



UNIVERSITY OF PATRAS

Department  
Of Chemical  
Engineering



# Research in Systems Engineering

Presenters' Name: Costas Kravaris

# Research Area Faculty Members



Michael Kornaros



Stavros Pavlou



Ioannis K. Kookos



Costas Kravaris

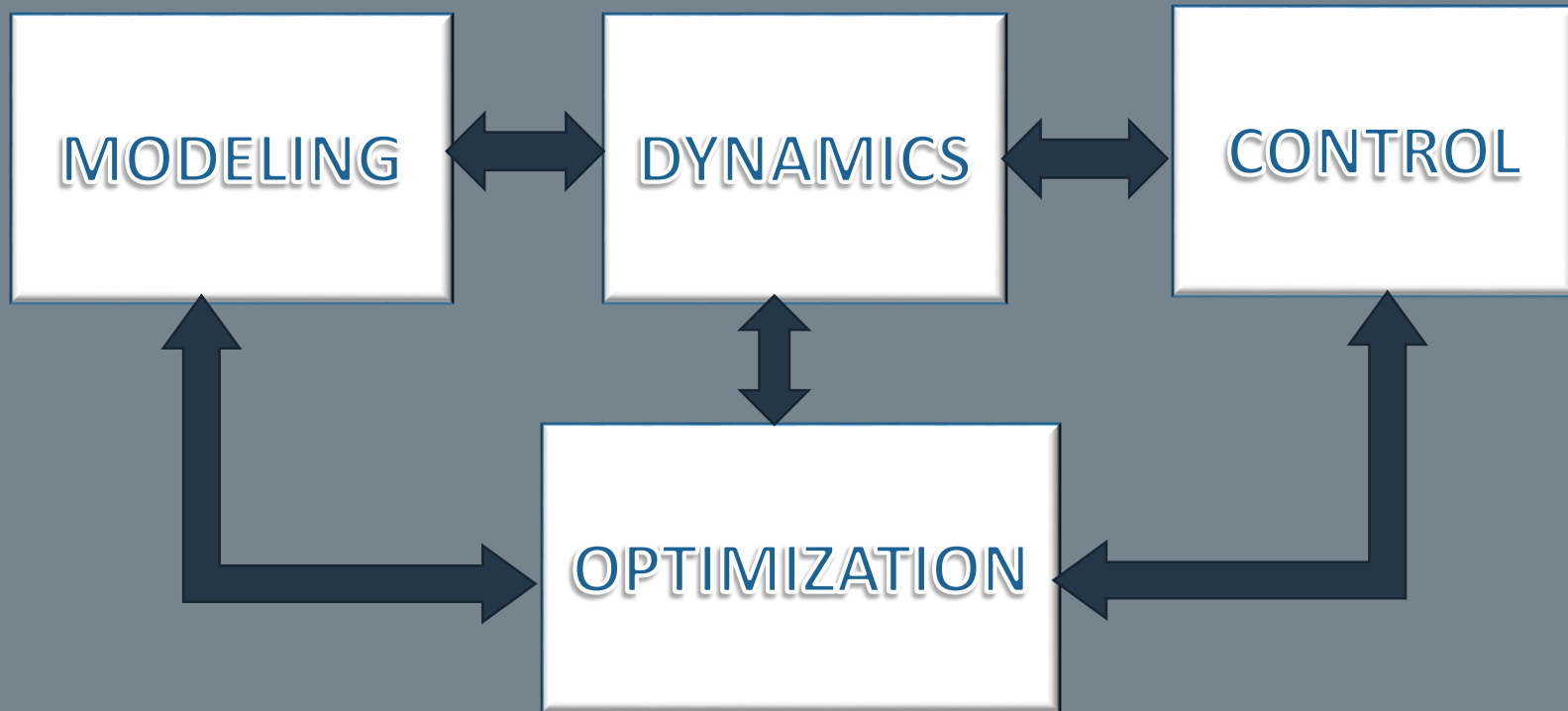


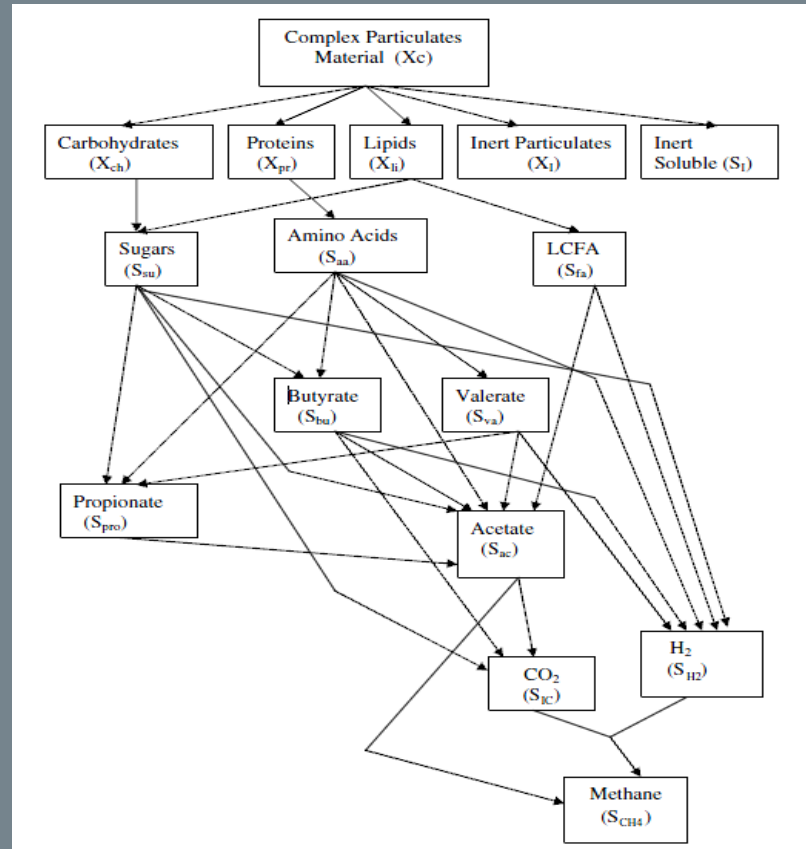
John Tsamopoulos



Yannis Dimakopoulos

# Overview of Research Activities

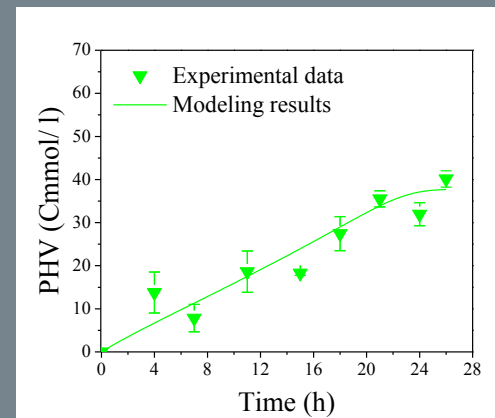
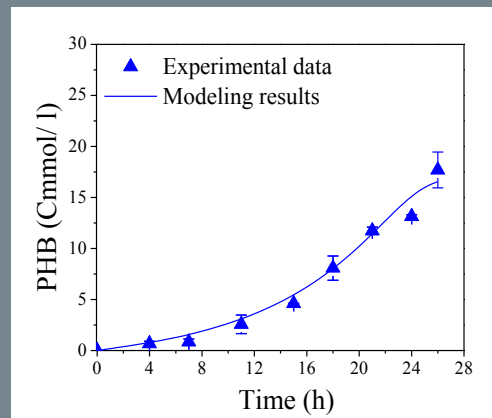
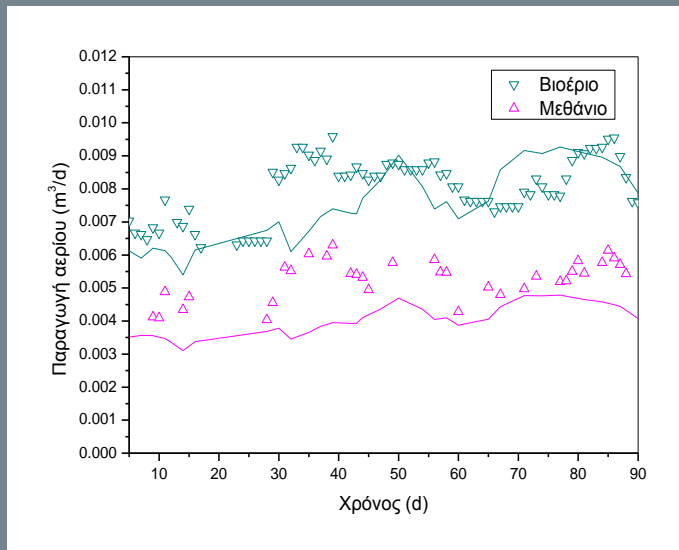


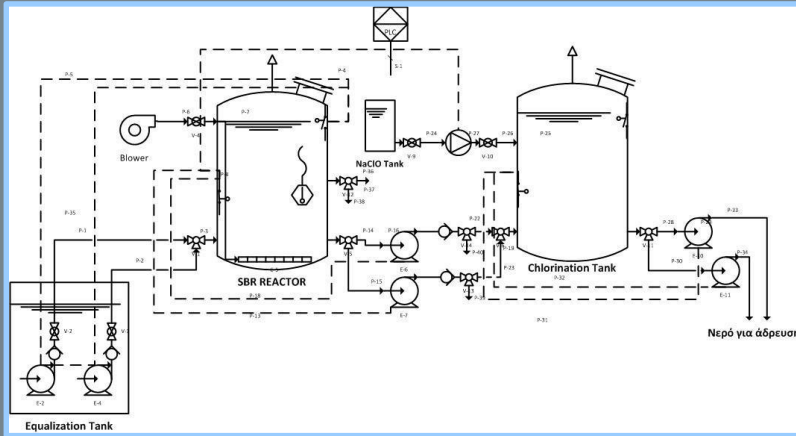


# Mathematical modeling and optimization of bio-processes

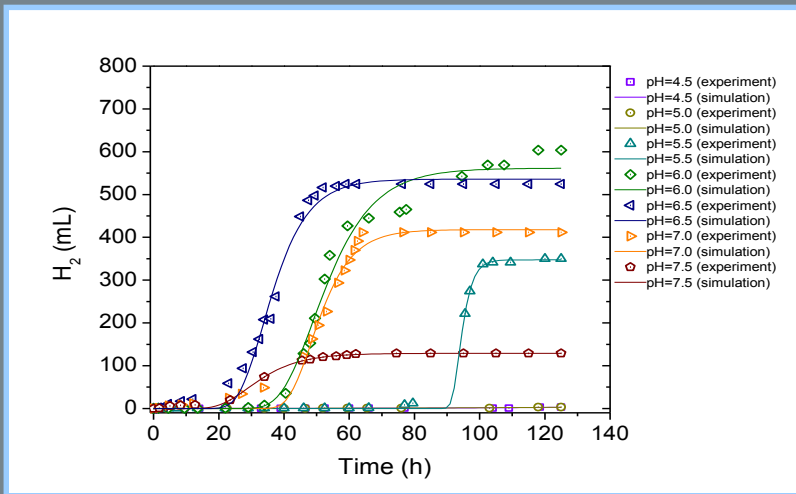
Michael Kornaros, Assistant Professor

- Kinetic studies, mathematical modeling and simulation of biotreatment and biotransformation processes for biofuels and high-added-value materials production
- Optimization of bioprocesses for municipal and industrial wastewater treatment.
- Modeling of methane production from agrowastes using the Anaerobic Digestion Model 1 (ADM1)
- Model development, parameter estimation and optimization of bioplastics (PHA) production





- Partial Nitrification-Denitrification process. Development of process and mathematical modelling in an SBR reactor.



- Kinetic simulation of hydrogen production from agro-wastes using a modified Gompertz bacterial growth model.

$$H = P \cdot \exp \left\{ -\exp \left[ \frac{R_m \cdot e}{P} (\lambda - t) + 1 \right] \right\}$$



N. Kourmentza,  
Postdoc researcher

***PHA production  
using pure & mixed  
