Chien-Hua Tu, Ph.D.

Postdoctoral Research Scholar
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EDUCATION

Max Planck Institute for Polymer Research (Mainz, Germany) July 2018 – Dec 2021
Ph.D. Chemistry
Honors/Awards: Graduate with *Magna Cum Laude*
APS Frank J. Padden Jr. Award in Polymer Physics – **Finalist** (2021)

- This honor is conferred to the graduate student with excellence in *Polymer Physics* research by the Division of Polymer Physics (DPOLY) in American Physical Society (APS).

National Cheng Kung University (Tainan, Taiwan) Sep 2015 – Jul 2017
M.S. Chemical Engineering
GPA: 4.3/4.3 *(*rank top 1% in the class*)*
Honors/Awards: *Phi Tau Phi* Scholastic Honor Society (Taiwan) (2017)
Travel Scholarship — Ministry of Science of Technology (MOST) EPF conference (Lyon) (2017)
Merit Award — Oral presentation competition (English), polymer society (Taiwan) (2017)
TASCO Chemical Corporation Scholarship (Taiwan) (2016)

National Cheng Kung University (Tainan, Taiwan) Sep 2011 – Jun 2015
B.S. Chemical Engineering
GPA: 3.91/4.0 (rank 2nd in the class)
Honors/Awards: Award of Outstanding Student in Graduate Program of Engineering College (top 1%) (2015)
Award of Outstanding Student for Academic Achievement (top 10%) (NCKU) (2012 – 2013)
Award of Outstanding Student for Academic Achievement (top 10%) (NCKU) (2011 – 2012)

RESEARCH EXPERIENCE

University of Pennsylvania, *Postdoctoral Research Scholar* | Philadelphia, PA, USA Jan 2023 – present
Lab of Prof. Dr. Karen I. Winey

The overarching goal of my current postdoctoral research is to provide an in-depth understanding of structural relaxation behavior of novel copolymers synthesized by polymer upcycling reactions using broadband dielectric spectroscopy (together with other techniques). Currently, totally 5 research projects are being conducted:

Project 1 – Acid-functionalized polycyclooctene copolymer

- ❖ Discover the coupling and decoupling between stickers and backbones in associating polymers with terminally functionalized side chains by dielectric spectroscopy.
- ❖ Provide molecule design rules for associating polymer with side-chain functionalization against main-chain functionalization in terms of dielectric spectroscopy findings.
- ❖ Reveal the intrinsic correlation between (de-)coupled motions of backbone/sidechains and the unexpected cryogenic self-healing behavior of glassy associating polymers via dielectric spectroscopy and rheology.
- ❖ Collaborate with polymer chemists at University of Massachusetts (Amherst).
- ❖ Collaborate with computational scientist in Harvard University to perform density functional theory (DFT) calculation and large-scale MD simulation for in-depth comprehension of self-healing behavior.

Project 2 – Alcohol-functionalized polycycloctene copolymer

- ❖ Decipher the polymer chain behavior in the amorphous region of semicrystalline polymer, poly(ethylene-co-vinyl alcohol) (EVOH), with and without double-bonds, which has strong relevance to the barrier performance (e.g., gas permeability through the amorphous layer) of this polymer.
- ❖ Collaborate with polymer chemists at University of Massachusetts (Amherst).

Project 3 – Ketone-functionalized polycycloctene copolymer

- ❖ Corroborate the chain scission behavior during polyolefin upcycling reaction into carbonyl-functionalized macromonomers using thermogravimetric and calorimetric methods.
- ❖ Collaborate with polymer chemists at University of Pennsylvania.

Project 4 – Ethylene alkylate polycycloctene copolymer

- ❖ Discover unexpected multimodal structural relaxation in ethylene alkyl copolymers compared to commercial poly(ethyl acrylate) via dielectric spectroscopy.
- ❖ Reveal multiple effects of number density of functional groups, block arrangements, and alkyl side-chain length on the local segmental dynamics and long chain behavior of ethylene alkylate copolymers.
- ❖ Collaborate with polymer chemists at University of Pennsylvania.

Project 5 – Thioacetic acid-functionalized polycycloctene copolymer

- ❖ Decipher the crystallization behavior and polymer chain dynamics behind the novel thioacetate materials with ultra-stretchability compared to commercial poly(ethylene-co-vinyl acetate) (EVAc).
- ❖ Collaborate with polymer chemists at University of Massachusetts (Amherst).

