films of high optoelectronic quality. A variety of methods have been developed to retard perovskite crystallization, such as adding HI or HCl acid and employing additives such as dimethyl sulfoxide (DMSO) or 1,8-diiodooctane (DIO) to form intermediate adducts with Pb2+. Several other techniques have been developed to improve the nucleation process, among which antisolvent-dripping has turned out to be an effective method by triggering homogeneous nucleation at the surface of the formed layer (solid/antisolvent/air interfaces) to make smooth perovskite films with high surface coverage However, further exploration of enabling both faster nucleation and slower crystal growth remains challenging.

In this PhD project, polymer-templated nucleation and growth (PTNG) as a method for crystal engineering of perovskites is proposed. The polymer template, whose morphology has to be engineered in a wide variety of possible cases, including porous films, enables heterogeneous nucleation, which is believed to be orders of magnitude faster than the homogeneous nucleation due to the lowering of the nucleation free energy barrier. On the other hand, the template may accelerate or retard crystal growth, possibly forming intermediate adducts and adjust crystal orientation to minimize the total Gibbs free energy and grow in the thermodynamically preferred orientation. The cooperation of these effects results in smooth perovskite films with fewer defects and larger oriented grains, enabling us to fabricate perovskite solar cells with increased power conversion efficiency (PCE).

References

[1] https://doi.org/10.1038/nenergy.2016.142

Borsa DICMAPI

Curriculum:
Ingegneria dei Materiali e delle Strutture & Ingegnria chimica

Advisor:
Prof. Antonio Abate
Prof. Pier Luca Maffettone
Prof. Massimiliano Villone

Financial support by:
DICMAPI Prof. Abate

Supporting information:
Collaboration with our Department of Biology, and group of Dott. Ferraro of CNR-ISASI

A stay of 6-12months at Swansea University in the lab of Dr. Francesco Del Giudice.

DEVELOPMENT OF A MICROFLUIDIC PLATFORM FOR BIOPHOTOVOLTAICS

Biophotovoltaics has emerged as a promising technology for generating renewable energy because it relies on living organisms as inexpensive, self-repairing, and readily available catalysts to produce electricity from sunlight. The basic idea is the conversion of light energy into electrical energy using photosynthetic microorganisms. The microbes will use their photosynthetic apparatus and the incoming light to split the water molecule. The generated protons and electrons are harvested using a bioelectrochemical system. Microfluidc platforms might be the base for efficient biophotovoltaic cells, microscale flow-based design allows for independent optimization of the charging and power delivery processes, as well as membrane-free operation by exploiting laminar flow to separate the catholyte and anolyte streams. Aim of this research is to design a novel microfluidic platform with a multidisciplinary approach ranging from fluid dynamics, material science, biology and optical characterization.

References

[1] Bombelli et al. Adv. Energy Mater. 2015, 5, 1401299
[2] Saar et al, Nature Energy 2018, 3, 75–81

Borsa Stevanato Group S.p.A

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Prof. Pier Luca Maffettone

Financial support by:
Stevanato Group Research Center (Padova)

Supporting information:
A possible stay in the Stevanato Labs and/or at the Fraunhofer Institute for Industrial Mathematics ITWM Kaiserslautern (D).

Attività in collaborazione con l'Azienda

MODELLING AND SIMULATION OF THE THERMOFORMING OF BOROSILICATE GLASS BOTTLES FOR PHARMACEUTICAL APPLICATIONS

Aim of research is to model and numerically simulate the forming process of containers for different types of glass starting from a glass tube by considering all the production steps: flame drilling, mouth/shoulder forming, cutting, case back forming. Modelling will address flow and heat transfer in each of the processes with the relevant transport and constitutive equations and boundary conditions [1, 2]. Dimensional optimization and fumes removal will be considered. The rheological properties of the glasses are of course relevant. Glass is a strongly temperature-dependent material. At room temperature, glass is a highly hard and brittle material; at a high temperature it becomes a viscoelastic body or a viscous liquid [3, 4].

References

[1] Yan et al. Precision Engineering 33, 150–159, 2009
[2] Choudhary et al., Int. J. Appl. Glass Sc. 1, 188-214, 2010
[3] Ding et al., J Am Ceram Soc. 101, 3936–3946, 2018
[4] Vu et al., J Am Ceram Soc. 103, 2791–2807, 2020.

Borsa CNR-Motocicli italiani srl

Curriculum:
Tecnologie e Sistemi di produzione

Advisor:
Prof. Enrico Armentani

Financial support by:
Motocicli Italiani S.r.l. Caserta

Supporting information:
Attività previste nel secondo Semestre, secondo anno, presso i lab del Prof. Filippo Berto, Norwegian University.