microbial cultures***



M. Dareioti,  
PhD student

***Valorization of  
agrowastes for  
gaseous biofuels***



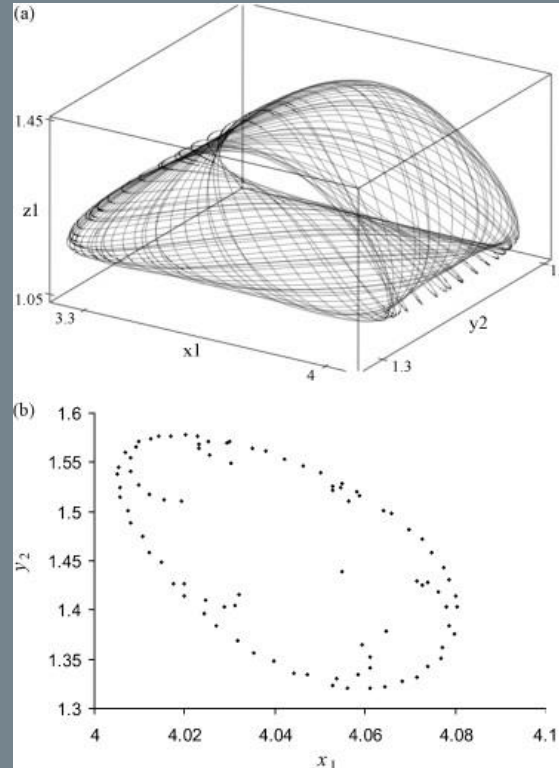
E. Taratsa,  
MSc student

***Mathematical  
modelling of two-  
stage anaerobic  
co-digestion***

# Research Projects - Some Publications

- *Project Title : “Biological nitrogen removal via nitrite in continuous operating wastewater treatment systems (Pythagoras I)”. Program: European Social Fund (ESF) and Operational Program for Educational and Vocational Training II (EPEAEK II)/ Ministry of National Education and Religious Affairs. Budget (LBEET) : 80 k€. Duration : 2004-2007.*
- *Kornaros M., Dokianakis S.N. and Lyberatos G. (2010) “Demonstration that the slow response of nitrite oxidizing bacteria to periodic anoxic disturbances is responsible for partial nitrification/denitrification”, Environmental Science & Technology, 44 (19), pp. 7245-7253.*
- *Kornaros M., Marazioti C. and Lyberatos G. (2008) “A Pilot Scale Study of a Sequencing Batch Reactor treating municipal wastewater operated via the UP-PND process”, Water Science and Technology, 58 (2) 435-438.*
- *Marazioti et al., (2003) “Kinetic modeling of a mixed culture of Pseudomonas denitrificans and Bacillus subtilis under aerobic and anoxic operation conditions”, Water Research, 37 (6), 1239-1251.*
- *Kornaros M. and Lyberatos G. (1998) “Kinetic modelling of Pseudomonas denitrificans growth and denitrification under aerobic, anoxic and transient operating conditions”, Water Research, 32 (6), 1912-1922.*