Project 6 – Reactive polymer system (ongoing work)

- ❖ *Ex situ* monitor the molecular mobility of dangling bonds of fully cured epoxy resin by dielectric spectroscopy.
- ❖ *In situ* monitor the evolution of epoxy-amine or epoxy-anhydride network by dielectric spectroscopy and further construct the activation energy map to differentiate the chemical reaction and associated physical phenomena at different stages.
- ❖ Collaborate with physical chemists in National Renewable Energy Laboratory (NREL).

Techniques

Dielectric spectroscopy, electrochemical impedance spectroscopy, DSC, DMA, tensile test, self-healing experiment, contact angle, TGA

Leadership

Guiding an undergraduate student for DSC and contact angle measurements.

Georg August University Göttingen, *Postdoc Research Scholar* | Göttingen, Germany Jan 2022 – Oct 2022
Lab of Prof. Joerg Enderlein

The overarching goal of this postdoctoral research is to employ fluorescence correlation spectroscopy to investigate fast conformational dynamics of biomolecules. I have totally finalized 1 project:

- ❖ Integrate fluorescence correlation spectroscopy and metal-induced energy transfer phenomenon to enable the investigation of conformational dynamics of single polymer chain with an isotropic 3D nanometer resolution.

Techniques

Fluorescence correlation spectroscopy (FCS), DNA origami

Max Planck Institute for Polymer Research, *PhD Graduate Researcher* | Mainz, Germany Jul 2018 – Dec 2021
Lab of Prof. Dr. Hans-Jürgen Butt and Prof. Dr. George Floudas

The overarching goal of my PhD research is to develop a novel methodology in terms of broadband dielectric spectroscopy to provide an in-depth understanding of how macromolecules and charges transport through the nanopores. I have totally achieved 5 milestones:

Milestone 1 – Successfully develop novel nanofluidic dielectric spectroscopy

- ❖ Successfully integrate the gold-electrode sputtered nanoporous scaffolds with dielectric spectroscopy to create a new platform for investigating polymer flow behavior within nanopores *in situ*.
- ❖ Demonstrate proof-of-concept experiments to validate the novel nanofluidic dielectric spectroscopy via poly(*n*-butyl methacrylate) with polar ester side-groups and easily accessible glass transition temperature.

Milestone 2 – Uncover the evolution of local segmental dynamics during polymer imbibition

- ❖ Successfully probe the evolution of local segmental dynamics of homopolymer poly(*n*-butyl methacrylate) and blends via *in situ* monitoring the relaxation time, relaxation time distribution and relaxation strength using my created nanofluidic dielectric spectroscopy.
- ❖ Reveal the difference between effective viscosity (during flow within nanopores) and bulk viscosity via in situ imbibition kinetics recorded by my created nanofluidic dielectric spectroscopy.

- ❖ Simulate the sliding behavior of polymers along the inner walls of nanopores by ex situ dynamic contact angle experiments.

Milestone 3 – Uncover the evolution of entire chain dynamics during polymer imbibition

- ❖ Provide a direct experimental evidence of polymer chain adsorption onto pore walls during imbibition of dielectric type-A polymer as *cis*-1,4-polyisoprene.
- ❖ Demonstrate the effects of molecular weights and pore sizes on the chain adsorption behavior.
- ❖ Reveal two stage imbibition of polymer blends with faster/earlier imbibition of low molecular weight polymers (shorter chains) and later followed by the slow imbibition of low molecular weight polymers (longer chains).

Milestone 4 – Uncover the charge transport behavior during imbibition of polymer electrolytes

- ❖ Revealed unexpected two-stage evolution of polymer and ionic motions during imbibition of PEO/LiTFSI electrolytes by my created nanofluidic dielectric spectroscopy.
- ❖ Visualize polymer and ion distribution along the nanopores via time-of-flight secondary ion mass spectroscopy (ToF-SIMS).

Milestone 5 – Discover the possibility to infiltrate polymer into nanopores in semicrystalline state

- ❖ Discover the infiltration of semicrystalline polymers [poly(ethylene oxide) (PEO) and poly(caprolactone) (PCL)] into nanopores at temperatures below melting point.
- ❖ Reveal the chemical fingerprint and associated phase morphology of infiltrated polymers with nanometer spatial resolution via the integrated technique AFM-IR or called NanoIR.
- ❖ Decipher the hierarchical time- and length scales of dynamics, including segmental dynamics by dielectric spectroscopy, imbibition time, behind this unexpected phenomena.

