NWO/RGC JOINT RESEARCH SCHEME
COMPLETION REPORT

Project Reference Number

D-HK009/11T

Project Title

Formation and mechanics of hierarchically structured soft particles by phase separation in confined droplets
分層結構軟顆粒的形成和力學研究--- 密閉液滴內之相分離

Particulars

	Hong Kong team	Dutch team
Name of Principal Investigator (with title)	English: Dr. SHUM, Ho Cheung Chinese: 岑浩瑋	Dr. WYSS, Hans M.
Name of Co-Investigator (if any)	English: Chinese:	
Institution or Institutional affiliation	[ ] CityU [√] HKU [ ] CUHK [ ] HKUST [ ] HKBU [ ] LU [ ] HKIEd [ ] PolyU	Eindhoven University of Technology, Eindhoven, the Netherlands
Other project team members (if any)		

Funding Period

	1st year	2nd year (if applicable)
Start Date	July 1, 2011	July 1, 2012
Completion Date	June 30, 2012	June 30, 2013

Objective(s) as per original application

1. Study of phase separation confined to microscopic droplets.
2. Exploit the observed behaviour for the production of multi-phase microgel particles with accurately defined microstructures in microfluidics.
3. Develop microfluidic capillary micromechanic techniques for continuous characterization of microscopic soft objects.
4. Systematically study the effects of microstructure on the mechanics and the stimuli responsiveness of these structured microgel particles.

[Please attach relevant document(s)]

i) Outline of proposed research and results obtained

Outline:

The degree of control over fluid flow has been taken advantage of to prepare uniform emulsion droplets that can be used as templates for fabricating particles and capsules with controlled structures. In the project, we harness the high degree of control in microdevices to characterize properties of the emulsion droplets and the emulsion-templated particles.

Results obtained:

- Investigated formation and stability of microscopic droplets using a custom developed device
- Generated microgel particles with tunable size and structures using microscopic emulsion droplets as templates
- Developed a microfluidic capillary micromechanic techniques for characterizing core-shell microgel capsules
- Systematically studied the mechanics, both in the linear and the non-linear deformation regimes, of microgel particles formed with different morphologies
- Devised a simple model for characterizing and predicting the deformation behaviors of core-shell microgel particles.

For more details, please check the attached manuscripts.

ii) Significance of research results

Emulsion Droplets Studies: Our device for characterizing the dynamics of a pair of charged droplets leads to the discovery of two novel distinct classes of periodic contact of droplets: "fuse-and-split" and periodic non-coalescence. By elucidating the kinetic pathways taken by electrically charged droplets, our study also suggests a new quantitative way to characterize emulsion stability and surfactant performance.

Microfluidic Micromechanics: We have developed a novel approach that captures the essential features of the deformation of microgel capsules and enables the design of materials with targeted strain-stiffening behaviors in the squeezing mode the particles undergo in a capillary. The same mode of deformation is potentially highly relevant in the transport of soft particles in other systems, such as the blood circulation, where the ability of soft particles to squeeze through narrow blood vessels is of key importance.

iii) Research output

2 Joint Scientific Publications are currently in revision:

- **"Capillary Micromechanics for Core-Shell Particles"** by Tiantian Kong, Liqiu Wang*, Hans M. Wyss, and Ho Cheung Shum*. In revision (2013)
- **"Dynamics of Oppositely Charged Emulsion Droplets"** by Zhou Liu, Hans M. Wyss*, and Ho Cheung Shum*. In revision (2013)

Another Joint Scientific Publication is being prepared:

- **"Microfluidic techniques for controlling and studying the properties of meso-structured materials"** by Ho Cheung Shum*, Hans M. Wyss*, and Zhengdong Cheng*. In preparation (2013)

The manuscripts are attached to this completion report.

iv) Potential for or impact on further research collaboration

The travel grant has enabled fruitful exchange of scientific understanding and technological developments.

As a direct result of the research grant, we will continue to collaborate on how to harness our devices for characterizing the dynamics of charged droplets. Thus far, we have only characterized unstabilized droplets; but the device can be exploited to study droplets stabilized by surfactants or other emulsifiers. It could potentially lead to a new way to understand surfactant performance in stabilizing droplets.

In addition, the combination of micromechanics and microfluidics for measuring the mechanical properties of core-shell particles makes it possible to characterize microscaled microgel capsules without costly equipment and tedious operations. The work suggests further collaborations on extending the application of the technique to other soft objects, such as biological cells and embryos.

Aside from the collaboration with Prof. Hans Wyss, through the NWO/RGC visits, I also got to interact with other faculty members at Eindhoven University of Technology (TU/e). For instance, with Prof. Patricia Dankers in the Institute of Complex Molecular Systems (ICMS) at TU/e, we have been exploring microfluidic approaches for fabricating functional microgel particles and capsules using their custom-synthesized macromolecules.

All of the above topics have excellent potential for bigger impacts; and we have been on the search for additional funding opportunities that support research projects in the context of a Dutch-Hong Kong collaboration.