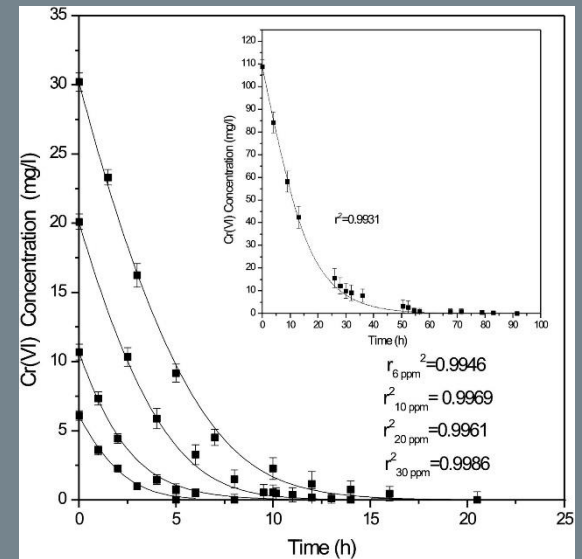
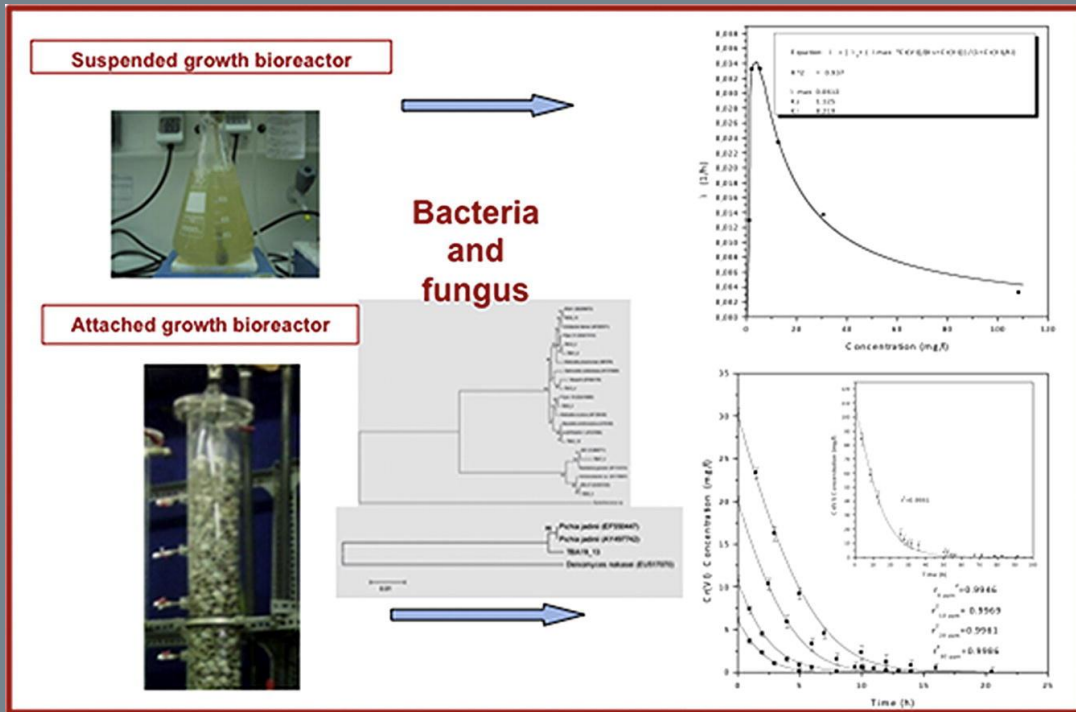




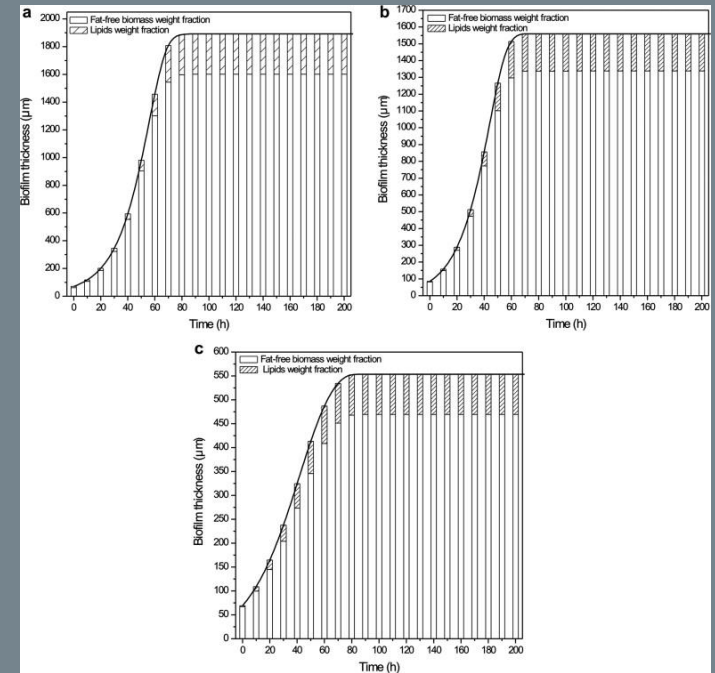
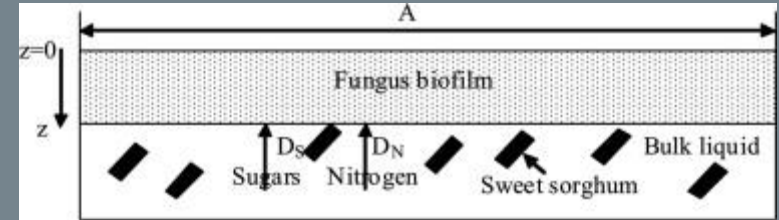
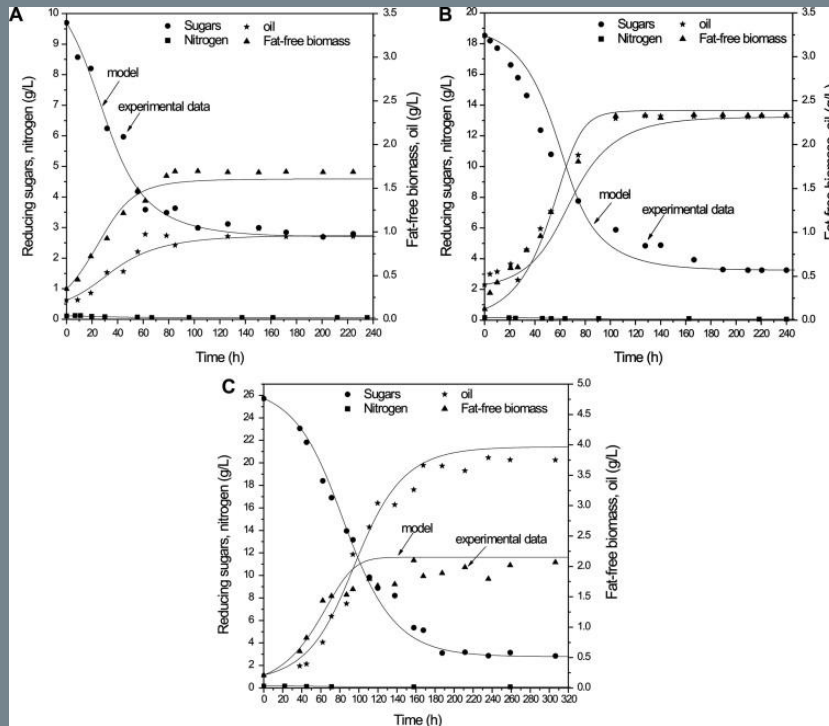
# Bioprocess modeling and dynamics

