Bulletin of the American Physical Society

77th Annual Meeting of the Division of Fluid Dynamics
Sunday–Tuesday, November 24–26, 2024; Salt Lake City, Utah

Session R17: Electrokinetic Transport II
1:50 PM–4:00 PM, Monday, November 25, 2024
Room: 250 A

Chair: Jerry Shan, Rutgers University

Abstract: R17.00004 : Influence of grafting properties on electrokinetic flow of polyelectrolyte solutions in brush-grafted microchannels*
2:29 PM–2:42 PM

← Abstract →

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Collaborations:
Complex Fluids Laboratory, Advanced Materials Research Division

Brush-grafted channels have the advantage of a tunable and wide range of response to external stimuli, allowing us to use them in various applications. We modeled the electrokinetic flows of Newtonian as well as polyelectrolyte (PE) solutions in PE brush-grafted microchannels, on the basis of the continuum approach. In our model framework, the Poisson-Nernst-Planck equations are explicitly solved for the electrostatic field incorporated with the Alexander-de Gennes model for PE brush-layer and each ion concentration estimated by multi-species ion balance. Accounting for the Brinkman hydrodynamic friction inside the brush-layer, Bird-Carreau constitutive model is applied in the Cauchy momentum equation to describe the PE solution of anionic polyacrylic acid (PAA). This presentation reports in-detail the new results regarding the effects of grafting properties in terms of grafting density and Kuhn segment length. The electrostatic potential increases with increasing grafting density, whereas the surface potential decreases with increasing Kuhn length clearly unlike in the bulk. It is emphasized that the flow velocity decreases with either higher grafting density owing to enhanced PAA chain friction or larger Kuhn length according to higher flow retardation due to chain stiffness. The corresponding viscosity profile inside the channel is also examined with variations of pH and concentration of PAA dispersion.

*Supported by the KIST Institutional Program (project no. 2E33162)

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Session R17: Electrokinetic Transport II

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Monday, November 25, 2024 2:03PM - 2:16PM	R17.00002: Giant osmotic power generation in subnanometer-diameter single-wall carbon nanotubes Da-Chi N/A Yang, Richard J Castellano, Ricardo P Silva, Robert F Praino, Jerry W Shan
Monday, November 25, 2024 2:16PM - 2:29PM	R17.00003: Net electroosmotic flow along an uncharged polarizable surface under DC electric field. Doyel Pandey, Somnath Bhattacharyya, Steffen Hardt
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Monday, November 25, 2024 2:42PM - 2:55PM	R17.00005: Abstract Withdrawn
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Monday, November 25, 2024 3:34PM - 3:47PM	R17.00009: Theoretical investigation of ion transport dynamics in current-time inside nanochannel and microchannel RAGULRANJITH S, Vishal V.R. Nandigana
Monday, November 25, 2024 3:47PM - 4:00PM	R17.00010: Reduced-Order Model of Multicomponent Electrolyte Transport in Bipolar Membranes Peter N Romero, Wilson Smith, Ankur Gupta

Permission Acknowledgement	Yes
Has the work you are presenting been submitted to or published in a peer-review journal?	No
Professional Title	Professor

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001	Seonghak Kim	Co-Author	seonghak35@gmail.com	Korea Institute of Science and Technology	
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If you are planning to attend the DFD 2024 meeting in person and would like to volunteer to serve as a session chair, please check this box:	Yes, I would like to serve as a session chair
If the speaker is outside the US, an invitation letter will automatically be sent to them upon registering for the meeting (registration opens July 10). Is the speaker requesting an early invitation letter for VISA purposes?	No
Presentation Type:	Oral
Select your Sorting Category:	24. Microscale and Nanoscale Flows
Select your Sub-Category	24.5 Microscale and Nanoscale Flows: Non-Newtonian
Abstract Title:	Influence of grafting properties on electrokinetic flow of polyelectrolyte solutions in brush-grafted microchannels
Abstract Body:	Brush-grafted channels have the advantage of a tunable and wide range of response to external stimuli, allowing us to use them in various applications. We modeled the electrokinetic flows of Newtonian as well as polyelectrolyte (PE) solutions in PE brush-grafted microchannels, on the basis of the continuum approach. In our model framework, the Poisson-Nernst-Planck equations are explicitly solved for the electrostatic field incorporated with the Alexander-de Gennes model for PE brush-layer and each ion concentration estimated by multi-species ion balance. Accounting

for the Brinkman hydrodynamic friction inside the brush-layer, Bird-Carreau constitutive model is applied in the Cauchy momentum equation to describe the PE solution of anionic polyacrylic acid (PAA). This presentation reports in-detail the new results regarding the effects of grafting properties in terms of grafting density and Kuhn segment length. The electrostatic potential increases with increasing grafting density, whereas the surface potential decreases with increasing Kuhn length clearly unlike in the bulk. It is emphasized that the flow velocity decreases with either higher grafting density owing to enhanced PAA chain friction or larger Kuhn length according to higher flow retardation due to chain stiffness. The corresponding viscosity profile inside the channel is also examined with variations of pH and concentration of PAA dispersion.

Team Acknowledgement: Complex Fluids Laboratory; Advanced Materials Research Division

Funding Acknowledgement: Supported by the KIST Institutional Program (project no. 2E33162)

Special Instructions: None.

Category Type: Computational

Publications Reference:
J.-M. Lim, M.-S. Chun, "Curvature-induced secondary microflow motion in steady electro-osmotic transport with hydrodynamic slippage effect", Physics of Fluids 23, 102004 (2011).
B. Chun, M.-S. Chun, "Electrostatic potential analysis in polyelectrolyte brush-grafted microchannels filled with polyelectrolyte dispersion", Micromachines 12, 1475 (2021).
S. Kim, M.-S. Chun, "Flow behavior of non-Newtonian polyelectrolyte solutions in brush-grafted soft microchannels", to be submitted (August 2024).

Newsworthy Research? Yes, I would like to consider highlighting my abstract in outreach to journalists.

Media Summary: Microscale and nanoscale channels grafted with polyelectrolytes have shown great promise for applications, such as lab-on-chips based sensing, actuators, and current rectification. Here, the polyelectrolyte means a charged and water-soluble polymer, which can be a typical soft matter. Our findings on PAA brush-grafted soft microchannels are expected to provide useful information and design platform aiming to develop efficient energy conversion according to enhanced electrokinetic streaming potential and current.

Keyword Label 1: Microfluidics

Keyword Label 2: Brush-Grafted Channel

Keyword Label 3: non-Newtonian Solution

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