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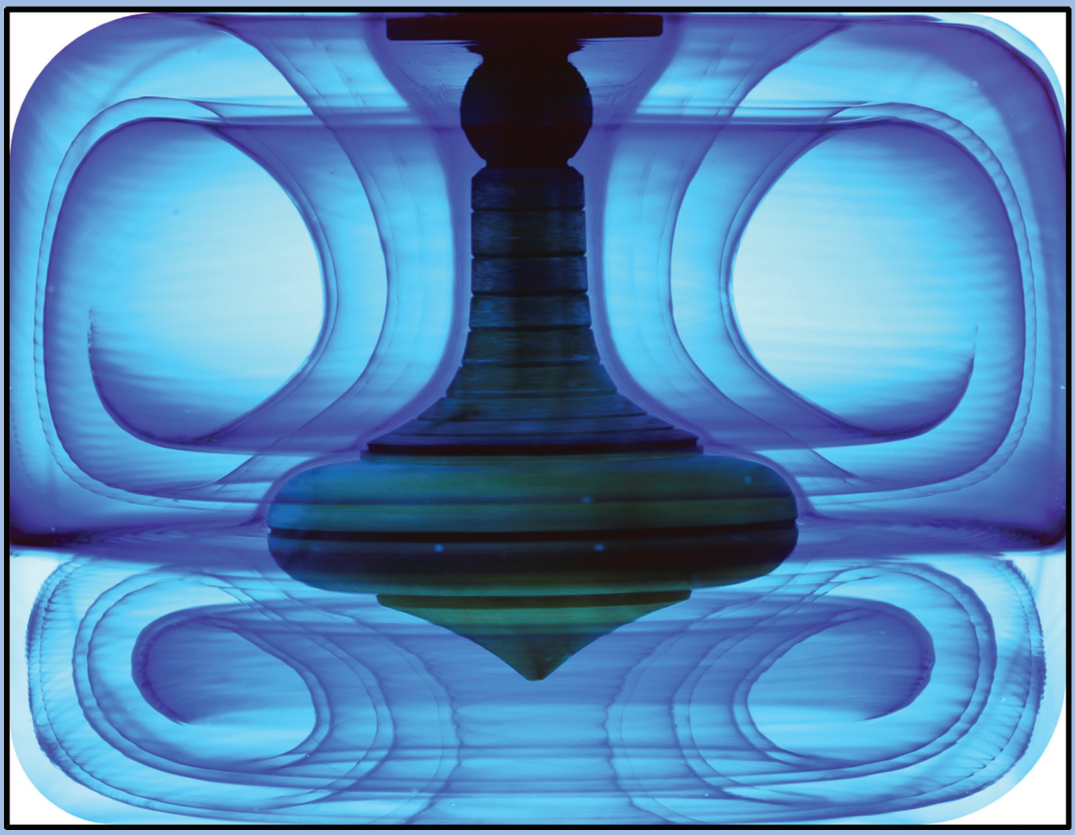
Volume 91 Number 1, September 2022

Rheology Bulletin



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Student Delegate+ (2022-2023)
Chunzi Liu

+ExCom appointment

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On the Cover: Using dye injection, we visualize the flow around a spinning top as it rotates in either Newtonian or viscoelastic liquids. In the Newtonian case, inertially-driven secondary flows generate toroidal vortices that roll around the geometry in an ever-spinning spiral (above). For viscoelastic liquids, the presence of long macromolecules lead to normal stresses that defy inertial effects. Thus, the flow separates into viscoelastic and inertial zones, giving rise to a unique butterfly pattern that revolves around the spinning top (below). One may perform a rheological Rorschach test with these mesmerizing patterns.

By Bavand Keshavarz & Michela Geri, Massachusetts Institute of Technology

The *Rheology Bulletin* is the news and information publication of The Society of Rheology (SOR) and is published yearly in July (in non-pandemic years). Subscription is free with membership in The Society of Rheology. Letters to the editor may be sent to Paulo E. Arratia at *parratia@seas.upenn.edu*

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Dear fellow rheologists:

As your new President, I am pleased to report that the Society of Rheology is healthy and strong. I am grateful to Mike Graham for his excellent leadership through the challenges of the past two years. We emerge from the pandemic enthusiastic about our mission and ready to reengage with our community. You need look no further than our upcoming Annual Meeting in Chicago which has already set a record for the number of abstracts submitted (422 abstracts as of June 5th) and is expected have our largest meeting attendance yet. The technical program promises to be exciting, capturing both the depth and breadth of our Society. I hope to see you there!

Part of our strength is the legacy of the many truly amazing volunteers who have contributed their time and energy since our founding in 1929. The Society of Rheology is the only professional society within the American Institute of Physics (AIP) Federation that is run solely by volunteers. Their diligence and dedication have left us with a solid foundation to execute our mission to expand the knowledge and practice of rheology. I was truly humbled taking on the role as president to acknowledge the over 80 volunteer positions within the Society. This now includes a new *ad hoc* Committee to start planning for our centennial celebration in 2029. We are a Society *of* the rheology community and *by* the rheology community.

I want to take time to acknowledge the efforts of three "Super" volunteers who have given tremendously of their time and energy to help us get where we are today. While they are all past recipients of the Society of Rheology Distinguished Service Award, much of their work has occurred behind the scenes and out of the spotlight and they have continued to contribute to the Society in so many ways. The first is Faith Morrison, past President, long-time editor of the Rheology Bulletin, board member of AIP and numerous other roles. She stepped down from the Bulletin at the beginning of 2020 and the onset of COVID 19 just a few months later turned everything upside down. She has always challenged the Society to live our mission. Albert Co was the local arrangements chair for the successful 2021 Annual Meeting in Bangor last fall, the Society webmaster for as long as I can remember and previously served on the Executive committee for 10 years as Secretary. His meeting organization software is used by multiple other rheology societies around the world and he puts in incredible time and effort to make the technical program and registration of every annual meeting a success. Last, but not least, Andy Kraynik, past President and Secretary of the Society and local organizer of two previous Annual Meetings in Santa Fe. Over the past 12 years Andy has provided invaluable support to an entire generation of Annual Meeting local organizers in the unofficial role of "meetings tzar." He has helped with site selection, guided budgeting, negotiated contracts for hotels and services and many other tasks associated with running a successful technical conference. Andy will be stepping up once again as local arrangements co-chair for the 2025 Annual Meeting in Santa Fe or as he likes to put it "hosting a party for my 500 closest friends." We thank the three of you and all of our incredible volunteers for helping make this society what it is today!

After the Santa Fe 2025 meeting, Andy has indicated he will be not as actively engaged with SOR meetings organization. This represents an important turning point for the Society. Our Annual Meetings continue to grow in size and become more complex. The role of local organizer has become such a heavy lift, that it has become increasingly difficult to find volunteers, even with Andy's expert advice. This spring, the Executive Committee has decided to take a different approach. Starting in 2026, the Society of Rheology will be partnering with the American Physical Society (APS) to help with local arrangements at our Annual Meetings. APS Director of Meetings Hunter Clemens leads a team that provides professional meeting services including site selection, logistics, contract negotiation and financial management. We will still have an SOR local arrangements chair who will be responsible for keeping the meetings true to our culture. As a meeting attendee, you should still enjoy the same friendly community and excellent science with the added benefit of your local arrangements team looking a little less stressed.

This spring, the Executive Committee approved a proposal for the first jointly organized Annual Meeting to be held in Boston in 2026. Another "super" volunteer Gareth McKinley (also past President, current Historian, and numerous other roles) will be the SOR local arrangements chair, partnering with Hunter Clemens and Andre Cholewinski from APS. The first contracts have already been signed and it promises to be an exciting meeting as well as a big step towards making our meeting organization more sustainable for our volunteers.

If you are interested in getting more involved in the Society, please find me in Chicago or email me directly. We depend on your efforts to sustain our Society and to think of new ways we can fulfill our mission to expand the science and practice of rheology for all.

Regards,

Anne M. Grillet, President, SOR, president@rheology.org

Report from Bangor

By Albert Co

The 92nd Annual Meeting of The Society of Rheology took place in Bangor, Maine on October 10-14, 2021 amid stunning fall colors and pleasing temperatures. The technical program was developed by Cari Dutcher and Patrick Underhill; the local arrangement committee consisted of Albert Co, Andy Kraynik, and Aileen Co. Despite the challenges, the meeting went well with lots of activities and impressive talks.

The technical program, the short course, the Rheology Research Symposium, the vendor exhibits, the banquet and several receptions were held at the Cross Insurance Center and in a 40 feet by 85 feet lighted and heated tent on its front lawn. These were COVID times, and precautions were needed.

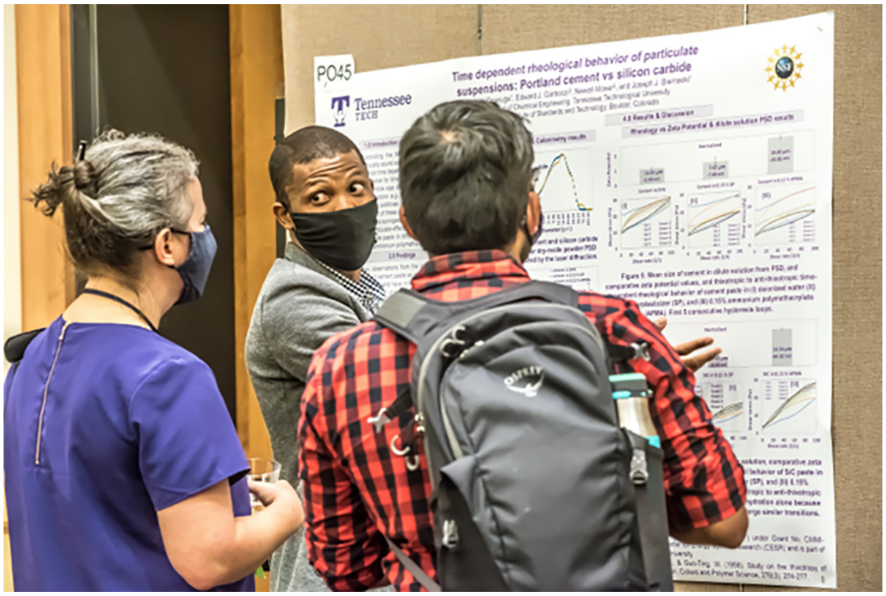
The 92nd Annual Meeting had a total of 460 attendees, with 278 in-person participants and 182 members participated online, due to pandemic-related travel limitations.

The second Rheology Research Symposium was held on October 9-10. The event brought together students and professionals to explore career development in the field of rheology. Twenty five students and seven mentors participated in this in-person symposium.

The short courses for this meeting were also held during the weekend preceding the Annual Meeting. The two-day short course "Colloidal Gels: Formation, Structure and Rheology" was presented by Matthew Helgeson (Chemical Engineering, UC Santa Barbara), Roseanna Zia (Chemical Engineering, Stanford University) and Safa Jamali (Mechanical and Industrial Engineering, Northeastern University). A total of 55 persons attended the short course, with 12 in person, 33 online and 10 online students who received the scholarships for students at international institutions.

Cari Dutcher and Patrick Underhill organized a terrific technical program for the 92nd meeting. The Annual Meeting had ten thematic sessions, the in-person poster session (including

Peaceful transfer of power: SOR's past president Mike Graham and current president Anne Grillet



Lively discussions during a well-attended poster session the annual Student/Post-doc Poster Competition), the in-person/virtual Gallery of Rheology Contest and the virtual pre-recorded flash presentations. In addition, online discussions of the pre-recorded flash presentations were held in Gather.town during the mornings of Monday through Thursday. These discussion sessions were organized by Anne Grillet and Marie-Claude Heuzey.

There were 206 in-person oral presentations, 94 virtual pre-recorded presentations, 67 in-person poster presentations and 11 entries in the Gallery of Rheology Contest. The plenary lectures were given in-person by Michael Solomon (Chemical Engineering, University of Michigan) and Petia Vlahovska (Engineering Sciences and Applied Mathematics, Northwestern University). The 2021 Bingham Medalist, Jan Vermant (Department of Materials, ETH Zürich), gave the Bingham Lecture remotely due to travel restrictions. Similarly, the 2021 Metzner Awardee, Quan Chen (Changchun Institute of Applied Chemistry, Chinese Academy of Sciences), presented his research work remotely. These four presentations were broadcasted live on line to all attendees.

Rheological vendors demonstrated their products Monday through Wednesday in the coffee break area. They were also present virtually in Gather.town. The strong support of SOR by the device manufacturers is greatly appreciated.

A welcoming reception, sponsored by TA Instruments, was held during the evening of Sunday October 10th at the Cross Insurance Center and in the tent on its front lawn. A virtual Student-Industry Forum, sponsored by the American Institute of Physics, occurred during the lunch break on Monday October 11th. Making its debut in Bangor, the Student Trivia Night was held Monday evening at the Sea Dog Brewing Company. Around 80 participants attended the Student Trivia Night. This event was organized by Keara Saud, Jennifer Mills, Ellie Porath and Aileen Co.