Stavros Pavlou, Professor

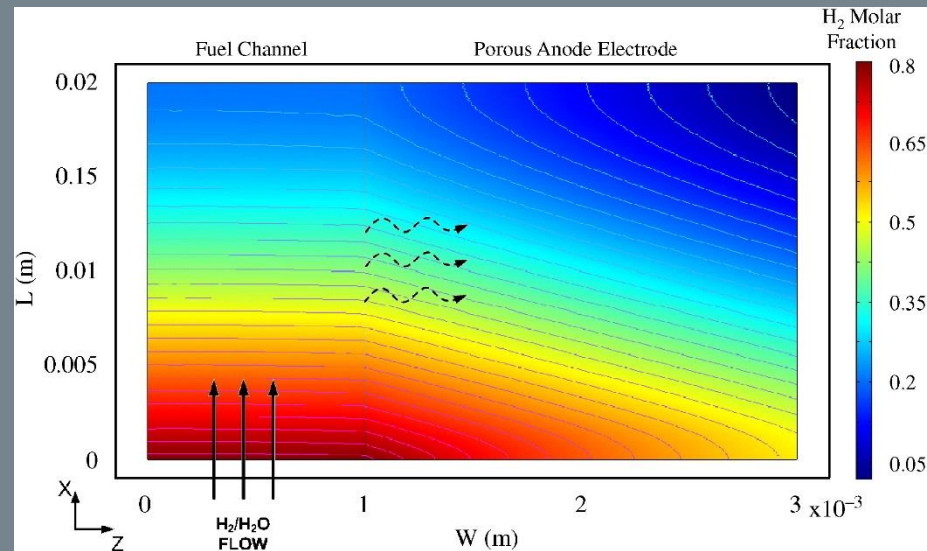
- Modeling of biological Cr(VI) removal in draw-fill reactors



## ■ Modeling of single cell oil production



- *Project Title : “Hexavalent Chromium Reduction from Contaminated Groundwater and from Wastwaters”. Program:Thalis/ Ministry of National Education and Religious Affairs. Total Budget: 600 k€, Budget (S. Pavlou): 30 k€. Duration : 2012-2015.*
- *A. G. Tekerlekopoulou, M. Tsiflikiotou, L. Akritidou, A. Viennas, G. Tsiamis, S. Pavlou, K. Bourtzis, D. V. Vayenas,(2013) “Modelling of biological Cr(VI) removal in draw-fill reactors using microorganisms in suspended and attached growth systems”,Water Research, 47 (2), pp.623-636.*
- *C. N. Economou, I. A. Vasiliadou, G. Aggelis, S. Pavlou, D. V. Vayenas,(2011) “Modeling of oleaginous fungal biofilm developed on semi-solid media”, Bioresource Technology, 102 (20), pp. 9697-9704.*
- *C. N. Economou, G. Aggelis, S. Pavlou, D. V. Vayenas, (2011)“Modeling of single-cell oil production under nitrogen-limited and substrate inhibition conditions”, Biotechnology and Bioengineering, 108 (5), pp. 1049-1055.*

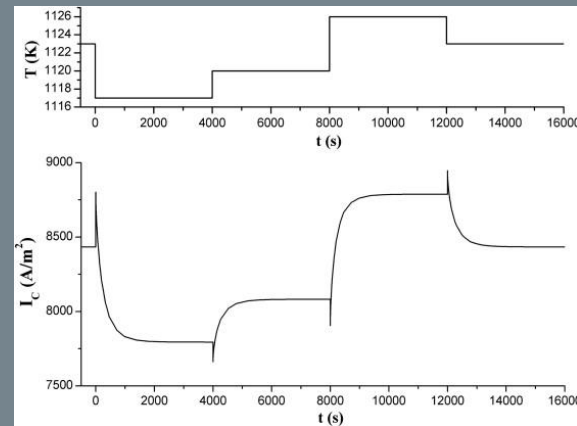
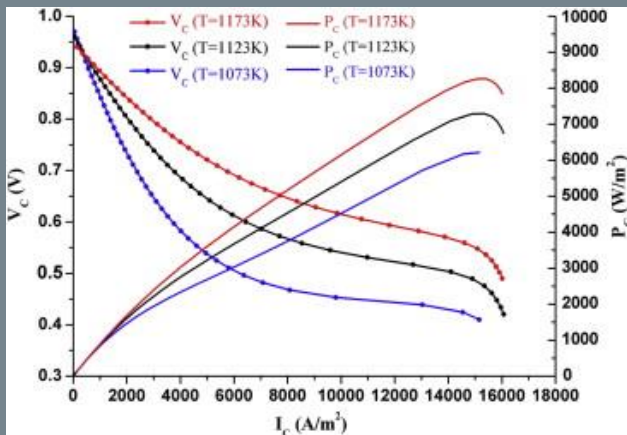
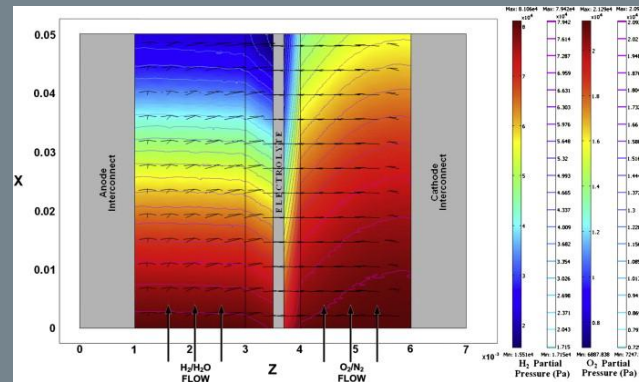
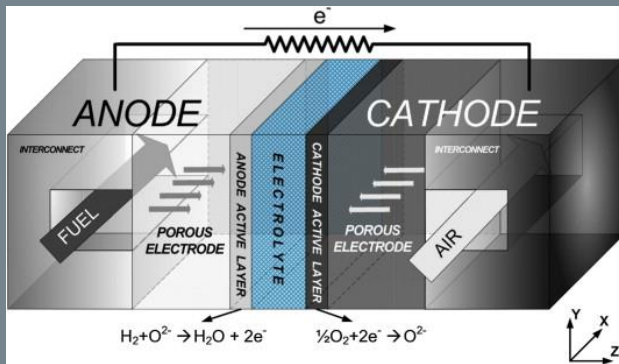