Attività in collaborazione con l'Azienda

SVILUPPO DI METODOLOGIE AVANZATE PER LA PROGETTAZIONE OTTIMIZZATA DI VEICOLI A DUE RUOTE PER UNA MOBILITÀ ELETTRICA CONNESSA ALTAMENTE EFFICIENTE

Le attività del dottorato di ricerca dovranno essere focalizzate sullo sviluppo di metodologie per la progettazione a calcolo di veicoli a due ruote dotati di propulsori elettrici o ibridi (termico-elettrico) caratterizzati da ridotti costi di produzione, flessibilità d'uso, ergonomia e sicurezza, efficienza e autonomia di esercizio elevate.
Il dottorando dovrà acquisire competenze di elevato livello nell'uso di tecniche di modellistica numerica multi-fisica (modelli di dinamica del veicolo con specializzazione per i singoli elementi costituenti) per l'analisi di sistema, la scelta o lo sviluppo di componenti e la loro integrazione ottimale: in particolare, si dovranno mettere a punto opportuni modelli numerici per le unità di conversione e di accumulo di energia di bordo e per l'intera catena cinematica di trasmissione del moto alle ruote, al fine di valutare consumi ed emissioni in ambiente, nonché per la migliore gestione dei flussi energetici di bordo. La metodologia della progettazione integrata trova applicazione in ambito automotive ma è scarsamente seguita nel caso di mezzi di mobilità di costo esiguo, come le biciclette elettriche a pedalata assistita.
Il progetto si articola in fasi successive, a partire appunto dallo studio di dettaglio di queste ultime, nelle attuali configurazioni commerciali, per arrivare ad una metodologia di progettazione che potrà permettere la scelta più opportuna di componenti e strategie di controllo su profili di utilizzo tipo, anche in relazione alle caratteristiche dimensionali del telaio. In una fase successiva, le metodologie apprese saranno applicate alla progettazione a calcolo di motocicli elettrici o ibridi ai fini dell'incremento dell'autonomia per una data ricarica dei sistemi di accumulo. Nel caso di propulsori ibridi, si studieranno le tecniche più opportune di recupero dell'energia in frenata e dell'uso del motore termico quale generatore per la ricarica delle batterie in esercizio e il massimo risparmio energetico anche in relazione alla trasmissione.
L'approccio che si intende perseguire è indirizzato verso una personalizzazione spinta dei mezzi di trasporto per la mobilità elettrica a due ruote, che dovranno essere il frutto di una progettazione "model-based" per l'attuazione di condizioni di esercizio ottime in contesti diversificati, dunque per un uso più razionale delle risorse e la massima riduzione degli sprechi energetici.
La simulazione numerica, d'altro canto, è oggi strettamente correlata al concetto dell'Internet of Things che si sta sempre più diffondendo in vari ambiti per descrivere una realtà in cui gli oggetti di uso comune sono in grado di scambiarsi informazioni e comunicare "misurando" la realtà che li circonda. Queste misure, raccolte ad esempio attraverso sensori, sonde e sistemi di georeferenziazione, per impieghi quali di delivery service o vehicle sharing, possono creare un flusso di dati che, a loro volta, possono permettere di ricostruire un oggetto o un luogo fisico in

maniera “virtuale”, in simulazione, anche a distanza. Tale approccio può generare enormi benefici come, ad esempio, la possibilità di ridurre i consumi o di segnalare sprechi e guasti. Nel corso del dottorato si applicheranno tecniche di ottimizzazione e di intelligenza artificiale per il miglioramento prestazionale o l’upgrade progressivo dell’esperienza d’uso in modalità connessa.

Borsa CNR-ISTITUTO PER I POLIMERI, COMPOSITI E BIOMATERIALI

Curriculum:
Ingegneria dei Materiali e delle Strutture

Advisor:
Dr. Assunta Borzachiello

Financial support by:
CNR - IPCB

Supporting information:
Collaborazioni con aziende Altergon, Medivis

Periodo all'estero alla McGill University presso i lab dei Prof. Showan Nazhat e Derek Rosenzweig