Techniques

Dielectric spectroscopy, atomic force microscopy (AFM), AFM-IR, rheology, scanning electron microscopy (SEM), SAXS, WAXS, DSC, contact angle, surface tension, ToF-SIMS, polarized optical microscopy (POM), sputtering

INDUSTRY EXPERIENCE

Taiwan Semiconductor Manufacturing Company (TSMC) *Process Engineer* | Tainan, Taiwan
Aug 2017 – Jun 2018

- ❖ Root-cause finding and maintaining the stability of chemical mechanical polishing (CMP) process.
- ❖ In situ monitoring the thickness of thin-film oxide and metals during CMP process.
- ❖ Coordinating the manufacturing tools of between CMP and other process including lithography and thin-film deposition.

PUBLICATIONS

Journals:

1. **Tu, C.-H.**; Steinhart, M.; Berger, R.; Kappl, M.; Butt, H.-J.; Floudas, G. "When crystals flow" *Science Advances* **2023**, 9, eadg8865.

   => *Selected as **Front Cover***
2. **Tu, C.-H.**; Veith, L.; Butt, H.-J.; Floudas, G. "Ionic conductivity of a solid polymer electrolyte confined in nanopores" *Macromolecules* **2022**, *55* (4), 1332-1341.
3. **Tu, C.-H.**; Zhou, J.; Butt, H.-J.; Floudas, G. "Adsorption kinetics of *cis*-1,4-polyisoprene in nanopores by *in situ* nanodielectric spectroscopy" *Macromolecules* **2021**, *54* (13), 6267-6274.
4. Ye, L.; Ji, H.; Liu, J.; **Tu, C.-H.**; Kappl, M.; Koynov, K.; Vogt, J.; Butt, H.-J. "Carbon nanotube-hydrogel composites facilitate neuronal differentiation while maintaining homeostasis of network activity." *Advanced Materials* **2021**, 2102981.
5. Woo, E.M.; **Tu, C.-H**; Nagarajan, S.; Lugito, G. "In-situ growth of nucleus geometry to dual types of periodically ringed assemblies in poly(nonamethylene terephthalate)." *Crystals* **2021**, *11*, 1338.
6. **Tu, C.-H.**; Woo, EM.; Nagarajan, S.; Lugito, G. "Sophisticated dual-discontunity periodic bands of poly(nonamethylene terephthalate)." *CrystEngComm*, **2021**, *23*, 892-903.

7. **Tu, C.-H.**; Zhou, J.; Doi, M.; Butt, H.-J.; Floudas, G. "Interfacial interactions during *in situ* polymer imbibition in nanopores" *Physical Review Letters* **2020**, *125* (12), 127802.
8. **Tu, C.-H.;** Steinhart, M.; Butt, H. J.; Floudas, G. "*In situ* monitoring of the imbibition of poly(*n*-butyl methacrylate) in nanoporous alumina by dielectric spectroscopy" *Macromolecules* **2019**, *52* (21), 8167-8176.
9. **Tu, C.-H.**; Woo, E. M.; Lugito, G. "Structured growth from sheaf-like nuclei to highly asymmetric morphology in poly(nonamethylene terephthalate)." *RSC Advances* **2017**, *7* (75), 47614-47618.

Invited Book Chapter:

10. **Tu, C.-H.**; Steinhart, M.; Butt, H.-J.; Floudas, G. "Polymers under 2-D confinement: flow of polymer melts at the nanoscale" *ACS Symposium Series – Broadband Dielectric Spectroscopy: A Modern Analytical Technique*; American Chemical Society: Washington, DC, **2021**, *Chapter 9*, 203-221.

Manuscript in submission or in preparation for my current postdoc work (*co-first author):

Project 1 – Acid-functionalized polycyclooctene copolymer

- **Tu, C.-H.**; Fastow, E.; Chethalen, R.J.; Papamokos, G.; Coughlin, E.B.; Winey, K.I. "Coupling and decoupling between stickers and backbones in associating polymers with terminally functionalized side chains" **2024** (submitted to *Macromolecules*, **under revision**).
- Chethalen, R.J.; **Tu, C.-H.**; Papamokos, G.; Ruiz, J.C.; Winey, K.I.; Coughlin, E.B. "Autonomous Healing of Robust Polymer Glasses at Cryogenic Conditions Enabled by Decoupled Fast Sticker Motions from Sluggish Main-Chain Backbones." **2024** (in preparation).