The Society Business Meeting during the lunch break on Tuesday October 12th was well-attended, both in-person and remotely. The events for Tuesday evening were the Awards Reception and the Awards Banquet. Due to pandemic-related social distancing, the banquet was limited to around 130 seats in the three ballrooms used. At the start of the Awards Banquet, Jan Vermant was warmly roasted by Eric Furst. We then heard from Jan remotely on his appreciation of the camaraderie of the rheological community. This special event was broadcasted live on line.

Plenary lecturer, Petia Vlahovska, in action

The last event of the week in Bangor was the Poster Session and Reception during the evening of Wednesday October 13th. Following the guide lines for social distancing, we spread out the poster boards over an area equivalent to six ballrooms. The Poster Reception, sponsored by Anton Paar, was well attended. The favorite at the reception was the Maine lobster roll. The winners of the Student/Post-doc Poster Competition and the Gallery of Rheology Contest were announced at the end of the reception.

Holding a meeting in the midst of a pandemic is both challenging and satisfying!

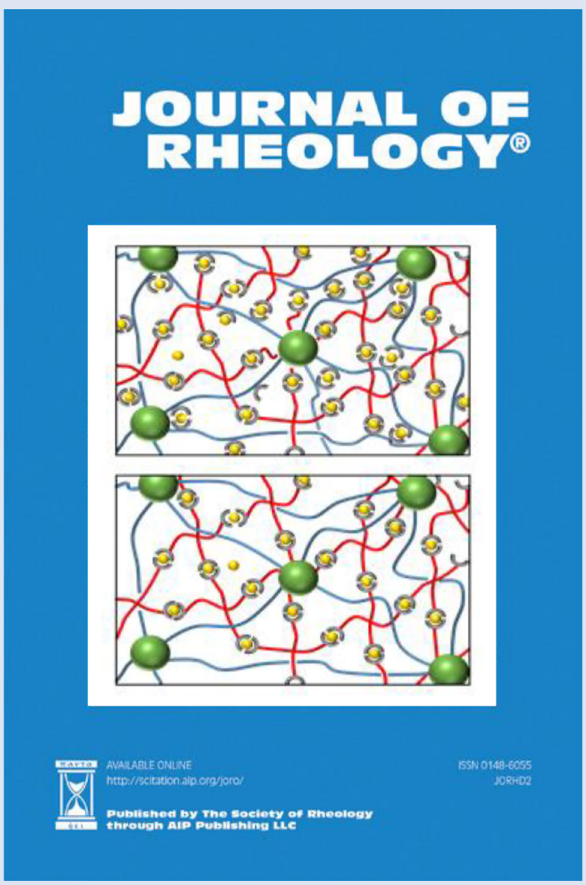
Greetings from Bangor

Special Issue on Double Dynamics Polymeric Networks

Guest Editors: Evelyne van Ruymbeke and Tetsuharu Narita

The special issue on Double Dynamics Polymeric networks of the *Journal of Rheology* is scheduled for **publication in the November/December issue of 2022**. This issue focuses on the properties of polymeric networks exhibiting double or multiple dynamics, such as dual networks or interpenetrated polymer networks, with particular emphasis on systems which combine supramolecular reversible junctions of different nature, or combine reversible junctions, entanglements and/or chemical crosslinks. Submissions are welcome from the entire spectrum (experiments, simulations and theory).

This special issue marks the final meeting of the European *Initial Training Network* DoDyNet. Some of the peer-reviewed articles from this special issue were presented in a focused discussion workshop in Crete in May of 2022.



SOR 93RD ANNUAL MEETING

OCTOBER 2-6 2022, CHICAGO, ILLINOIS

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PLENARY LECTURERS

Prof. LaShanda Korley
University of Delaware

Prof. Jacinta Conrad
University of Houston

Technical Program co-chairs: Emanuela Del Gado (Georgetown University) & Charles Schroeder (UIUC)

14 Technical Program Areas:

1. Suspensions and Colloids (Gilchrist, Hsiao, Khair)
2. Polymer Solutions, Melts and Blends (O'Connor, van Ruymbeke, Walker)
3. Flow-induced Instabilities in Non-Newtonian Fluids (Oliveira, Shen, Vlahovska)
4. Techniques & Methods: Rheometry & Spectroscopy/Microscopy (Ewoldt, Helgeson)
5. Biomaterials and Bio-fluid Dynamics (Graham, Marciel, Schultz)
6. Rheology of Gels, Glasses and Jammed Systems (Divoux, Mai, Schweizer)
7. Surfactants, Foams and Emulsions (Christopher, Mohraz, Srivastava)
8. Additive Manufacturing and Composites (Bischofberger, Olmsted, Seppala)
9. Rheology of Active Matter and Directed Systems (Biswal, Cheng, Furst)
10. Interfacial Rheology (Fuller, Samaniuk, Tang)
11. AI and ML Based Rheological Characterization (Caggioni, Jadhao, Jamali)
12. Sustainable and Recyclable Polymers (Migler, Olsen, Zhang)
13. Rheology of Soil, Mud and Construction Materials (Datta, Erk, Roussel)
14. Applied Rheology for Pharmaceuticals, Food & Consumer Products (Calabrese, Sharma, Richards)

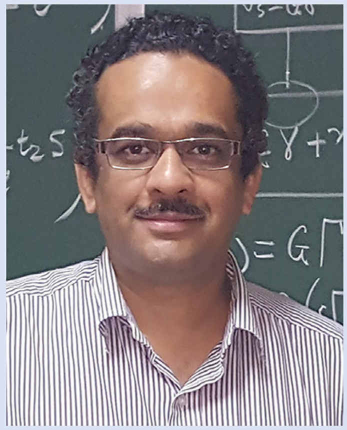
Poster Session Chairs: Charles E. Sing (UIUC), Qin (Maggie) Qi (MIT)
Gallery of Rheology Chair: Susan J. Muller (Berkeley)

Largest number of abstracts ever received for both talks (>430) and posters (>120) πάντα ῥεῖ

Announcing the 2022 Fellows of the Society of Rheology

Please join us in congratulating the new class!

Aloyse Franck
TA Instruments

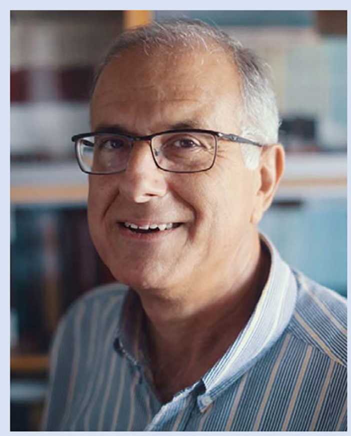


Yogesh Joshi
Indian Institute of Technology - Kanpur

Carlos Rinaldi-Ramos
University of Florida

Amy Shen
Okinawa Institute of Science and Technology

Michael Solomon
University of Michigan



John Tsamopoulos
University of Patras

2022 Metzner Award Winner: Simon Rogers

by Charles Schroeder

Simon Rogers, Assistant Professor of Chemical and Biomolecular Engineering at the University of Illinois at Urbana-Champaign, is the recipient of the 2022 Arthur B. Metzner Early Career Award from The Society of Rheology. Simon's research focuses on understanding the structure and dynamics of soft materials far-from-equilibrium by developing creative new experimental and analytical modeling techniques. In recent years, Simon's work has provided an improved understanding of complex flow phenomena in yield stress fluids, polymer solutions, and colloidal suspensions by developing fundamentally new experimental and analytical methods for linear and nonlinear transient rheology.

Simon Rogers obtained his Ph.D. in Physics from Victoria University of Wellington in New Zealand in 2011 under the supervision of the late Sir Paul Callaghan. During his Ph.D., Simon used rheo-nuclear magnetic resonance (rheo-NMR) and rheological methods to study the aging and rejuvenation of soft glassy materials. It was during that time that he developed a keen interest in transient nonlinear rheology. Following the completion of his Ph.D., Simon became a postdoctoral research associate at the Foundation for Research and Technology - Hellas (FORTH) in Crete, Greece, where he worked with Dimitris Vlassopoulos on the rheology of ring and star polymers. Simon then moved to the Forschungszentrum Jülich, where he worked with Peter Lang, in the group of Jan Dhont, on understanding the near-wall dynamics of colloids using evanescent wave dynamic light scattering. In October 2012, Simon moved across the Atlantic to the University of Delaware, where he worked with Norm Wagner and served as the UD liaison to the National Institute of Standards and Technology's Center for Neutron Research. During his time at Delaware, Simon also interacted with Antony Beris, where he developed an interest in experimental and theoretical descriptions of thixotropy. In August 2015, Simon began his position as Assistant Professor in the Department of Chemical and Biomolecular Engineering at the University of Illinois at Urbana-Champaign.

Not surprisingly, Simon has been honored by multiple awards and accolades in his career. Simon was awarded the NSF CAREER award in 2019, a Doctoral New Investigator Award from the American Chemical Society Petroleum Research Fund (ACS PRF) in 2018, and the School of Chemical Sciences Teaching Award at the University of Illinois at Urbana-Champaign in 2020. He was recently awarded the 2022 Campus Distinguished Promotion Award at Illinois and has been named a 2022-2023 I. C. Gunsalus Scholar. He has given over 30 invited lectures at national and international conferences and universities.

A main focus of Simon's independent research program lies in combining bulk rheological characterization of materials with dynamic, molecular-level structure determination using scattering. In this area of research, Simon's work addresses long-standing challenges in understanding the far-from-equilibrium behavior of soft materials by directly linking microstructural rearrangements to macroscopic flow properties. In one demonstration, his group showed that bulk stress can be unambiguously understood from local microstructural rearrangements in wormlike micelles and polymer networks using time-resolved rheo-small-angle neutron scattering (rheo-SANS) (Lee et al. *Phys. Rev. Lett.*, 2019). Impressively, this work showed that nonlinear rheological structure-property relations can be clearly determined using a new analytical framework developed by Simon and his team known as 'transient recovery rheology'. Broadly, this framework relies on performing traditional strain-controlled and stress-controlled rheological experiments with zero-stress imposed recovery steps during the experiment. Using this approach, his group is able to clearly quantify and track the evolution of the recoverable component of the strain during a deformation experiment. Remarkably, Simon and his team found that the recoverable strain correlates with the temporal evolution of microstructure, which revealed that the shear stress and normal stress evolution in materials such as polymer networks and wormlike micelles is controlled by the recoverable strain. This groundbreaking work provides a fundamentally new framework with which to perform and analyze nonlinear rheological experiments that differs from the traditional measure of 'shear strain' in a sample, which invariably consists of components of strain that can be recovered (elastic strain) and components that are unrecoverable during a deformation event.

Using the transient recovery rheology framework, Simon and his team have also provided a new way to understand transient oscillatory rheology experiments such as large amplitude oscillatory shear (LAOS). When viewed in the context of recoverable strain, stress-recoverable strain curves show clear, physically relevant features, such as a linear relation between stress and strain for intermediate ranges of recoverable strain. Within the framework of recovery rheology, the transient Lissajous curves begin to make physical sense (e.g., linear relations are obtained between stress and recoverable strain, which reveals a plateau modulus), as opposed to viewing them in the traditional units of shear strain, where a physical interpretation of elliptical curves in stress-shear strain axes can be elusive. Simon's advances in this area hold important implications for designing new rheological protocols and definitions of important dimensionless groups such as the Deborah number (Rogers et al., *Rheol. Acta*, 2019), for developing new property-processing relationships for soft materials (Donley et al., *Proc. Nat. Acad. Sciences*, 2020; Singh et al., *Journal of Rheology*, 2020), and in the development of new models for yield stress fluids (Kamani et al., *Phys. Rev. Lett.*, 2021). Moreover, this approach has provided a new understanding of the Payne effect in filled polymers and the G'' overshoot in concentrated suspensions and yield stress fluids.

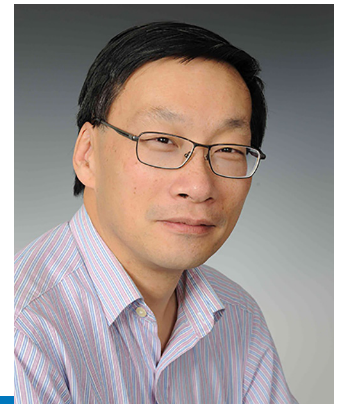
Simon has also developed a new framework for understanding large amplitude oscillatory shear (LAOS) known as the 'sequence of physical processes' (SPP). Importantly, the SPP framework has provided an unambiguous and systematic framework for understanding transient, non-linear materials deformation protocols by considering the dynamics as a sequence of processes occurring within the material described by differential geometry and the Frenet-Serret apparatus. Simon's work in this area has had a significant impact on the field, with broad adoption of open-access SPP software by over 35 companies, collaborators, and national labs. In one demonstration of the SPP method, Simon and his team studied the transient structural and rheological behavior of soft glassy materials far-from-equilibrium under small, medium, and large amplitude oscillatory shear (Park and Rogers, *Journal of Rheology*, 2018). Through such publications, it was shown that the SPP modulus reflects how much of the imposed strain is stored in the form of recoverable elastic strain, establishing it as an accurate measure of structural elasticity. The SPP method was further validated by directly matching strain values estimated solely on the basis of the macroscopic stress to structural measures. In 2018, Simon provided a clear overview of the LAOS analysis literature and the SPP method in a feature invited article in *Physics Today*.