# Process modelling, design and optimization

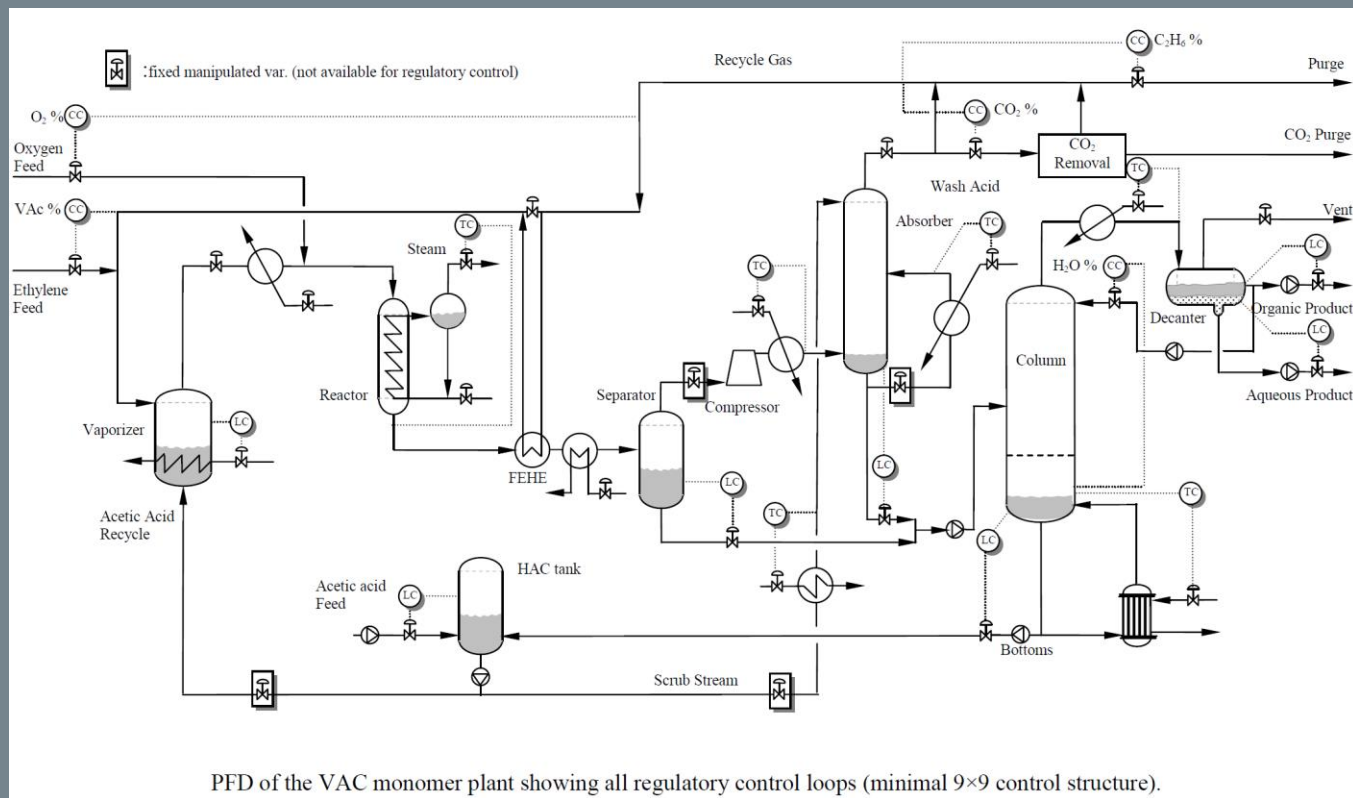
Ioannis K. Kookos, Assistant Professor

- Development of High Fidelity Models and Optimization of Energy Systems

Application : high fidelity dynamic models for SOFCs



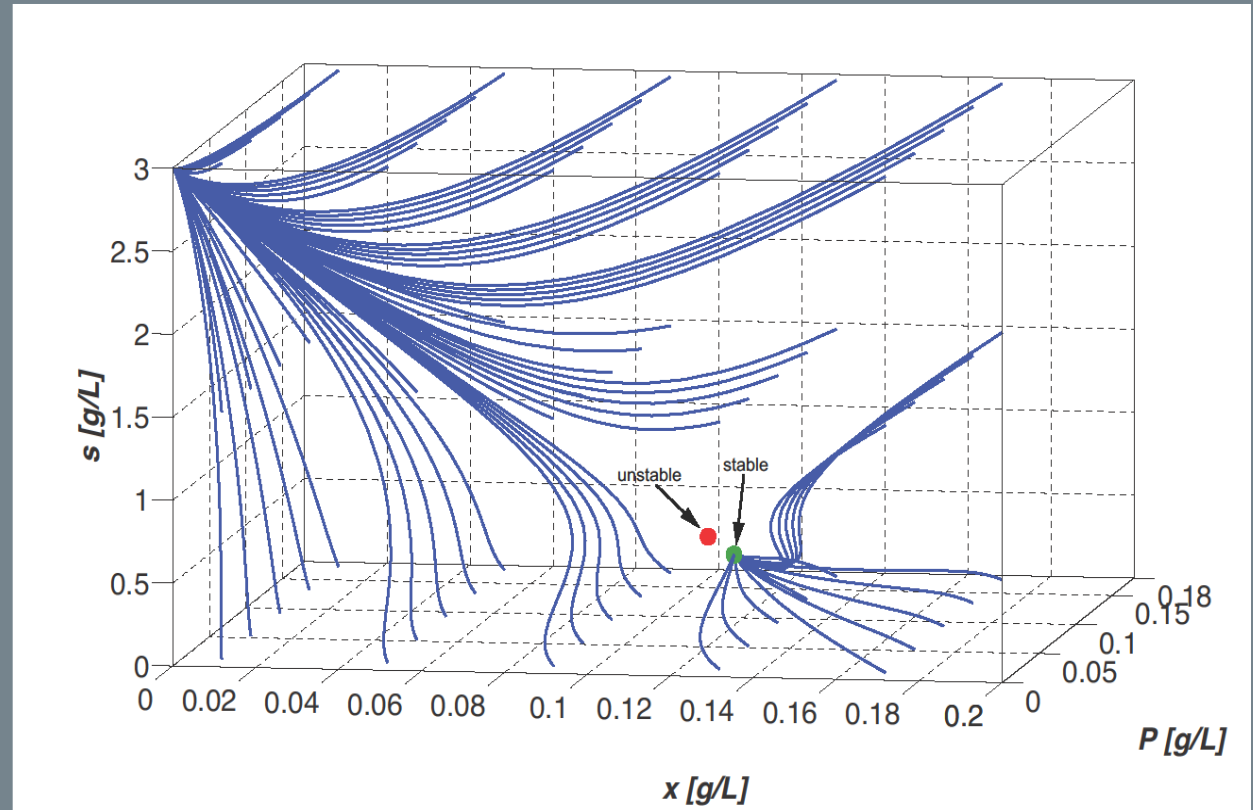
- Plantwide regulatory control structure selection



# Research Projects - Representative Publications

- AA Koutinas, A Chatzifragkou, N Kopsahelis, S Papanikolaou, IK Kookos, Design and techno-economic evaluation of microbial oil production as a renewable resource for biodiesel and oleochemical production, **Fuel** 116, 566-577, **2014**
- A Psaltis, IK Kookos, C Kravaris, Plant-wide control structure selection methodology based on economics, **Computers & Chemical Engineering**, 52, 240-248, **2013**.
- P Kandyliis, A Mantzari, AA Koutinas, IK Kookos, Modelling of low temperature wine-making, using immobilized cells, **Food Chemistry** 133 (4), 1341-1348 , **2012**.
- AA Apostolakou, IK Kookos, C Marazioti, KC Angelopoulos, Techno-economic analysis of a biodiesel production process from vegetable oils, **Fuel Processing Technology** 90 (7), 1023-1031, **2009**.
- K Tseronis, IK Kookos, C Theodoropoulos, Modelling mass transport in solid oxide fuel cell anodes: a case for a multidimensional dusty gas-based model, **Chemical Engineering Science** 63 (23), 5626-5638, **2009**.