Project 2 – Alcohol-functionalized polycycloctene copolymer

- Radzanowski, A.N.; Fastow, E.; **Tu, C.-H.**; Votruba-Drzal, J.; Nair, V.; Winey, K.I.; Coughlin, E.B. "Impact of hydroxyl functionalization and unsaturation on linear poly(ethylene-co-vinyl alcohol) analogs" **2024** (submitted to *ACS Macro Letters*).
- Antenucci, P.M.J.; Radzanowski, A.N.; Fastow, E.; **Tu, C.-H.**; Winey, K.I.; Kozlowski, M. "Dihydroxylation of polypolycyclooctene" **2024** (in preparation).

Project 3 – Ketone-functionalized polycycloctene copolymer

- Ogbu, M.I.; **Tu, C.-H.**; Fastow, E.; Winey, K.I.; Kozlowski, M. "N2O deconstruction of polycyclooctene to generate carbonyl-functionalized macromonomers" **2024** (submitted to *Polymer Degradation and Stability*).

Project 4 – Ethylene alkylate polycycloctene copolymer

- **Tu, C.-H.**; Ogbu, M.I.; Fastow, E.; Kozlowski, M.; Winey, K.I. "Multimodal structural relaxation in ethylene alkyl acrylate copolymers by dielectric spectroscopy" **2024** (in preparation).

Project 5 – Thioacetic acid-functionalized polycycloctene copolymer

- Chethalen, R.J.; Kim, M.; Ruiz, J.C.; **Tu, C.-H.**; Gray, J.; Winey, K.I.; Crosby, A.J.; Coughlin, E.B. "Incorporation of thioacetate pendants on a polyalkenomer enables high extensibility" **2024** (in preparation).

CONFERENCE

Oral Presentations:

1. "Decoupled Main-Chain and Sticker Dynamics in Associating Comb Polymers" American Physical Society (APS) March Meeting, Minneapolis, MN, March **2024**.
2. "Decoupled Main-Chain Backbone and Sticky-Group Dynamics in Associating Comb Polymers by Dielectric Spectroscopy" Polymer Physics Symposium, in virtual, **2023** (sponsored by Division of Polymer Physics in American Physical Society – DPOLY/APS)) (invited talk)
3. "Investigating Polymer Chain Dynamics in Bulk and under Confinement by Broadband Dielectric Spectroscopy" The Chinese University of Hong Kong (CUHK) – Shenzhen Long Feng Science Forum, in virtual, **2022** (invited talk)
4. "*In Situ* Monitoring Polymer Imbibition in Nanopores by Nanodielectric Spectroscopy" American Physical Society (APS) March Meeting, in virtual, **2021** (invited – Padden Award Symposium).
5. "*In Situ* Monitoring the Imbibition of poly(*n*-butyl methacrylates) in Nanoporous Alumina by Nanodielectric Spectroscopy" American Chemical Society (ACS) National Meeting, Philadelphia, PA, March **2020** (cancelled due to outbreak of corona virus).

6. “Interior Analyses on Lamellar Assembly in Dual Types of Ring-banded Spherulites of Poly(nonamethylene terephthalate)”, Annual Meeting of Polymer Society, Taichung, Taiwan, January **2017**.

Poster Presentations:

7. “Structural Dynamics Evolution of EVOH during Polymer Upcycling Reaction by Ex-Situ Electrochemical Impedance Spectroscopy” American Physical Society (APS) March Meeting, Minneapolis, MN, March **2024**.
8. “*In Situ* Monitoring the Imbibition and Adsorption Kinetics of cis-1,4-polyisoprene in Nanopores by Nanodielectric Spectroscopy” International Dielectric Society (IDS) Online Workshop **2021**.

OUTREACH EXPERIENCE

1. **Outreach Coordinator** February 2023
   Philly Materials Day, University of Pennsylvania and Drexel University
   - Collaborate with students, postdocs, and faculty at UPenn and Drexel Univ. to host a series of scientific demonstration open to the public nationwide.
2. **Guest Instructor** Jan – Feburary 2023
   Invited EIS/BDS lectures, Department of Materials Science and Engineering, University of Pennsylvania
   - Delivered a series of lectures about the principles and applications of broadband dielectric spectroscopy (BDS) (or called electrochemical impedance spectroscopy, EIS) in soft matter to scientists from the Departments of Chem/ChE/MSE.

REFERENCES

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