RIGENERAZIONE DEL TESSUTO POLMONARE

Le malattie polmonari sono caratterizzate da danno alveolare come la broncopneumopatia cronica ostruttiva (BPCO) o la displasia broncopolmonare (BPD) dei prematuri e l'enfisema negli adulti. Un comune denominatore di queste malattie è l'assenza di risoluzione della lesione che porta a una riparazione tissutale distorta con conseguente arresto della crescita alveolare nella BPD o distruzione alveolare nell'enfisema come risultato della BPCO [1]
Nel polmone, gli alveoli rappresentano il sito di scambio gassoso, che comprende un monostrato di pneumociti di tipo I e II, una matrice extracellulare a strato sottile (ECM) e, a seconda della posizione, l'interstizio o lo strato endoteliale di un vaso sanguigno. L'ECM parenchimale è composto principalmente da collagene di tipo I meccanicamente dominante e collagene di tipo III, che forniscono integrità strutturale [2]. Altri importanti costituenti della ECM polmonare sono l'elastina ei proteoglicani, che sono associati in modo non covalente e in gran numero a una singola molecola di acido ialuronico. L'elastina svolge un ruolo fondamentale nella funzione meccanica del tessuto polmonare. È stato dimostrato che le proprietà elastiche e dissipative macroscopiche del tessuto alveolare sono dominate sia dal collagene che dall'elastina [3]. Inoltre, è stato dimostrato che l'elastina è il fattore più importante nel determinare il recoil per piccoli volumi polmonari, mentre all'aumentare del volume il collagene inizia a prendere il sopravvento [4,5]. Pertanto, sia il collagene che l'elastina sono di notevole interesse a causa dei loro ruoli complementari nel comportamento biomeccanico del tessuto polmonare sano. In precedenti lavori di letteratura, è stato riportato l'uso di cellule staminali mesenchimali (MSC) come possibile strategia per trattare le patologie polmonari, grazie alle loro funzioni regolatorie paracrine, migliorano la maturazione alveolare durante lo sviluppo polmonare mediante la secrezione di fattori di crescita e anche grazie alla corretta differenziazione in cellule alveolari di tipo II [1,4,5]. Tuttavia, sfortunatamente, le terapie con cellule staminali per il trattamento delle malattie polmonari sono state ostacolate dal basso attecchimento di cellule.
In questo contesto, l'obiettivo di questo progetto di ricerca è produrre un sistema che combini l'effetto benefico delle MSC e l'uso di scaffold polimerici iniettabili biocompatibili e biodegradabili che supportano e trasportano le cellule staminali nel polmone. L'approccio innovativo di questo progetto è la costruzione di uno scaffold che mima le proprietà meccaniche della parete alveolare. Verrà sfruttata la possibilità di incorporare negli scaffold, sistemi particolati di dimensioni micro-nano

per controllare il rilascio di fattori di crescita principi attivi biologici in grado di avvantaggiare le MSCs.

Bibliografia

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[2] Yuan H,et al. Journal of Applied Physiology. 2000;89(1):3–14.
[3] Dunphy et al.. J Mech Behav Biomed Mater. 2014 Oct;38:251-9.
[4] Laube M,et al. Int J Biochem Cell Biol. 2016 May;74:18-32.
[5] Chang YS et al. J Pediatr 2014;164:966–972.e6.

Borsa ASI – Agenzia Spaziale Italiana

Curriculum:
Ingegneria Chimica

Advisor:
Prof. Pier Luca Maffettone
Prof. Gaetano D'Avino

Financial support by:
Agenzia Spaziale Italiana

Supporting information:
The PhD student will collaborate with the ISASI-CNR institute where experimental tests will be carried out to validate the numerical tool.

From six to nine months to be spent at a University or research center abroad are planned.

FLUID DYNAMICS OF COMPLEX MULTIPHASE MATERIALS THROUGH PYRO-ELECTROHYDRODYNAMIC EFFECT FOR MICROFLUIDC APPLICATIONS

Manipulation of droplets at nano-/picoliter scale is of interest in several applications in nanotechnology, biology, medicine for diagnosis, counting, encapsulation, analysis. In many processes, an external field is applied in order to induce a desired and well-controlled droplet deformation. A typical example is the use of an electrical force that causes a distribution of the charges over the liquid surface with a significant impact on the fluid dynamics [1]. A very recent technology exploiting this "electro-hydrodynamic" (EHD) effect is the droplet "shooting", i.e., a technique aimed at generating sub-micron droplets from a large sessile drop of a liquid film [2]. Due to the small dimensions involved, a conventional apparatus made by electrodes and voltage/current generator is difficult to be used. An interesting technological solution is to generate the electric field through the "pyro-electro-hydrodynamic" (pEHD) effect, i.e., by heating a substrate of lithium niobate [3]. It has been shown that the generated electric field is sufficient to deform the mother droplet/film and "shoot" microdroplets [3].
The characteristics of the electric field generated by the pEHD technique, however, are not yet understood. This makes such a process far from being general (e.g., changing the fluid properties or operating conditions require a re-calibration of the thermal history of the lithium niobate substrate). Furthermore, the pEHD technique is so far applied to simple Newtonian fluids.
The first objective of this project is to carry out a detailed analysis of the fluid dynamics of droplet/liquid film deformation induced by pEHD effect for microfluidic applications. The study will be carried out by accurate numerical simulations accounting for all the relevant phenomena. The second objective will be the extension of the shooting technique to complex fluids as viscoelastic liquids, suspensions and foams.
The research activity will be organized as follows:
1st year: literature analysis, set-up, validation of the simulation tool
2nd year: analysis of the pEHD effect for a Newtonian liquid by varying the relevant parameters and comparison with experimental results from the literature
3rd year: investigation of the pEHD effect on complex materials

[1] J. Zeng and T. Korsmeyer, Lab Chip, 4 (2004) 265-277
[2] P. Ferraro et al., Nat. Comm. 5 (2010) 429-435
[3] O. Gennari et al., Appl. Phys. Lett. 106 (2015) 054103