Simon is an active member and contributor of The Society of Rheology. Professor Rogers continues to serve on the Membership Committee for the Society of Rheology and as one of two SoR Representatives on the AIPP Publishing Partners Committee, and he participated in the first Rheology Research Symposium in 2019. Simon is serving as the local arrangements chair for the 2022 Annual Meeting of the Society of Rheology in Chicago.

Simon's creative work continues to push the boundaries of modern rheology into new and interesting directions. Simon is outgoing and engaging, and he brings a warm and welcoming spirit to personal and scientific conversations and meetings. Simon continues to draw in new members into our Society, and he is an outstanding citizen for the rheology community. We look forward to seeing the ongoing contributions that Simon will bring to the field of rheology and the ways in which he will continue to inspire researchers in our Society at all levels of their careers in the future.

Wilson Poon
2022 Bingham Medalist

—Michael Cates



It is a pleasure to sketch the achievements of Wilson Poon, this year's Laureate for the Bingham Medal.

Wilson Poon was born in Hong Kong, and was educated there to the age of 16, learning to do mental arithmetic in Chinese (a habit that, he says, remains). He was especially fond of reading science books, including a slim volume on 'Atoms' which became heavily annotated and dog-eared. Before long he was teaching himself calculus. Finding it easier to read and think about science in English, he persuaded his parents that he should study physics at university in the UK, prefaced with two final high-school years there. He departed Hong Kong for Rugby School in 1978. A precocious scholar even then, the school gave him his first teaching opportunity – giving a class to younger pupils on a subject of his choice (group theory).

Wilson studied Natural Sciences at Cambridge University, graduating with first class honours in Physics and Theoretical Physics in 1984. He was especially influenced by the problem-based pedagogy of his tutors, including biophysicist Aaron Klug and astrophysicist Peter Scheuer. He remained in Cambridge for his PhD work on phase transitions in minerals, before moving to his first academic post, a lectureship in Portsmouth Polytechnic in 1989. A year later he moved to the Department of Physics at the University of Edinburgh where he has remained ever since, being promoted to a Personal Chair in 1999 and to the Chair of Natural Philosophy in 2016. The latter chair has existed since 1708 and was famously not awarded to James Clerk Maxwell when he applied for it in 1860, being given instead to Peter Guthrie Tait. (Maxwell had to be content with the Cavendish Professorship in Cambridge instead.) Tait was a scientist of great distinction but clearly no rival to Maxwell; he won the chair on the grounds that, quite unlike Maxwell, he was an inspiring teacher. Poon likewise embodies the strong Scottish tradition that leadership in research and in pedagogy go hand in hand.

Wilson's early research career focused on Raman spectroscopy, fluorescence and birefringence studies of molecular materials in complex stuctural phases. In Edinburgh, however, he encountered Peter Pusey (recently appointed to a chair there), already renowned as one of the outstanding colloid physicists of his generation, and a pioneer in the use of light scattering to elucidate structure and dynamics of colloids. Thus began a scientific collaboration that lasted over two decades: Pusey's insistence on leaving no stone unturned proved a productive counterweight to Poon's creative flair. Over time, however, Wilson came to share Peter's eye for detail, with no dimming of his own natural tendency to innovate. By the time Pusey retired, Poon had not only assumed the mantle as head of the experimental soft matter group in Edinburgh, but also emerged as a scientific powerhouse in his own right. In particular he was among the first to recognize, and develop, the power of direct microscopy in colloidal materials. He showed this capable of resolving individual particle trajectories even in systems under flow, enabling for the first time the connection to be made between continuum physics (phase equilibria and rheology) and fully resolved microstructural data. This goal had eluded the scattering methods that had held sway for the preceding half century.

Poon's early work with Pusey on the phase behaviour of colloid-polymer mixtures remains widely influential today. His subsequent career included numerous important contributions to the rheology of Brownian colloidal suspensions, while in the past 5 years, Wilson has made pivotal contributions to an emerging understanding of dense non-Brownian suspensions. These two bodies of work on rheology are discussed further below. Alongside them, Poon has made a series of important contributions to biophysics and to the dynamics of self-propelled colloids.

Contributions to rheological science

Poon's first paper in colloid rheology put the entire field onto a firmer footing. The 'standard model' in the field (since Einstein) addresses a suspension of Brownian hard spheres, and how its reduced viscosity (η) varies with volume fraction (ϕ), up to the point at which the system crystallises at $\phi = 0.49$. Precise measurement of both quantities is crucial; its absence had led to published results for $\eta(0.49)$ varying by more than an order of magnitude. Poon's careful measurements using a bespoke Zimm rheometer established the 'gold standard' data set for the reference hard-sphere system.

Wilson then turned to the exploration of kinetically arrested states in colloid-polymer mixtures. His studies in the 1990s of 'delayed sedimentation' in low-ϕ

1. Wilson Poon aged 18 months. It looks like he has just irreversibly dismantled the object that lies in front of him – an early experiment gone wrong?

2. Wilson aged 9, manning an school exhibition on metric units (then yet to be introduced in Hong Kong). The poster above the glassware explains that 1 litre = 0.22 gallons.

gel states were ahead of their time, and underpinned a subsequent resurgence of interest in the mechanisms of such phenomena. This work combined macroscopic flow observation of gel collapse with microstructural probes using light scattering.

There followed a seminal body of work on high-ϕ glassy states. Leading a team of experimentalists, simulators and theorists, Poon announced in 2002 the experimental existence of two distinct glassy states in colloidal suspensions (attractive and repulsive glasses). This was exactly as predicted by mode-coupling theory (MCT) and established this rather mathematical theory as the predictive method of choice for colloid rheology at high ϕ. This work on glassy states framed the agenda for a decade's research (by Poon and many others) on experimental colloid rheology. Poon himself soon discovered that repulsive hard-sphere glasses yield in a single step, while attractive colloidal glasses yield in two distinct steps. These and his other observations on well-characterised model systems have now been replicated in a multitude of academic and industrial contexts.

3. Wilson's BA graduation photo, 1984.

During this period Poon's team invented confocal rheo-imaging, a combination of hardware and software tools that allow the mapping of thousands of time-dependent particle coordinates while rheological measurements are being made. Such approaches form part of a wider transformation in the way rheology is done, of which Poon is one of the key architects. The ability to make precise microstructural measurements under flow, alone or simultaneously with measurements of bulk rheological stresses, helped establish the modern approach whereby the links between microstructural evolution and rheology are nailed down experimentally rather than left to the theorist's imagination. This raises the bar for successful theories – a development not always welcomed by theorists, but greatly benefitting rheological science.

For the past decade or so, Poon has focussed his attention on the rheology of dense non-Brownian suspensions. Such suspensions are widely viewed as capricious and unpredictable; their rheology appears very sensitive to small changes in materials, conditions and experimental protocols. This is unfortunate, since such supra-Brownian 'granular suspensions' are ubiquitous in industrial settings.

Poon has made pivotal experimental contributions to a recent paradigm shift in how these suspensions are viewed. This is based on the realization that frictional forces, acting at direct solid-solid contacts between particles, are crucial determinants of the rheology. This leads for example to a new and compelling explanation of shear thickening, whereby sufficient stress overcomes short-scale repulsive forces, allowing formation of frictional contacts that stop neighbouring particles from sliding past each other. Such contacts necessitate extra local motions to achieve a given bulk deformation, which leads to higher dissipation and increased viscosity. Within a window of density it can also lead to jamming whereby the suppression of sliding prevents bulk flow altogether (resulting in fracture or granulation instead).

In 2015 Poon used well characterised suspensions to validate a theory for friction-driven shear thickening due to Wyart and Cates, and showed moreover that practically any realistic stress will cause friction to dominate in most granular suspensions of industrial interest. With colleagues from Cornell, he then demonstrated the key role of direct contact forces, including friction, using an elegant modern version of a shear-reversal protocol first used by Acrivos and others in the 1980s. That contact forces including friction dominate granular suspension rheology is now broadly accepted, in large part due to Wilson's efforts.

Since then, progress has been rapid. Poon's 2019 experiments probe the origins of oscillatory flow instabilities and explain them with an extension of the same model. His subsequent study of extrusion in shear-thickening suspensions explains the ubiquitous industrial phenomenon of dewatering, showing its onset to be predictable using shear rheology data alone. In 2018, Poon's group published a model that generalised further the 'constraint rheology' theory, in which particles may form adhesive contacts alongside frictional ones. This allows almost all classes of rheology so far reported for non-Brownian suspensions to be explained within a single framework. The industrial value of this framework was established in a 2019 paper on the physics of chocolate conching, opening the way to a more rational approach to formulation of granular suspensions in an industrial context based on 'contact engineering'.

Interacting with Wilson: a personal note

Anyone who has heard Wilson Poon lecture at a conference or summer school will be aware of his infectiously energetic style of delivery. The same characteristic has enthused students, postdocs, and senior collaborators for many years. On the other hand, he is happy to play devil's advocate, which sometimes can lead to ruffled feathers – years ago I heard him ask a seminar speaker "but isn't that a complete waste of time?" (followed by a good reason to think it might be). Wilson

4. The Poon family in 2022. Left to right: Aidan, Heidi, Rebecca and Wilson. They are on a walk in Holyrood Park, a mile or so from their Edinburgh home.

has mellowed since, but in any case his adoption of such positions is never entrenched. His issuing of such a challenge does not represent a dismissal, but an invitation to advance science through unfettered discussion of the key ideas.

During the 20 years I myself spent in Edinburgh, such discussion with Wilson was a constantly productive feature of my own scientific life. One crucial element in our collaborations has been to find where there is genuine overlap between what is calculable and what is measurable – for only here can hypotheses be tested, and theories stand or fall. Another has been to jointly shape the scientific agenda, not just identifying the questions that matter most, but also ensuring that experiments remain maximally informative, and theory does not stray into idle speculation.

In his role as the head of an experimental lab, Wilson Poon is unusual in several ways, including the ability to successfully delegate work when appropriate. For instance, most organisers of extended theory-based workshops find it hard to attract senior experimentalists to leave their lab teams unattended for more than a few days. Not so Wilson, who was happy to leave experiments in the capable hands of colleagues during his 6-month immersion in 2004 at the Isaac Newton Institute in Cambridge to explore emerging ideas of biological physics.

Beyond science

Wilson is a lover of music and an accomplished amateur pianist. He is an avid reader across diverse areas of the arts and humanities, as well as science, and owns a substantial library. He is a lay preacher (sermons are available on his website!) and has played a major role in Edinburgh in exploring the connections between science and religion. He is married to Dr Heidi Poon, a distinguished lawyer and latterly a Judge, specializing in UK taxation law. They have two children – Rebecca, now doing a PhD in biophysics at the University of Exeter, and Aidan, who has just completed a Masters in Mechanical Engineering at the University of Warwick.

In conclusion

Wilson Poon's experiments on the rheology of suspensions, first in the Brownian and then in the non-Brownian domain, have conspicuously and consistently shaped the field over the last two decades. He has introduced major new methods for connecting rheology to microstructure, and his work on frictional suspensions has very direct implications for industrial practice. Wilson Poon is a worthy winner of the SOR's Bingham Medal.

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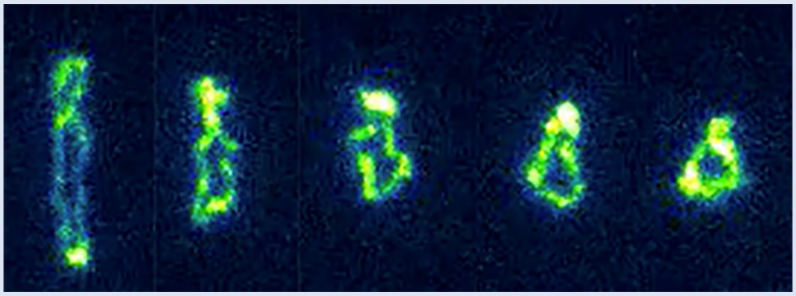
Special Issue on Ring Polymers

Guest Editor: Charles Schroeder, University of Illinois at Urbana-Champaign
Guest Co-Editor: Ravi Prakash, Monash University



The *Journal of Rheology* will publish a special issue on the dynamics and rheology of ring polymers. Scheduled for publication in 2023, this issue will focus on the dynamics of rings across all concentration regimes, including the melt state. We have already received a large number of high-quality submissions for this special issue. Given the interest in this topic, we are reaching out for additional contributions from experiments, theory and simulation, as well as from academia, national labs, and industry.

This special issue is planned in conjunction with a **Workshop on Ring Polymers** to be held between **June 14 and June 16 of 2023** at the **Monash University Prato Centre** in Prato, Italy (http://monash.it). The meeting is organized by J. Ravi Prakash, Burkhard Duenweg, and Charles Schroeder. The conference site is in the beautiful Tuscany Region of Italy in close proximity to multiple cultural centers including Florence. The meeting will be sponsored in part as a CECAM event (Centre Européen de Calcul Atomique et Moléculaire); website coming soon with more details. Consider joining your colleagues for an enjoyable meeting and event!

Accepted articles will be circulated among all authors participating in the special issue and/or the meeting, for comments and questions that will be published following the article, with replies from the authors.