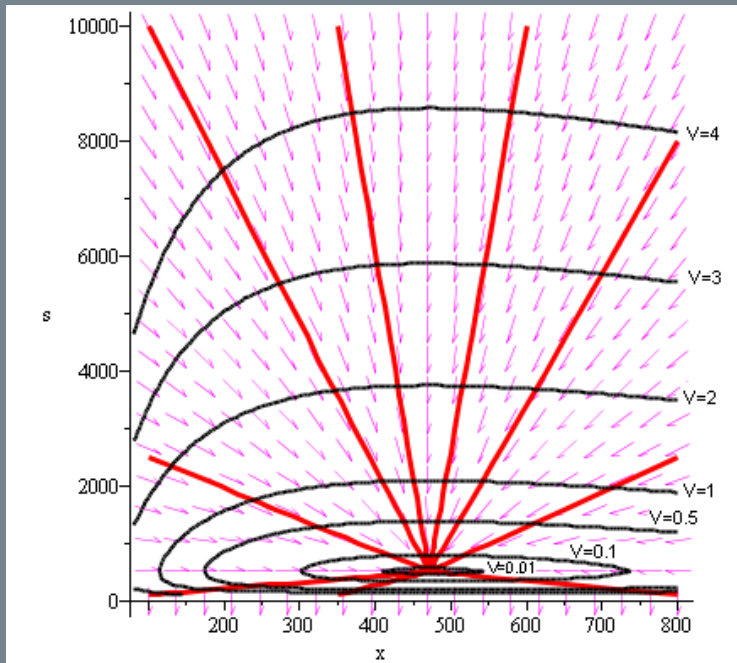


# Nonlinear Systems - Applications to Bioprocesses

Costas Kravaris, Professor

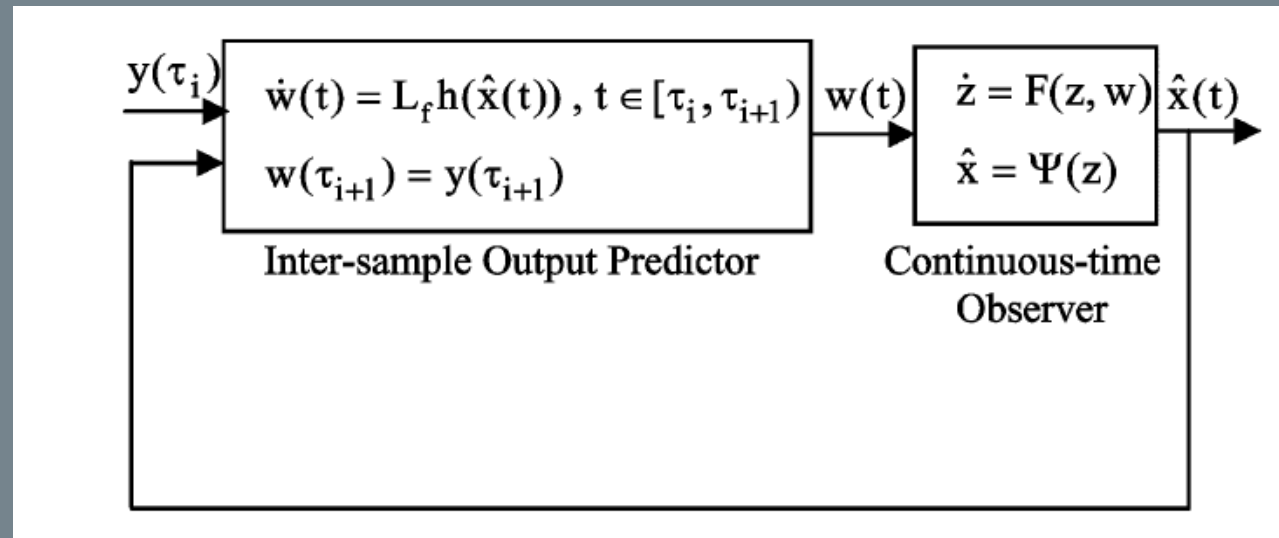
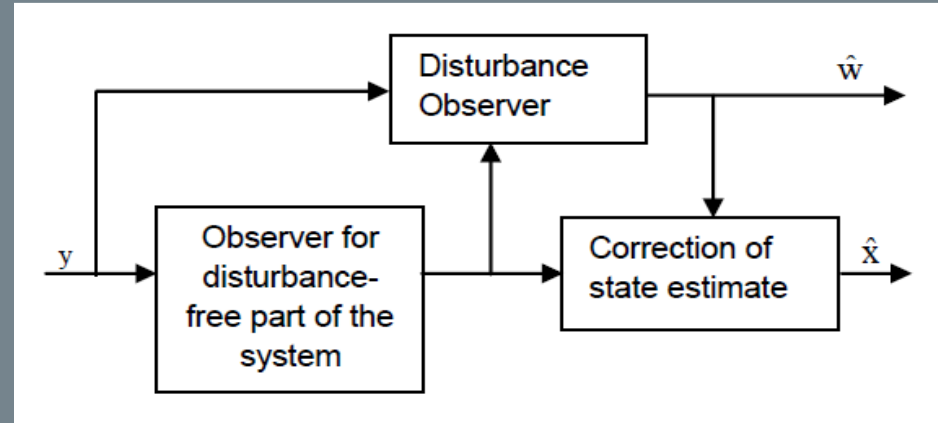
## NONLINEAR CONTROL:

- Lyapunov methods for stabilization (global or with guaranteed stability region)
- Application to bioreactor control