How to submit / Expression of intent

If you plan to submit a paper to this issue, expressions of intent are encouraged at your earliest opportunity. Alternatively, upon submission, please indicate in your cover letter that your article should be considered for the special issue.

- Expressions of intent can be sent to Ania Bukowski, Editorial Assistant, by e-mail to JOR-EditorialOffice@aip.org
- Use **INTENT - Special Issue/Ring Polymers** in the subject of your message
- Indicate a tentative title for your manuscript
- Include contact author's name, institution and email, and those of known or proposed co-authors
- For additional inquiries, please feel free to contact the guest editors

DEADLINE FOR SUBMISSIONS: **December 1, 2022**

The Society of Rheology Mission Statement

Our Vision

An international community of rheologists working towards common goals as articulated in our founding Constitution.

Values

We are the nexus of excellence in the theory and practice of rheology. We are committed to advancement and promotion of the rheological sciences and practice of rheology broadly across diverse groups of individuals, disciplines and industries.

Mission

We aim to expand the knowledge and practice of rheology through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what rheology is, and how it impacts humanity and the world.

– Adopted by the SoR Executive Committee, 10 June 2017

A Brief History of Society of Rheology Meetings

Andy Kraynik, Retired, and Albert Co, University of Maine

The Society of Rheology is planning a Centennial Celebration for 2029 to observe the 100th anniversary of its founding on December 19, 1929 at the 1st Annual Meeting, which was held at the National Bureau of Standards (currently NIST) in Washington, D.C. The Centennial will be the 100th Annual Meeting of the Society – not the 101st. The simple explanation is: the winter meeting scheduled for February 2021 in Austin, TX was cancelled because of the Covid 19 pandemic and a virtual technical meeting was not held because of the very recent virtual International Congress on Rheology that was organized from Rio de Janeiro, Brazil in December 2020. However, the picture is more intriguing than one annual meeting per year, and is summarized in this brief history, which was compiled from two principal resources: a very readable article by Eugene C. Bingham on "The History of the Society of Rheology from 1924–1944" [1], and the Annual Meeting Archive on the SOR website [2].

The following comments refer to the Table of Meetings.

Bingham's article covers annual meetings through 1943 while the entries on the SOR website begin with the eighth meeting that was convened at the Hotel Pennsylvania in New York City in 1936. There is a discrepancy between the two sources: Bingham claimed that the eighth meeting was held at the Bell Telephone Laboratories in New York City and even cited a related article in *The New Yorker* [3] as being published in 1936, which was in error. The article can be found on the internet and was published in 1935. Bingham had overlooked the 7th annual meeting.

The "1941 Annual Meeting" was called just that – not the 13th annual meeting – perhaps because of superstition surrounding the number 13. That convention for naming meetings persisted through the 1958 Annual Meeting. Unfortunately,

Year	Annual Meeting	Location
1929	1st	National Bureau of Standards, Washington, DC
1930	2nd	Easton, PA
1931	3rd	Rochester, NY
1932	4th	Atlantic City, NJ
1933	5th	Pittsburgh, PA
1934	6th	Franklin Institute, Philadelphia, PA
1935	7th	Bell Telephone Laboratories, NYC, NY
1936	8th	Hotel Pennsylvania, NYC, NY
1937	9th	Hotel Mayflower, Akron, OH
1938	10th	Mellon Institute of Industrial Research, Pittsburgh, PA
1939	11th	National Bureau of Standards, Washington, DC
1940	12th	American Museum of Natural History, NYC, NY
1941	1941	Hotel Pennsylvania, NYC, NY
1942	1942	Hotel Pennsylvania, NYC, NY
1943	1943	Hotel Pennsylvania, NYC, NY
1944	1944	Hotel Pennsylvania, NYC, NY
1945	1945	Hotel Pennsylvania, NYC, NY
1946	1946	Hotel Pennsylvania, NYC, NY
1947	1947	Hotel Pennsylvania, NYC, NY
1948		1st ICR - Scheveningen, The Netherlands
1948	1948	Hotel Pennsylvania, NYC, NY
1949	1949	Hotel New Yorker, NYC, NY
1950	1950	Hotel New Yorker, NYC, NY
1951	1951	Hotel Sherman, Chicago, IL
1952	1952	Franklin Institute, Philadelphia, PA
1953		2nd ICR - Oxford, United Kingdom
1953	1953	Hotel New Yorker, NYC, NY
1954	1954	National Bureau of Standards, Washington, DC
1955	1955	Hotel Henry Hudson, NYC, NY
1956	1956	Mellon Institute, Pittsburgh, PA
1957	1957	Textile Research Institute, Princeton, NJ
1958		3rd ICR - Bad Oeynhausen, Germany
1958	1958	Franklin Institute, Philadelphia, PA
1959	30th	Lehigh University, Bethlehem, PA
1960	31st	Mellon Institute, Pittsburgh, PA
1961	32nd	University of Wisconsin, Madison, WI
1962	33rd	The Johns Hopkins University, Baltimore, MD
1963	34th	4th ICR - Brown University, Providence, RI
1964	1st Winter	Claremont University Center, Claremont, CA
1964	35th	Mellon Institute, Pittsburgh, PA
1965	2nd Winter	Miramar Hotel - Motel, Santa Barbara, CA
1965	36th	Case Institute of Technology, Cleveland, OH
1966	3rd Winter	U.S. Naval Post Graduate School, Monterey, CA
1966	37th	Traymore Hotel, Atlantic City, NJ
1967	4th Winter	Miramar Hotel - Motel, Santa Barbara, CA
1967	38th	Sheraton Park Hotel, Washington, DC

(*Continued*)

the following meeting in 1959 was labeled the "30th Annual Meeting" and should have been the 31st, consequently the meeting numbers going forward were too low by one, until this was corrected in 1981.

The Table of Meetings also includes International Congresses on Rheology, starting with the 1st ICR in 1948 in Scheveningen, The Netherlands, and run every five years until 1968. The Society of Rheology held an annual meeting in the same year as the first three ICRs. This practice ceased in 1963 when the ICR came to Brown University and the meeting also served as the 34th Annual Meeting.

During the next four years, 1964–1967, the Society organized two meetings every year: a small, more focused winter meeting in California and the regular annual meeting in the fall. The constitution of the Society requires technical sessions, and a business meeting, to be held at each regular annual meeting. The San Diego winter meeting in 1968 was followed by an ICR in Kyoto, Japan later that year, but neither qualified as an annual meeting. Thus began the practice of delaying the fall meeting in the year of an ICR until the winter of the following year, which meant that there would be two annual meetings, with business meetings, in the years following an international congress. After Kyoto, ICRs were convened more frequently: every four years.

The Society co-organized a US-Japan Joint Meeting in Kona, Hawaii in 1979; since then, only annual meetings have been conducted. The year 1979 also featured the 50th Jubilee Meeting of the Society in Boston. The jubilee resulted in the recognition that meeting numbers were incorrect; consequently, the 1981 winter meeting in Williamsburg, VA was the 52nd Annual Meeting.

The four-year cycle of ICRs and annual meetings was followed for four decades until the cancellations caused by the pandemic. The Austin cancellation resulted in the 92nd Annual Meeting in Bangor; and the numbering of meetings changing for the third time.

The 19th ICR in Athens in 2023 will involve two substantial changes. It will convene three years after the ICR in Rio de Janeiro so that the four-year ICR cycle will no longer coincide with the four-year cycle of the International Congress of Theoretical and Applied Mechanics (ICTAM). But more significant is the

Year	Annual Meeting	Location
1968	5th Winter	Vacation Village Hotel, San Diego, CA
1968		5th ICR - Kyoto, Japan
1969	39th	Williamsburg Lodge, Williamsburg, VA
1969	40th	The St. Paul Hilton Hotel, St. Paul, MN
1970	41st	Nassau Inn, Princeton, NJ
1971	42nd	University of Tennessee, Knowville, TN
1972		6th ICR - Université Claude-Bernard, Lyon, France
1973	43rd	Stouffer's Cincinnati Inn, Cincinnati, OH
1973	44th	Sheraton-Mount Royal Hotel, Montréal, Canada
1974	45th	University of Massachusetts, Amherst, MA
1975	46th	Chase Park Plaza Hotel, St. Louis, MO
1976		7th ICR - Chalmers Univ. of Tech., Gothenburg, Sweden
1977	47th	Biltmore Hotel, NYC, NY
1977	48th	University of Wisconsin, Madison, WI
1978	49th	Stouffer's Greenway Plaza Hotel, Houston, TX
1979		Hotel King Kamehameha, Kona, HI
1979	50th Jubilee	Copley Plaza Hotel, Boston, MA
1980		8th ICR - University of Naples, Italy
1981	52nd	Williamsburg, VA
1981	53rd	Louisville Inn, Louisville, KT
1982	54th	Holiday Inn of Evanston, Evanston, IL
1983	55th	Knoxville Hilton, Knoxville, TN
1984		9th ICR - Acapulco, Mexico
1985	56th	Virginia Polytechnic Institute and State University, Blacksburg, VA
1985	57th	Ann Arbor Inn, Ann Arbor, MI
1986	58th	Radisson-Excelsior Hotel, Tulsa, OK
1987	59th	Pierremont Plaza Hotel, Atlanta, GA
1988		10th ICR - University of Sydney, Australia
1989	60th	Gainesville, Florida
1989	61th	Grant Hotel, Montréal, Canada
1990	62nd	Sweeney Center, Santa Fe, NM
1991	63rd	Holiday Inn - Genesee Plaza, Rochester, NY
1992		11th ICR - Brussels, Belgium
1993	64th	Sheraton Santa Barbara, Santa Barbara, CA
1993	65th	Omni Parker House, Boston, MA
1994	66th	Hotel Atop the Bellevue, Philadelphia, PA
1995	67th	Hyatt Regency Hotel, Sacramento, CA
1996		12th ICR - Québec, Canada
1997	68th	The San Luis Hotel, Galveston, TX
1997	69th	Hyatt on Capitol Square, Columbus, OH
1998	70th	Monterey Marriott, Monterey, CA
1999	71st	Monona Terrace, Madison, WI
2000		13th ICR - Cambridge, United Kingdom
2001	72nd	Westin Resort, Hilton Head Island, SC
2001	73rd	Hyatt Regency Hotel, Bethesda, MD
2002	74th	Radisson Hotel Metrodome, Minneapolis, MN
2003	75th	Sheraton Station Square Hotel, Pittsburgh, PA
2004		14th ICR - Seoul, Korea
2005	76th	Lubbock Memorial Civic Center, Lubbock, TX
2005	77th	Westin Bayshore Resort and Marina, Vancouver, Canada
2006	78th	Holiday Inn by the Bay, Portland, ME
2007	79th	Hilton Salt Lake City Center, Salt Lake City, UT
2008	80th	15th ICR - Monterey Conference Center, Monterey, CA
2009	81st	Monona Terrace, Madison, WI
2010	82nd	Santa Fe Convention Center, Santa Fe, NM
2011	83rd	Intercontinental Cleveland, Cleveland, OH
2012		16th ICR - Lisbon, Portugal

(*Continued*)

decision of the Society of Rheology to partner with ICR organizers so that we can hold a business meeting and present awards at future international congresses. The Society is committed to enhancing future ICRs for the benefit of the entire international rheology community. This change will satisfy the constitutional requirement of conducting a business meeting at a technical conference; and alleviate the need to hold two meetings the following year. Coincidentally, the regular annual meeting following the Athens ICR will take place in Austin; the meeting canceled in 2021 was postponed until the fall of 2024.

References

[1] https://www.rheology.org/sor/History/Bingham-History_of_SoR_1924-1944.pdf

[2] https://www.rheology.org/sor/Annual_Meeting/MeetingArchive

[3] The *New Yorker*, November 23, 1935, pp. 61–71.

Year	Annual Meeting	Location
2013	84th	Pasadena Convention Center, Pasadena, CA
2013	85th	Hilton Montréal Bonaventure, Montréal, Canada
2014	86th	Loews Philadelphia Hotel, Philadelphia, PA
2015	87th	Hyatt Regency Baltimore, Baltimore, MD
		17th ICR - Kyoto, Japan
2017	88th	Grand Hyatt Tampa Bay, Tampa, FL
2017	89th	Embassy Suites, Denver, CO
2018	90th	Westin Galleria Houston, Houston, TX
2019	91th	Raleigh Convention Center, Raleigh, NC
2020		18th ICR (Virtual) - Rio de Janeiro, Brazil
2021		2020 SOR Business Meeting (Virtual)
2021	92nd	Cross Insurance Center, Bangor, ME
2022	93rd	Sheraton Grand Chicago, Chicago, IL
2023	94th	19th ICR - Athens, Greece
2024	95th	JW Marriott, Austin, TX
2025	96th	Santa Fe Convention Center, NM
2026	97th	Boston, MA
2027	98th	20th ICR - Asia
2028	99th	TBD
2029	100th	TBD - Centennial Meeting of the Society of Rheology

Investigating Rheology and Texture of Dairy and Plant-Based Alternative Cheeses Using the Scott Blair Fractional Model

Francesca De Vito, Julie B. Hirsch, and Senghane D. Dieng

On Feb 2, 1977, the New York Times published an article called 'Forget Cheese, Smile and Say Analog'. This article by Rona Cherry introduced the world to imitation cheese and described this "new culinary hurdle" as "a new type of product, analogous to the real thing, using vegetable oil to replace butterfat, and 'various chemicals' [1]. The article offers that simple economics was the reason behind the introduction of this relatively new class of food called imitation cheese or substitute cheese [2].

Fast forward to 2022 and these imitation cheeses are now also known as plant-based, non-dairy, 'vegan', alternative cheese, or any combinations thereof. One could argue that these non-standard products, both then and now, are a sinister act of deception by the food industry, and potentially government, to make money and fool us. On the flip side, we can look to the positive and see that consumers now have so many more options from which to choose. In 2020, there was approximately \$270 million dollars in sales of plant-based cheese, with 42% growth from the previous year [3]. Collectively, we are voting with our dollars, whether it's because of lower price, nutrition, longer shelf stability, allergies, sustainability, or animal welfare.

Regardless of why alternative cheese consumption is on the rise, we, as rheologists and scientists, are fortunate to have an incredibly vast world of beautiful semisolid, non-Newtonian, gel filled colloids to explore. During the past 55 years, technology advancement has spanned a wide array of ingredients and processing techniques to understand the systems and behaviors, as well as the elegant micro- and macro-structure and physical functionality, of both cheese and imitation cheese [4]. With imitation cheese, the challenges are in reduction and replacement of fats, and replacement of casein, the predominant milk protein responsible for gelling, melting and stretch. The complexity of duplicating the intricacies of the networks and interactions of fat, protein, carbohydrate, and salts that give rise to the texture and all the totality of qualities that make natural cheese so extraordinary have necessitated invention in materials, processes, and of course methodologies.

The inspiration for this work came from the publications of Faber et al. [5,6] who described a theoretical framework and defined texture parameters for semi-hard cheese, using fractional calculus. They showed that the constitutive Scott Blair element known as the "springpot" could be used to describe the viscoelastic properties of cheese and defined a model to quantify the textural parameters of firmness, springiness, and rubberiness of zero fat, low fat, and full fat gouda cheese.

In this study, we applied the constitutive equations of the Scott Blair fractional model (described below) to plant-based alternative cheeses. While there are a multitude of plant-based cheeses on the market, improvements in texture, flavor, function (e.g., melting and stretching), and nutrition (protein-content) and the levers that control them, are much needed. Here, we tested the applicability of the Scott Blair fractional rheological model on plant-based alternative cheese, compared currently marketed (US) cheese products on the basis of firmness (F), springiness (S), and rubberiness (R), and investigated the effect of different ingredients on cheese textural attributes.

1. Theory

The Scott Blair fractional model is described by one mechanical analogue element known as the springpot which interpolates between the elastic response of a spring and the viscous response of a dashpot. Its constitutive equation relating the instantaneous stress, σ(t) to the instantaneous strain, γ(t) is expressed by the fractional differential equation [13]:

$$\sigma(t) = \mathbb{V}\frac{d^{\beta}\gamma(t)}{dt^{\beta}} \tag{1}$$

where $\mathbb{V}$ is a quasi-property (units: Pas$^{\beta}$), and β is a fractional exponent (dimensionless) $0 < \beta < 1$. For $\beta = 0$ and $\beta = 1$, Eq. 1 reduces to the constitutive equations of an Hookean spring (with $\mathbb{V}$ equivalent to a modulus G [Pa]) and a Newtonian dashpot (with $\mathbb{V}$ equivalent to a viscosity η [Pa s]), respectively. The derivative in Equation (1) is the Caputo derivative [14] for which the Laplace and Fourier transforms exist.

The analytical expression of the creep compliance J(t) in the linear viscoelastic region for the Scott Blair model is obtained through the Laplace transformation of the constitutive equation (Eq. 1) with a step shear stress as input and then solving for the strain γ(t) by inverse Laplace transformation [15]:

$$J(t) = \frac{\gamma_{creep}}{\sigma_0} = \frac{t^{\beta}}{\mathbb{V}\Gamma(1+\beta)} \tag{2}$$

If the creep experiment is performed until t_f, the fractional expression of the compliance $J(t)$ in the recovery phase is given as [16]:

$$J(t) = \frac{\gamma_{recovery}}{\sigma_0} = \frac{t^\beta - (t - t_f)^\beta}{\mathbb{V}\Gamma(1+\beta)},\ \text{for } t > t_f \quad (3)$$

Similarly for the small amplitude oscillatory shear with angular frequency ω, using the Fourier transform the analytical expressions of the elastic modulus, G′, the loss modulus, G′′, for the Scott-Blair model are obtained [6]:

$$G'(\omega) = \mathbb{V}\omega^\beta \cos\left(\frac{\pi\beta}{2}\right) \quad (4)$$

$$G''(\omega) = \mathbb{V}\omega^\beta \sin\left(\frac{\pi\beta}{2}\right) \quad (5)$$

The phase angle, tan(δ) is independent of the frequency of the oscillation:

$$\tan(\delta) = \tan\left(\frac{\pi\beta}{2}\right) \quad (6)$$

Precise rheological definitions of the textural attributes of firmness, springiness and rubberiness have been introduced in the context of cheeses as complex food gels for a creep/recovery experiment at specific points of the linear compliance curve [5].

Firmness, F (units: Pa) is defined as the resistance to creep and is calculated as the inverse of the max compliance at the end of the creep, t_f:

$$F = \frac{1}{J(t_f)} \quad (7)$$

Springiness S, refers to the instantaneous response of the cheese once the stress is removed and is defined as the absolute secant rate of recovery in a very short interval time Δt_s after creep:

$$S = \frac{\left|J(t_s) - J(t_f)\right|}{\Delta t_s} \quad (8)$$

where $t_s = t_f + \Delta t_s$.

Rubberiness R (dimensionless), is defined as the extent to which a cheese returns to its original shape during the recovery phase of duration Δt_r and is calculated as the ratio of recoverable compliance to the total creep compliance:

TABLE 1. FRS Fractional Equations.

Textural attribute	Symbol, unit	Fractional Equation
Firmness	F, [Pa]	$F = \mathbb{V}\Gamma(1+\beta)t_f^{-\beta}$
Springiness	S, [1/ Pa s]	$S = \frac{\left\|-\Delta t_s^{\beta-1}\right\|}{\mathbb{V}\Gamma(1+\beta)}$ for $\Delta t_s \ll t_f$
Rubberiness	R, [-]	$R = 1 - t_f^{-\beta}\left[(t_f + \Delta t_r)^\beta - \Delta t_r^\beta\right]$

$$R = \frac{\left[J(t_f) - J(t_r)\right]}{J(t_f)} = 1 - \frac{J(t_r)}{J(t_f)} \quad (9)$$

where t_r is the time at end of the recovery step i.e., $t_r = t_f + \Delta t_r$.

Each of the above equations contains a characteristic time (t_f, t_s, and t_r) known as the time of observation corresponding to the measuring time of a texture attribute [5]. This time-dependency reflects the dynamic aspect of the perception of texture.

By combining the analytical expressions of the springpot compliance for the creep and recovery (Eqs. 2-3) with the rheological definitions of F, S, and R (Eqs. 7-9), the fractional equations are obtained (Table 1).

2. Material and composition

In this work, four commercial products in slices were used: three plant-based alternative cheeses and a dairy Gouda cheese chosen as benchmark. The composition of each cheese, as reported on the product label, is shown in Table 2. In comparison to the dairy Gouda, all the plant-based alternative cheeses contain high amounts of carbohydrates but no proteins. Their main ingredients are water, coconut oil as the source of solid fat, blends of native and modified starch from different sources (corn, potato, tapioca, etc.) with or without other hydrocolloids acting as the primary structural agent. All the formulations also contain other minor ingredients such as salts and flavoring agents.

3. Rheometry

Rheological measurements were performed at T = 25 °C using the controlled stress MCR 502 rheometer (Anton Paar, Graz, Austria) equipped with a Peltier system and a sample cover to control temperature on both the lower and upper plate. This temperature value was selected since it is considered a reasonable temperature for oral processing [7]. The use of 25 mm serrated parallel plates allows us to minimize slip. Three discs of 25 mm in diameter were cut with a cork borer from each slice. The slices

TABLE 2. Composition of the cheeses used in this work.

Cheese Type	Ingredients as reported on the products label	Total protein content (gr)
Dairy Gouda	Pasteurized milk, cheese culture, salt, microbial enzymes, annatto (Vegetable color).	**5**
Plant- based alternative cheese A	Filtered Water, Highly Refined Coconut Oil, Modified Potato Starch, Modified Tapioca Starch, Sea Salt, Olive Extract, Natural Flavors (Contains Wheat), Beta Carotene (Color).	**0**
Plant-based alternative cheese B	Cashew milk (water, cashews), coconut oil, modified food starch, xanthan gum, Konjac.	**0**
Plant-based alternative cheese C	Filtered water, coconut oil, modified corn and potato starch, potato starch, fermented tofu (soybeans, water, salt, sesame oil, calcium sulphate), sea salt, natural flavor, olive extract (antioxidant used as a preservative) and beta carotene.	**0**

were sampled immediately after removal from the fridge (4 °C) to ensure a clean cut. The exposed edge of the sample was coated with a thin layer of mineral oil to minimize moisture loss during the measurements. To ensure good contact between the sample and the geometry, the loading procedure used consists in a first compression of the sample until the normal force of 1N is attained and then further reduction of the gap (at 1 N) by 5 % of its initial value. Time for sample relaxation and temperature equilibration was set to 5 min and the measuring gap varied between 1.9-2.6 mm depending on the product tested.

Small amplitude oscillatory shear (SAOS) measurements (frequency sweeps) were performed in the range 0.1-100 rad/s in controlled deformation mode at a strain level in the linear viscoelastic region (0.02 %). Transient creep tests were conducted by applying a stress of 20 Pa (in the LVR) for 10 s, followed by a recovery phase with the same duration ($t_f = \Delta t_r = 10$ s). The value of 10 s was selected to compare mechanical and sensory evaluation of texture. Rheological tests were performed in triplicate.

3. Determination of Scott Blair parameters and texture attributes calculation

Frequency sweep data were fitted to the Scott Blair fractional model (Eqs. 4-5) to obtain the values of the quasi-property $\mathbb{V}$ and the fractional exponent β. For this scope a least-square optimization routine was written in MATLAB based on its minsearch function. The fitting parameters have been validated by proving they can predict the linear compliance, J(t) in the creep and recovery. Firmness, F springiness, S and, rubberiness, R and were estimated using the validated constitutive parameters and the FSR fractional equations. In the calculation of the texture attributes $t_f = \Delta t_r = 10$ s and $\Delta t_s = 0.1$ s have been assumed. The latter time has been considered representative of modern controlled stress rheometers [5]. The flowchart in Fig. 1 reports the above-described methodology used in this work to calculate the textural attributes of the investigated cheeses.

4. Results and Discussion

Figure 2a-b show the rheological fingerprint of the dairy Gouda (orange) and the plant-based alternative cheese A (green). Since the mechanical spectra of the plant-based cheeses were similar, only one is reported as an example. Both types of cheese exhibit solid-like viscoelastic behavior with the storage modulus (G′) greater than the loss modulus (G″) within the measurement frequency range.

As in general observed for food gels, the dairy cheese exhibits the viscoelastic response of a critical gel with both dynamic moduli increasing with the angular frequency, ω following a power-law relationship. In the double logarithmic plot, G′(ω) and G″(ω) appear as straight lines almost parallel and close. This response has been already observed for wheat dough and full-fat Gouda cheese [6] and reported by several researchers on other cheese varieties and even in the melted state [9-11].

On the contrary, the viscoelastic moduli of the plant-based cheese reveal only a slight dependency on the frequency with two almost horizontal lines very distant from each other. This response resembles the behavior of a cross-linked material with strong interactions (covalent bonds) such as vulcanized rubber which has been already observed in gels made of another polysaccharide i.e., agarose [8].

The difference between the two cheese types and their rheology is even more evident looking at the phase shift angle, δ (Fig. 2b). At extremely low frequencies, i.e., for ω < 1 rad/s, the dairy cheese's phase angle increases at lower frequencies reaching a maximum value of 19°. Clearly, the dairy cheese shows a more dissipative-like character at extremely low frequencies, likely due to molecular relaxations and rearrangement of casein protein [7]. On the contrary, the phase angle of alternative cheeses is almost constant in the same range with a value of 5° much closer to zero (which identifies an ideal elastic rubbery material), consistent with a highly elastic/solid-like behavior of a strong cross-linked gel.