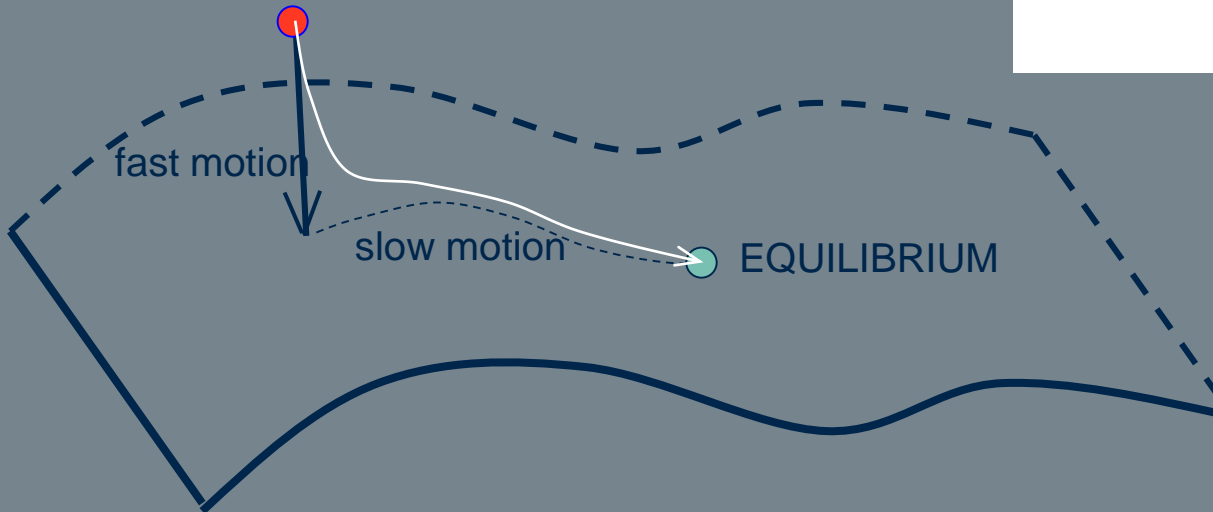
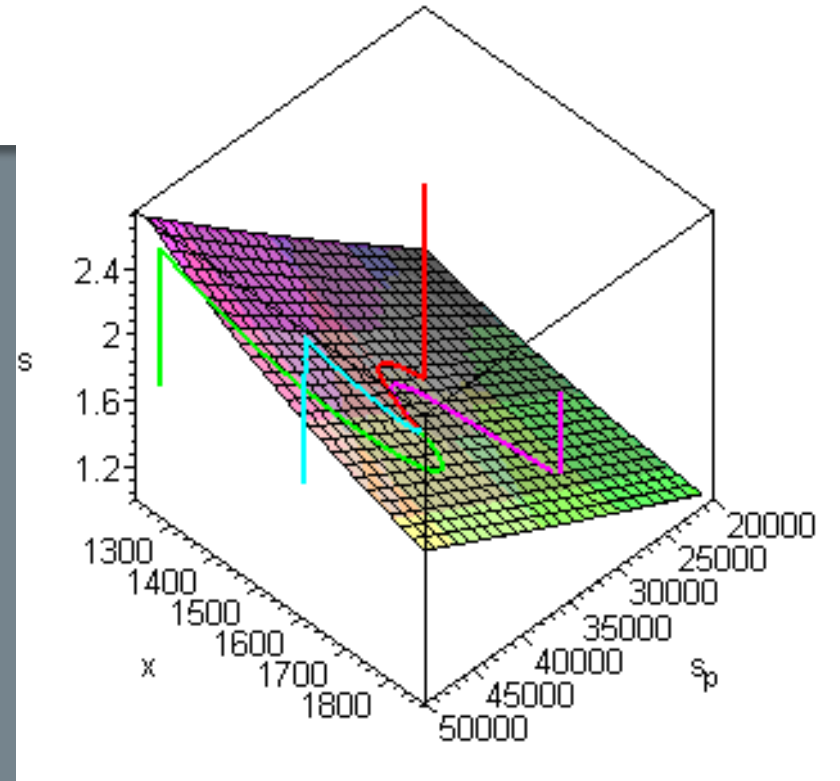
## NONLINEAR OBSERVERS:

- Global observers via Lyapunov methods
- Modular observers for state and disturbance estimation
- Sampled data observers
- Functional observers



## NONLINEAR MODEL REDUCTION:

- Slow manifold calculation and projection of the dynamics
- Model reduction for anaerobic digestion



- I. Karafyllis, C. Kravaris, L. Syrou and G. Lyberatos, "A Vector Lyapunov Function Characterization of Input-to-State Stability with Application to Robust Global Stabilization of the Chemostat", **European Journal of Control**, **14** (2008), pp. 47-61
- I. Karafyllis, C. Kravaris and N. Kalogerakis, "Relaxed Lyapunov Criteria for Robust Global Stabilization of Nonlinear Systems", **International Journal of Control**, **82** (2009), pp. 2077-2094.
- G. Savoglidis and C. Kravaris, "Constant - Yield Control of Continuous Bioreactors", **Chemical Engineering Journal**, **228** (2013), pp. 1234-1247.
- C. Kravaris and G. Savoglidis, "Modular Design of Nonlinear Observers for State and Disturbance Estimation", **Systems & Control Letters**, **57** (2008), pp. 946-957.
- I. Karafyllis and C. Kravaris, "From Continuous-Time Design to Sampled-Data Design of Observers", **IEEE Trans. Autom. Control**, **54** (2009), pp. 2169-2174.
- K. Stamatelatou, L. Syrou, C. Kravaris and G. Lyberatos, "An Invariant Manifold Approach for CSTR Model Reduction in the Presence of Multi-step Biochemical Reaction Schemes - Application to Anaerobic Digestion", **Chemical Engineering Journal**, **150** (2009), pp. 462-475.



# Modeling and stability analysis of complex flows

John Tsamopoulos, Professor and Yannis Dimakopoulos, Assistant Professor\*

\*Appointment Pending

- Prediction and understanding the mechanism of interfacial instabilities

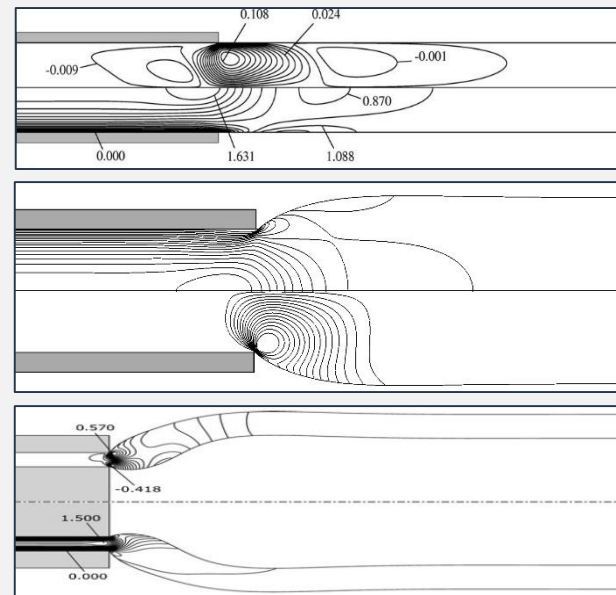
Miller et al. (2006)



## The shark-skin instability in polymer extrusion process

The extrusion is a forming process for producing plastic articles. During it, interfacial instabilities such as shark-skin, arise limiting the production rate.

### 1. Modelling & steady state calculations

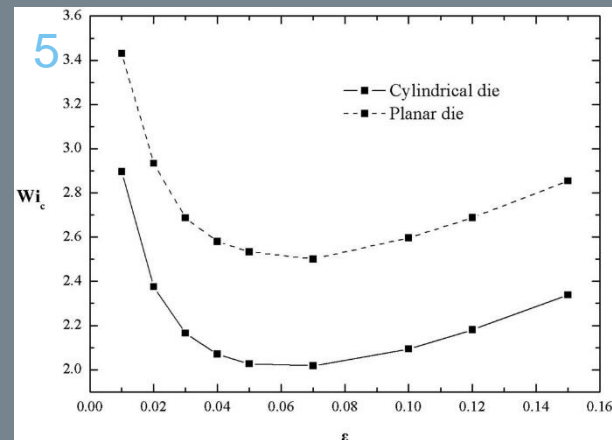
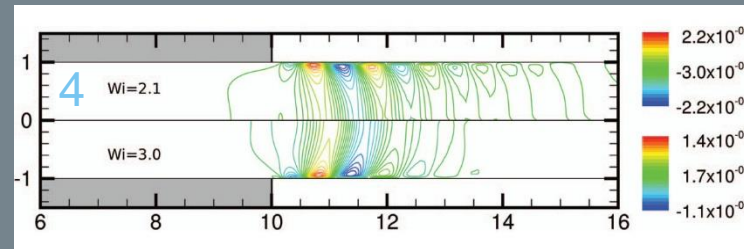
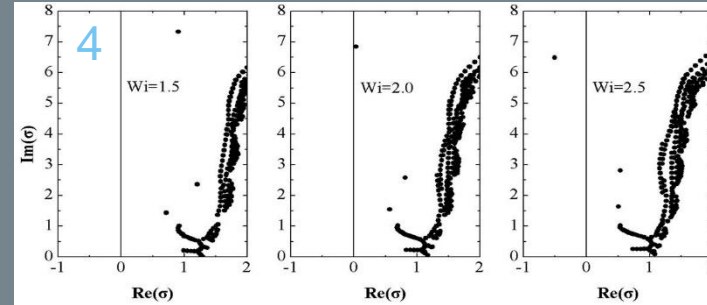