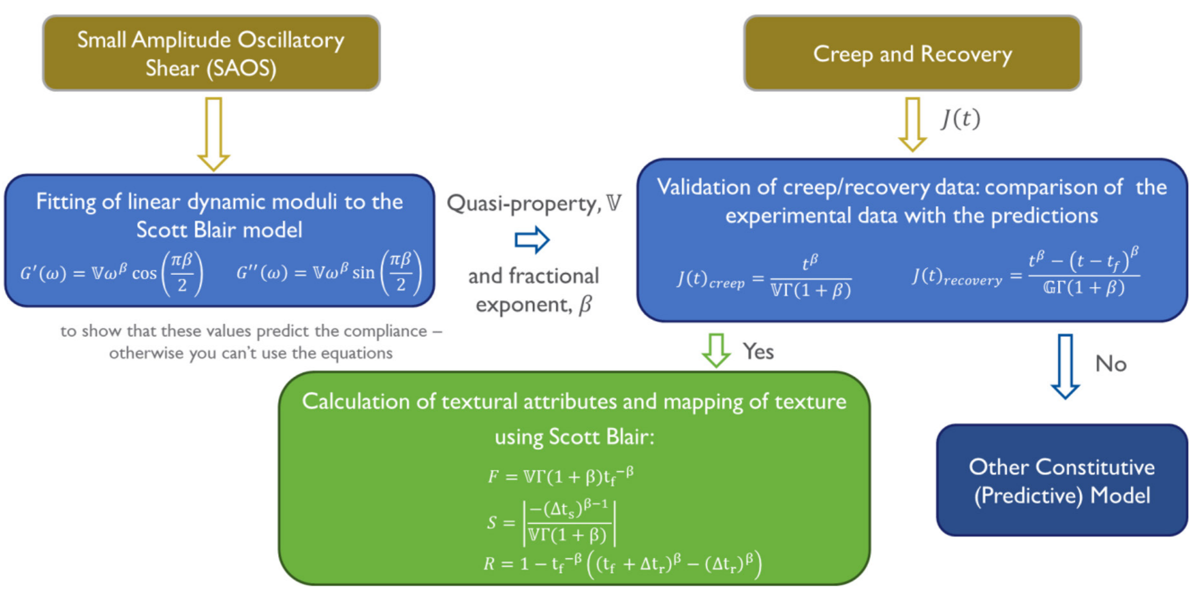


FIGURE 1. Methodology Flowchart showing steps followed in this work to calculate textural attributes.

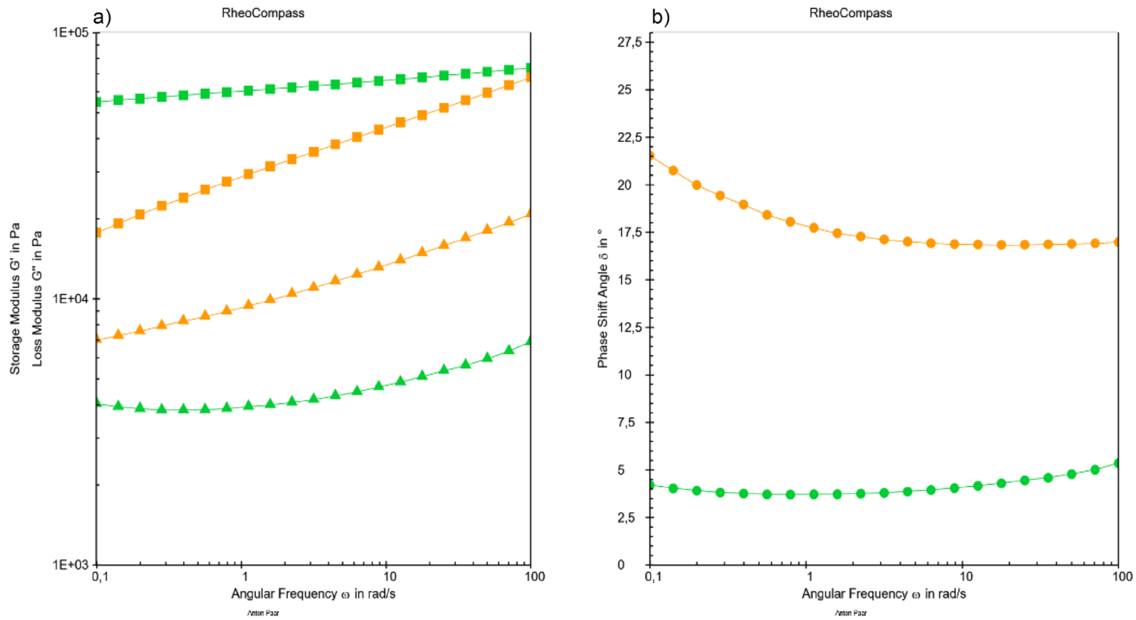


FIGURE 2. Mechanical spectra for the dairy Gouda (orange curves) and plant-based alternative cheese A (green curves) at 25°C. a) The storage modulus, G′(ω), (square) and loss modulus, G″(ω), (triangle); b) phase shift angle, δ(ω).

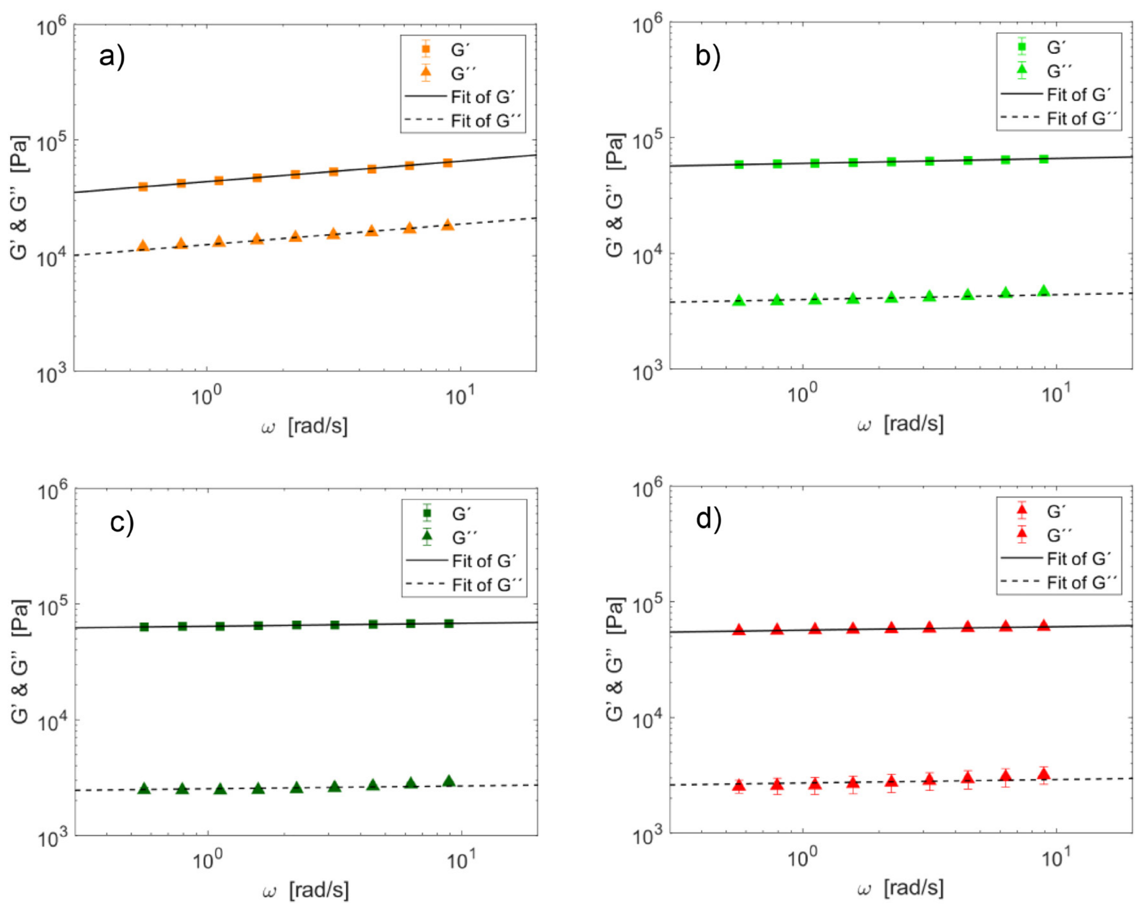


FIGURE 3. Fitting of the averaged measured dynamic moduli, G′ and G″ (symbols) to the Scott Blair model (solid and dotted black lines) to determine the quasi-property, $\mathbb{V}$ and the fractional exponent, β for the dairy Gouda (a) and plant-based alternative cheeses (b-d) at 25°C.

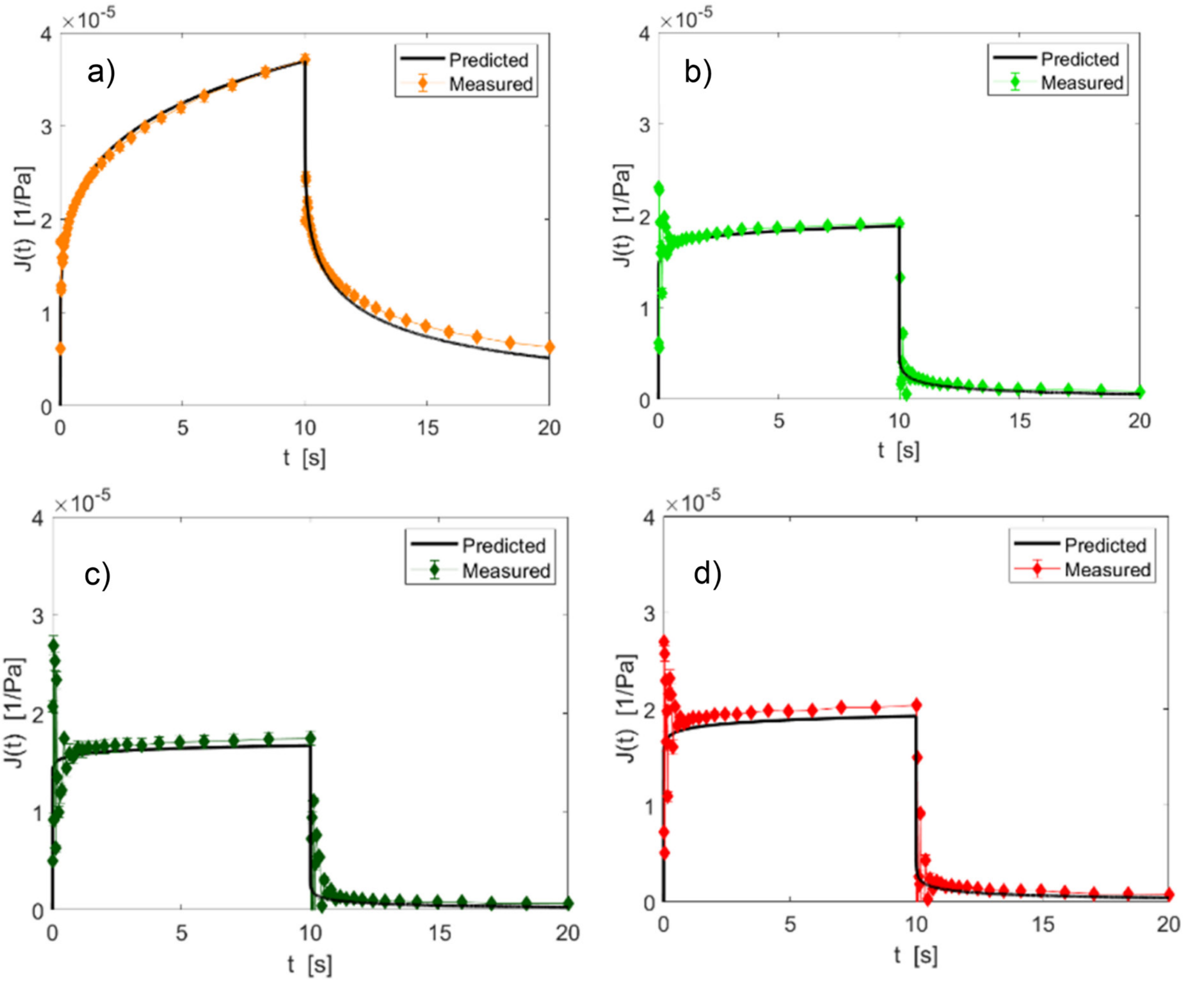


FIGURE 4. Comparison of the experimental data (symbols) and predicted linear viscoelastic compliance J(t) (solid black line) for dairy (a) and plant-based alternative cheeses (b-d) at 25 °C. For the predictions the values of the constitutive parameters from Table 1 have been used.

The manufacturing process of plant-based cheeses comprises mixing the ingredients at high temperatures (80 °C), during which starch gelatinization and melting of fat occur. The subsequent cooling step induces the desired sol-gel transition and the formation of the final gel, mainly with the starch cross-linking and the crystallization of the fat [12]. Therefore, the significant difference in the viscoelastic behavior reveals the impact of the nature and properties of the main component of the tri-dimensional network, that is, protein (casein) vs. the polysaccharide (starch and hydrocolloids) network. Casein networks give rise to a weaker and less interconnected (higher mobility) gel while the polysaccharide networks generally show stronger interactions. Details on the composition and additional knowledge of the processing conditions is necessary to provide further understanding on the structure-function relationship to explain the observed differences among the plant-based cheese.

Fig. 3 shows the fitting results of the storage modulus G'(ω) and the loss modulus G''(ω) to the Scott Blair fractional model for each cheese. The corresponding numerical values of the quasi-property V and the fractional exponent β are reported in Table 3.

The graphical comparison between the creep/recovery experimental data and the corresponding predicted values of the linear viscoelastic compliance J(t) is presented in Fig. 4.

The step-like shape of the compliance curves with very narrow viscoelastic region and delayed recovery in both the creep and recovery of all the plant-based alternative cheeses confirms their highly elastic behavior as shown by the results of the frequency sweeps. Compared to the dairy cheese, the plant-based products also reveal a very high degree of recovery in the same time.

Clearly, very good agreement between the experimental data and the corresponding predictions is achieved. These results show that a minimal number of constitutive parameters (only two) are needed to predict the linear viscoelastic properties of all the investigated plant-based cheeses despite their differences in the composition.

Table 3 reports the calculated values of the three texture attributes of the investigated cheeses. The values of firmness, springiness and rubberiness for the dairy Gouda are consistent with the values already reported on the same variety of cheese [6]. Among the plant-based alternative cheeses no differences in any of the three texture attributes are noticeable. Compared to the dairy Gouda, the plant-based alternative cheeses are in general significantly firmer (almost three-fold)

TABLE 3. Numerical values of the Quasi-property $\mathbb{V}$ and fractional exponent β, obtained from the fitting of the SAOS measurements (Fig. 1) and calculated textural attributes for the investigated cheeses.

Cheese	Quasi-property, $\mathbb{V}/10^4$ [Pa s^β]	Fractional exponent, β [–]	Fitting error, ε [%]	Firmness, $F/10^4$ [Pa]	Springiness, $S/10^{-4}$ [1/Pa s]	Rubberiness R [–]
Dairy Gouda	4.52	0.18	1.34	2.78	1.58	0.87
Plant-based alternative cheese A	5.97	0.04	1.22	5.29	1.55	0.97
Plant-based alternative cheese B	6.42	0.02	1.44	5.98	1.49	0.98
Plant-based alternative cheese C	5.66	0.03	2.24	5.19	1.67	0.98

and slightly rubberier while equally springy. The latter result has been confirmed also in the Texture Profile Analysis [3].

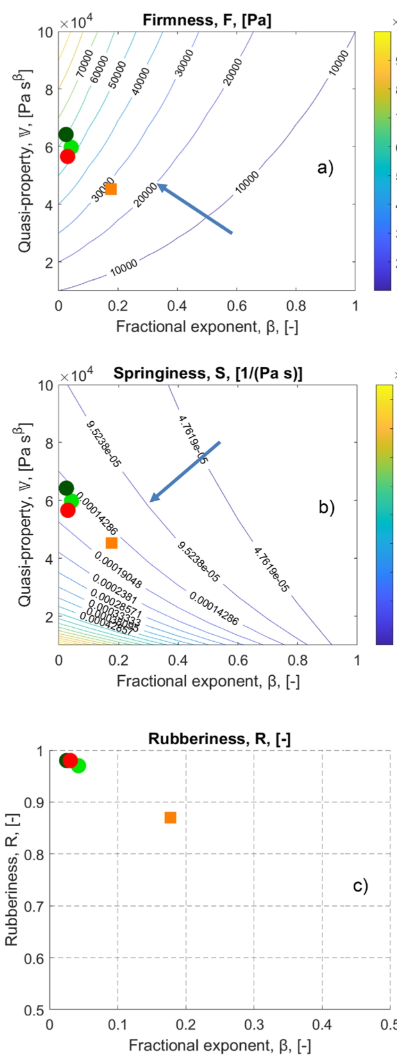


FIGURE 5. Contour plots of firmness (a), springiness (b) and 2D plot of rubberiness (c). The values of the textural attributes for the cheeses (markers) are calculated at $t_f = \Delta t_r = 10$ s and $\Delta t_s = 0.1$ s.

Fig. 5 shows the contour plots built for each of the three textural attributes using the FSR fractional equations reported in Table 1. The curves in the contour plots (Fig. 5a-b) represent the same magnitude of firmness and springiness, while the contour plot of rubberiness, R reduces to a two-dimensional plot due its dependence on only one constitutive parameter (Fig. 5c). The locus of each cheese on the plots is defined by its precise set of values for {$\mathbb{V}$, β}.

Following these charts, we can identify the changes to make to the formulations and the processing conditions to mimic textural properties of the benchmark product.

5. Conclusions

The Scott Blair fractional rheological model has been used to model the linear viscoelastic properties of commercially available plant-based alternative cheeses and quantify their textural attributes in terms of firmness, rubberiness and springiness.

The model accurately describes the rheological behavior of all the investigated cheese despite the complexity of their formulation. Comparison of the rheological properties to the reference dairy cheese chosen as benchmark reveal a stronger and more interconnected three-dimensional network, which ultimately determines the texture of the product. At the testing conditions, compared to dairy, the plant-based alternative cheeses exhibit higher values of both firmness and rubberiness. All cheeses are similarly springy.

Mapping texture using contour plots can potentially enable us to improve and forward the design thinking and development of new products in identifying and incorporating plant-based proteins in formulation and optimizing processing conditions able to meet the desired textures and functionalities as a healthier and sustainable alternative to what is currently available on the market.

We are in exciting times as the market for plant-based foods is skyrocketing. The world needs more healthful, sustainable food products. We believe this type of work will lead food ingredient and consumer products manufacturers to a more rational design of alternative cheeses based on fundamental understanding, and application of, these types of rheological models.

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Biographies

Dr. Francesca De Vito is currently a consultant for Ingredion Inc. in the Food Texture Science Platform. Before her recent role, she worked as an application specialist in rheology for Thermo Fisher Scientific Inc. and a postdoc research associate at the Department of Food Science and Human Nutrition of the University of Illinois at Urbana-Champaign. She earned her Ph.D. in chemical engineering from the Department of Chemical and Food Engineering of the University of Salerno in Italy. Her areas of interest and expertise include food materials science, rheology, phase behavior, pulsed electric field, and powder technology.

Dr. Julie B Hirsch has over 20 years leading global discovery technology and product development teams in food, food ingredients, and personal care for large multinational companies, consultancies, and start-ups. She has a passion for creating technology/product strategies and roadmaps, and translating science, especially rheological concepts, to consumer-relevant product features and benefits. She earned a BS in Food Science from Cornell University (NY USA), and PhD in Food Science/Engineering from Rutgers (NJ USA).

Senghane Dominique Dieng is a Senior Chemist in the Analytical Science & Measurement Group at Ingredion, Inc. He thrives in researching and developing new analytical methods to understand structure and function. He is currently focused on plant based protein characterization. This was his first project in rheology and he performed all the meticulous measurements needed for this work. He earned an MS in Analytical Chemistry from Montclair State University (NJ) and BS in Chemistry from Fairleigh Dickenson University (NJ USA).

In Memoriam

James W. Swan (1982-2021)
By Eric Furst

James W. Swan passed away suddenly and unexpectedly November 5, 2021. He was 39. As a member of our rheology community, he had already made brilliant and foundational contributions to the fields of soft matter, colloid science, fluid mechanics, and computational modeling, with an increasing interest in societally relevant end-use applications of complex fluids. We recognized Jim for his extraordinary intellect. His original contributions to our field are notable for their breadth; his scholarship delved into topics related to the stability of biopharmaceutical formulations, the rheology of colloidal suspensions, new techniques for material characterization, nanoparticle self-assembly, colloid uptake in living plants, and electrokinetics. Little seemed to escape his curiosity and his remarkable talent for elucidation.

One advance Jim made stands out as particularly important: his development and application of fast Stokesian dynamics simulations. His novel computational method addressed a long-standing and critical need in the field to efficiently incorporate hydrodynamic interactions into large-scale simulations of colloidal suspensions, polymers, proteins, and other complex fluids. Jim developed a new algorithm that scales linearly with system size to calculate Brownian motion in hydrodynamically-interacting systems using an Ewald summation of the Rotne-Prager-Yamakawa (RPY) tensor. In practical terms, the method was faster and less computationally expensive than state-of-the art iterative schemes that preceded it, and it avoided the shortcomings of other implicit solvent approaches in the overdamped regime of Stokes flow that governs the dynamics and rheology of soft materials. However, the work stood out for its sheer intellectual achievement that demonstrated Jim's gift for penetrating the core physics of a problem and his tremendous skills synthesizing rigorous and useful solutions. The results of the work, published as "Rapid sampling of stochastic displacements in Brownian dynamics simulations," J. Chem. Phys. 146, 2017, is a beautiful expression of his insights and a masterful piece of scholarship.

Jim applied his simulations and theories to gain insight into the microscopic dynamics and mechanics that accompany colloidal glass and gel transitions, which are important in a fundamental sense and relevant to a wide range of industrial applications, spanning from coatings to the stability and shelf-life of consumer products. Jim and his students showed how much is missed when hydrodynamics are neglected: gel lines and percolation boundaries shift when the collective motion induced by hydrodynamics is accounted for (Soft Matter, 11, 2015; Soft Matter, 12, 2016), hydrodynamics fundamentally alter the normal modes of gels (Physical Review E, 97, 012608, 2018), and large scale anisotropies in sheared colloidal gels, of long-standing interest and a subject of intense debate, are properly understood (Journal of Rheology, 62, 405-418, 2018). Among my favorite papers from Jim's group in this area is his work on the catastrophic collapse of quiescent colloidal gels—a problem that has long fascinated academic scientists and frustrated industrial practitioners of particle technology (Z. Varga, J. L. Hofmann, J. W. Swan, J. Fluid Mech. 856, 2018). Here, simulations play the role of validating an elegant first-principles theory of streamer formation and erosion that also capture the key observations of published gel collapse experiments. The paper concludes with scaling predictions for the "blow up" time of a gel—when and how it will consolidate. This result is the first truly predictive theory of gel collapse. It is a comprehensive work of scholarship that develops theory, computation, and explains a puzzling phenomenon.

A native of Scottsdale, Arizona, Jim received his bachelor's degree in chemical engineering from the University of Arizona in 2004. He then went to Caltech, where he earned a master's degree in 2007 and a PhD in 2010, both in chemical engineering, under the mentorship of John Brady. After finishing his doctorate, Jim worked with me at the University of Delaware, where he directed our investigations of colloidal self-assembly on the International Space Station and helped to build and analyze new optical trapping experiments. He joined the chemical engineering faculty at MIT in 2012 as an assistant professor and had recently been promoted to the rank of associate professor. He was awarded tenure in July 2021.

At MIT, Jim was living his dream as a scholar-educator. He was beloved by students for his teaching. He taught Introduction to Chemical Engineering for several years to second term, first-year undergraduates; he was also the instructor for the department's core required graduate course in numerical methods. For three years in a row, Jim won the MIT Chemical Engineering Graduate Teaching Award, an honor conferred by students. Training students was one of Jim's greatest joys. He was keen to spend hours working out ideas on the whiteboard with his advisees, but Jim also carved out time to talk about non-technical sides of life and work with them, too.

Outside of his research and teaching, Jim was a loving husband and father who enjoyed spending time and activities with his wife of 17 years, Laura Swan, and their son Henry. Jim would cook, fish, and spend time outdoors, as well as do science experiments with Henry. The activities that sparked Jim's interest over the years included quilting, photography, home-brewing, and self-publishing "The Really Big SCRABBLE Word List." He often sought to master a topic that captivated him, as evidenced by the third-degree black belt that he held in karate. Jim was also an active member of his Arlington, Massachusetts community. Their neighbors remember him for his thoughtful voice and as an articulate and supportive member of the Arlington and Hardy Elementary School communities. Jim was a patient listener and facilitator who believed in the transformative power and importance of civil discourse.

In addition to Laura and Henry, Jim is survived by his parents, Gregory Swan and Jeanine Blanchard; his stepmother, Paulette Swan; his stepfather, Tim Blanchard; a sister, Heather Evanoff; parents-in-law, Thomas and Betsy McPhee; sisters-in-law Diana McPhee and Lisa Grinnell; brother-in-law Andrew McPhee; and many aunts, uncles, and cousins.

Jim was regarded for his scholarship and intellectual contributions to our field, but he was also known as a wonderful speaker, teacher, and mentor, and especially for his generous spirit and kindness. He was quick to smile, to laugh, and to share his delight in creative ideas and projects. He was humble about his many talents. Jim was poised to become one of the great rheologists, chemical engineers, and scientists of his generation. He is sorely missed.

Secretary's Report

By Kal Migler

The Secretary's Report, moving forward, will consist of the motions adopted in the prior year by the Executive Committee and by the Society at the Business meeting. It will exclude pro forma motions, such as accepting minutes of previous meetings.

Motion to approve Dimitris Vlassopoulos as the next JOR Editor by the Executive Committee via email on 9/21/2021. Motion passes.

Business meeting, Fall 2021

Motion to approve budget passes by voice and online vote.

Executive Committee Meeting, FALL 2021

Motion to change date of Fall 2022 meeting to Oct. 9-13, 2022. This avoids a conflict with Yom Kippur. Same rates with a few concessions/amenities and similar meeting space. Motion passes.

Motion to hold Rheology Research Symposium (RRS) at Chicago meeting with SOR funding the full amount. Friendly amendment: take $30k from the $33k SOR venture fund to support this effort, and add it to the $30k of existing travel support, for a total support of $60k to the RRS. Use $3k from the SOR venture fund to support the obligation to the student trivia night. Motion passes.

Motion to provide funds to support harassment training. Live webinar: The Impact of a Bystander. Can invite up to 30 people and training is recorded. Adopt harassment training, (topic 1), aimed at the Executive Committee, people running society meetings, and SOR committee chairs: $7,500. Motion passes.