2. Linearization of governing equations

3. Normal mode analysis

4. Eigenvalue calculations

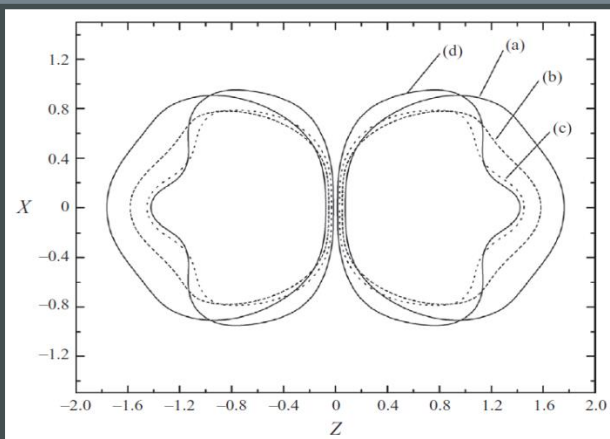
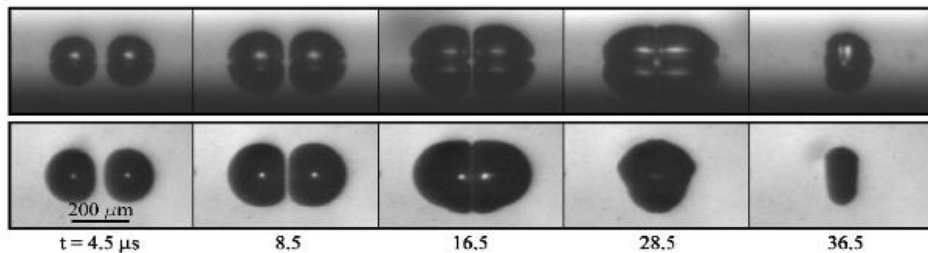
5. Parametric Studies and calculation of critical values





## Purification of liquid solutions from dissolved gases via Acoustic Treatment

N. Bremond, M. Arora, S. M. Dammer, D. Lohse (2006)



Time evolution of bubble shapes for two equal bubbles.

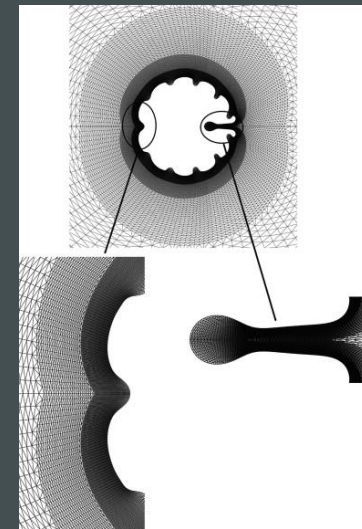
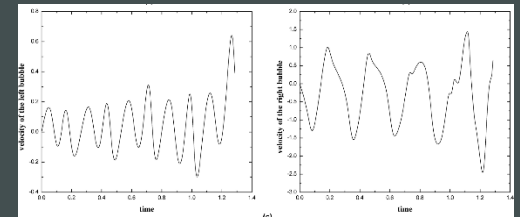
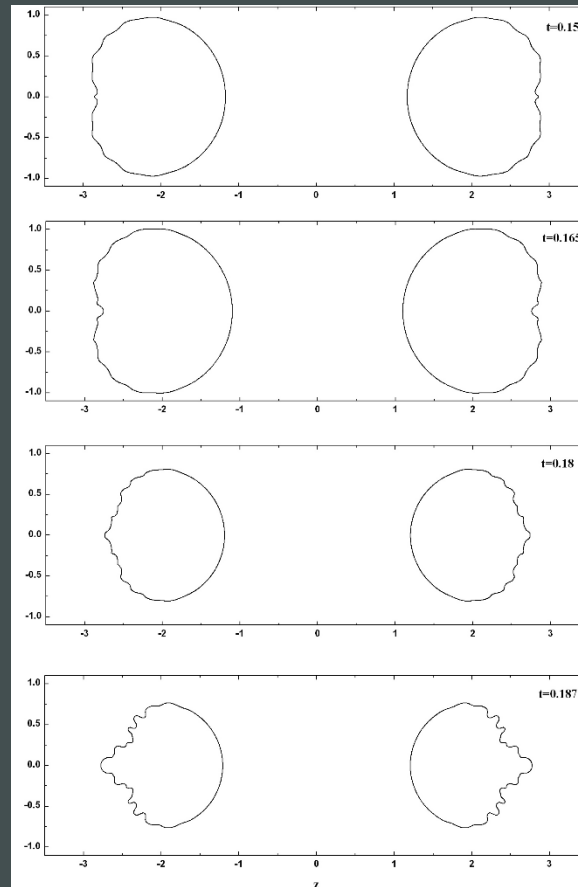
### macro-scale level

The goal is to control large bubble populations and direct bubbles towards different regions in space via acoustic treatment.

### micro-scale level

Identify conditions, with respect to bubble size and sound amplitude and frequency, for which two bubbles interacting with the acoustic wave and between them, coalesce, break-up or form a stable pair.

1. Normal mode analysis at  $t=0$
2. Calculate resonance frequencies and damping rates
3. Dynamics
4. Fourier-Lagrange decomposition of the bubble surface





Dr. G. Karapetsas,  
Post doctoral  
researcher

Modelling and  
simulation of Shark-  
Skin instabilities in  
extrusion process



Dr. N. Chatzidai,  
Post doctoral  
researcher

Bubble Dynamics



Mr. D. Pettas,  
MSc student

Modelling and simulation  
of Shark-Skin instabilities  
in extrusion process

- G. Karapetsas, J. Tsamopoulos, "Steady extrusion of viscoelastic materials from an annular die", **Journal of Non-Newtonian Fluid Mechanics**, 154(2-3) (2008), pp. 136-152.
- G. Karapetsas, J. Tsamopoulos, "On the stick-slip flow from slit and cylindrical dies of a Phan-Thien and Tanner fluid model. II. Linear stability analysis", **Physics of Fluids**, 25(9) (2013), a.n. 093105.
- G. Karapetsas, J. Tsamopoulos, "On the stick-slip flow from slit and cylindrical dies of a Phan-Thien and Tanner fluid model. I. steady state", **Physics of Fluids**, 21 (12) , art. no. 011912PHF, pp. 1-18.
- N. Chatzidai, A. Giannousakis, Y. Dimakopoulos, J. Tsamopoulos, "On the elliptic mesh generation in domains containing multiple inclusions and undergoing large deformations", **Journal of Computational Physics**, 228 (2009), pp. 1980-2011.
- N. Chatzidai, Y. Dimakopoulos, J. Tsamopoulos, "Viscous effects on the oscillations of two equal and deformable bubbles under a step-change in pressure", **Journal of Fluid Mechanics**, 673 (2011), 513-547.