Executive Committee Meeting Spring 2022

Motion: For 2022, mail the printed Bulletin to all SOR members, and then for future issues, work with AIPP to have members opt-in to receive a printed bulletin. Motion passes.

Motion to give flexibility to meeting organizers to set the talk duration to either 20 or 25 minutes. Motion passes.

Motion to approve Kendra Erk and Safa Jamali as the Austin 2024 Technical Program Coordinators. Motion passes.

Motion to add specific text to the Bingham medal nominations webpage that reflects Society values of diversity, equity and inclusion. Motion passes.

Motion to provide $1k to fund community outreach event at Chicago '22 meeting. Motion passes.

Motion to provide $8k to fund Student Trivia Night in 2022 ($3375 above original budget) at Chicago '22 meeting. Motion passes.

Motion: For a period of three years, provide a one-year gratis membership to the Society of Rheology for authors who have recently published in JOR and who have never been members of SOR. Such gratis members do not have the option to receive the JOR print version. Motion passes.

Motion to approve Boston as the host city for the Annual Meeting of the SOR in 2026. Motion passes.

Motion to rename the student poster award of the annual meeting as the Jim Swan Memorial Poster Award. Motion passes.

Treasurer's Report

By Chris White

The Society of Rheology is currently in good financial condition. There are concerns going forward, but these have been mitigated in the short term. For the year 2021 the SOR ran a surplus of $192K. This increase in net revenue over 2020 is due to a successful Maine Meeting (Net $11K), the continued decrease in the cost of producing the journal, and revenue from the Journal of Rheology.

In 2022, the SOR will host its 93rd Annual Meeting in Chicago. An ongoing concern is building a consensus about the financial direction of the SOR/JOR. This will require significant discussion about the financial goals of the Society of Rheology and how they support the mission of the Society of Rheology more broadly. The Treasurer will assume that the goal is to run a cost neutral annual budget while anticipating and insuring against potential financial shocks to the Society of Rheology. Budget highlights for 2022 (approved in Bangor, see Table 2) include increased funding for the student travel grants, to $35K, funding of the rheology venture fund, $30K and funding for the diversity, equity, and inclusion effort, $7.5K. The proposed budget for 2023 is also included in Table 2.

This report will detail the major activities of the Society of Rheology and how they are accounted for in the American Institute of Physics (AIP), the American Institute of Physics Publishing (AIPP), the Schwab account, and QuickBooks online account. There are a number of highlights. Each section of this report is built around a major activity for the SOR. **Below is a simplified summary of the major accounts and totals for 2021. A detailed accounting is presented following this summary.**

SOR has significant financial reserves, a strong brand, and a dedicated membership base. The accompanying charts document expenditures and revenues for the specific time periods in the Society's history. The dues revenue was in-line with previous years. The Venture Fund is listed above, and it is not counted as revenue, but as an asset. The net revenue for SOR in 2021 is predominately due to the subsidy created by the combination of constant revenue and the decreased production cost for the Journal of Rheology along with several one-time decrease in expenses.

We are a society with appreciable financial reserves that require more extensive oversight and management. The Executive Committee has recognized this transition and taken three definitive steps: the establishment of a regular formal audit, financial advisement committees, and an AIPP partnership for publishing the JOR.

The society greatly appreciates the contributions from the three members of the Audit Committee: **Rekha Rao (Chair), Brian Edwards and Anthony Kotula**. The Audit Committee has already met, examined the books, reported to the Executive Committee and delivered recommendations on the accounting practices for the Society at the 2021 Annual Meeting. These recommendations have been implemented.

The society also appreciates the contributions from the three members of the Financial Advisement Committee: **Lisa Biswal (Chair), Wesley Burghardt, and Phil Sullivan**. This committee is charged with developing specific recommendations for investments based on the directions given to it by the Executive Committee. This committee presented a report at the spring Executive Committee meeting.

The third major change started in 2019 and continuing into 2021, was the five-year partnership with the American Institute of Physics Publishing (AIPP) for the Journal of Rheology. While this arrangement has several implications, here we will address the impact on the treasury. The partnership will guarantee revenue of $100K/yr. to the Society of Rheology. Any net revenue greater than the $100K minus the expenses, will be split with AIPP in a 50-50 arrangement.

TABLE 1.

Society of Rheology
January- December 2021

Revenue		Expenses	
Bangor Meeting	$11,548	AIP expenses	$35,417
Dues	$55,166[2]	Awards	$23,062
Journal of Rheology	$239,613	Journal of Rheology	$47,563
Venture Fund	$27,000	ExCom	$1,603
Interest Income	$101	Student Travel	$20,532
Total Revenue	**$296,743**	**Total Expenditures**	$124,144
		Net Revenue[1]	**$192,795**

[1]NR is accurate, not all accounts are represented
[2]The dues figure includes revenue from multi-year memberships

Journal of Rheology

Prior to 2004, SOR subsidized the publication of the JOR. In Figure 1, from 1998-2004 the net revenue from the JOR was *de minimis*. Figure 3 and Figure 4 shows the significant expenses relative to revenue for producing and distributing the Journal were the underlying cause. In

TABLE 2. Revenue and Expenses for the past five years for Society of Rheology.[3]

The Society of Rheology Receipts and Disbursements	**2023 Budget (proposed)**	**2022 Budget**	**2021**	**2020**	**2019**	**2018**	**2017**
RECEIPTS							
Dues	$ 55,000	$ 55,000	$ 55,166	$ 55,154	$ 50,890	$ 57,135	$ 63,935
Interest	$ 10,000	$ 10,000	$ 101	$ 11,688	$ 28,493	$ 19,089	$ 6,817
Venture fund(asset)	$ -						
Journal of Rheology	$ 239,631	$ 239,631	$ 239,631	$ 239,813	$ 275,613	$ 308,773	$ 321,436
Donations	$ -			$ 1.51		$ 2,500	
Bulletin Advertising	$ -				$ 10,000	$ 9,265	$ 10,855
Annual Meeting (net)	$ (10,000)	$ (85,000)	$ 11,548	$ (12,566)	$ (33,001)	$ (13,725)	$ 38,975
Short Course (net)	$ -		$ -	$ -	$ 10,371	$ 10,500	$ 10,575
TOTAL RECEIPTS	**$ 294,631**	**$219,631**	**$ 306,446**	**$ 294,090**	**$ 342,366**	**$393,537**	**$452,593**
DISBURSEMENTS							
AIP Dues Bill & Collect.	$ 36,000	$ 36,000	$ 35,417	$ 34,940	$ 39,769	$ 39,769	$ 28,561
Contributions and Prizes	$ 25,000	$ 25,000	$ 23,062	$ 22,742	$ 25,996	$ 1,650	$ 1,650
Journal of Rheology	$ 50,000	$ 50,000	$ 47,563	$ 43,407	$ 49,308	$ 208,742	$ 219,043
Bulletin	$ 10,000			$ 9,799.70	$ 18,920	$ 17,036	$ 17,036
Executive Cmt. Meetings	$ 10,000	$ 10,000	$ 1,605		$ 9,318	$ 11,493	$ 18,163
Pres. Discretionary Fund	$ 5,000	$ 5,000	$ -				$ 462
Treas. Discr. Fund	$ 3,000	$ 3,000	$ -	$ 755		$ 125	$ 479
Bulletin Editor support	$ 4,000	$ 4,000	$ -				
Progr. Chm. Discr. Fund	$ 5,000	$ 5,000	$ -			$ -	
Webmaster Discr. Fund	$ 5,000	$ -		$ 2,702		$ 1,368	$ 3,025
International Activities Fund	$ 3,000	$ 3,000	$ -			$ 3,065	$ 2,963
Liability Insurance	$ 8,000	$ 8,000		$ 7,189		$ 5,928	$ 5,928
Accountant	$ 3,000	$ 3,000				$ 2,720	$ 2,580
History Project	$ 3,000	$ 3,000					
Legal Fees	$ 10,000	$ -		$ 17,581			
Student member travel	$ 45,000	$ 33,000	$ 20,532	$ 1,000	$ 16,200	$ 22,000	$ 31,767
RRS		$ 30,000					
RVF	$ 30,000						
DEI		$ 7,500					
Annual meetings, future	$ -	$ -	$ (10,000)			$ 9,200	$ 3,000
Website	$ 1,000	$ 1,000		$ 566		$ 497	$ 99
Targeted Investments	$ -	$ -					
Miscellaneous	$ -			$ 29,906	$ 22,135	$ 3,845	$ 21,930
TOTAL DISBURSEMENTS	**$ 256,000**	**$ 226,500**	**$ 118,179**	**$ 170,587**	**$ 181,646**	**$ 327,438**	**$ 356,686**
Net	**$ 38,631**	**$ (6,869)**	**$ 192,795**	**$ 123,503**	**$ 160,720**	**$ 66,099**	**$ 95,907**

[3]The $10k of "income" in the 2021 entry "Annual meeting, future", is a result of the Art Institute in Chicago cancelling the planned Monday event reception and returning the deposit to SOR.

1992 the publication of JOR was moved to AIPP from a commercial publisher. This resulted in decreasing costs to produce JOR. With stable revenue and decreased cost, a net positive revenue stream was generated and transferred to SOR. From 2005-2018, the JOR has had positive revenue that varied from ~$50K/yr. to ~$100K/yr. There were two years, 2011 and 2012, with one-time revenue jumps (due to one-time copyright payments), but the underlying finances of JOR remained stable within this range. Starting in 2013, the net revenue from JOR began to decrease (declining subscription revenue, increased production costs) with 2014-2016 consistently closer to $50K than $100K. Beginning in 2017, the SOR began a deeper publishing partnership with AIPP, resulting in increased revenue through consortium marketing and decreased cost of producing JOR resulting in increased JOR net revenue. As this data suggests, JOR is not a fixed, nor a guaranteed, source of revenue over time (in the short term, there is a guarantee for the next three years). There are several unresolved threats to this economic model. The largest of these is Gold Open Access. Open Access policies at the national and international levels may result in libraries no longer willing to pay for a full or even partial subscription to a hybrid journal such as JOR. As our history demonstrates, even small changes in the revenue, library subscriptions, or cost of production of JOR will significantly affect the net annual revenue.

Society of Rheology

As shown in Figure 3, the revenue for the SOR outside of the journal is mainly

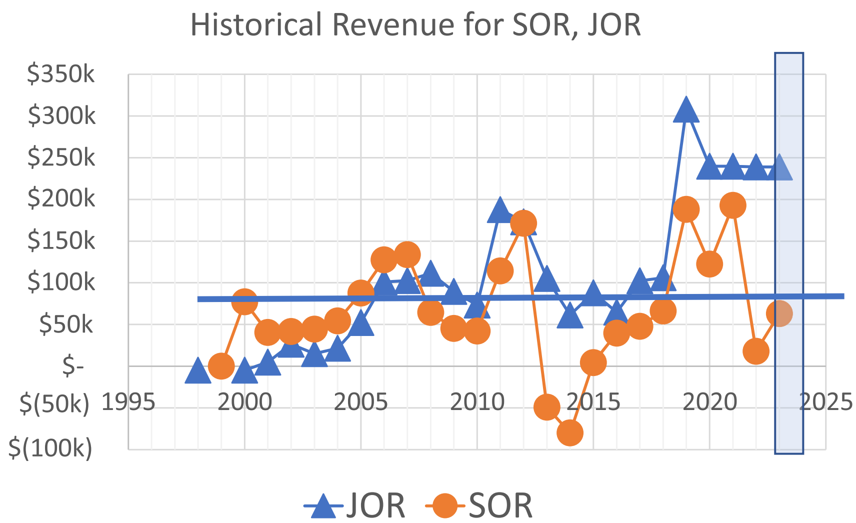


FIGURE 1. The annual net revenue from the Society of Rheology and the Journal of Rheology.

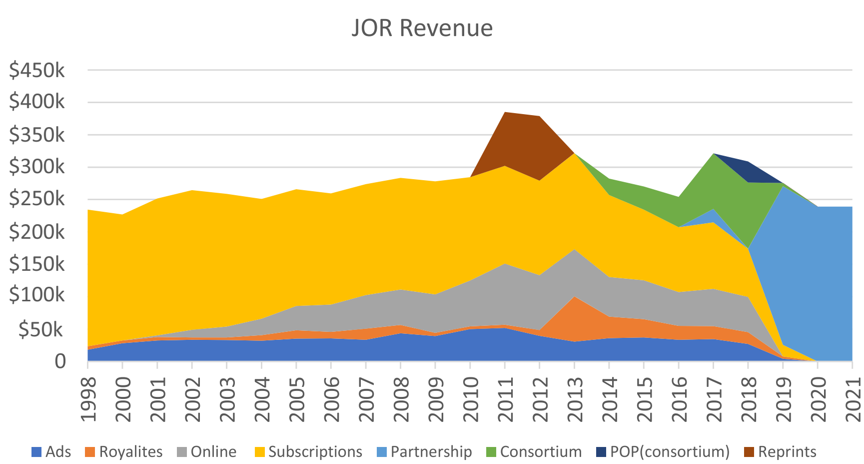


FIGURE 2. Journal of Rheology revenue from 1998-2021.

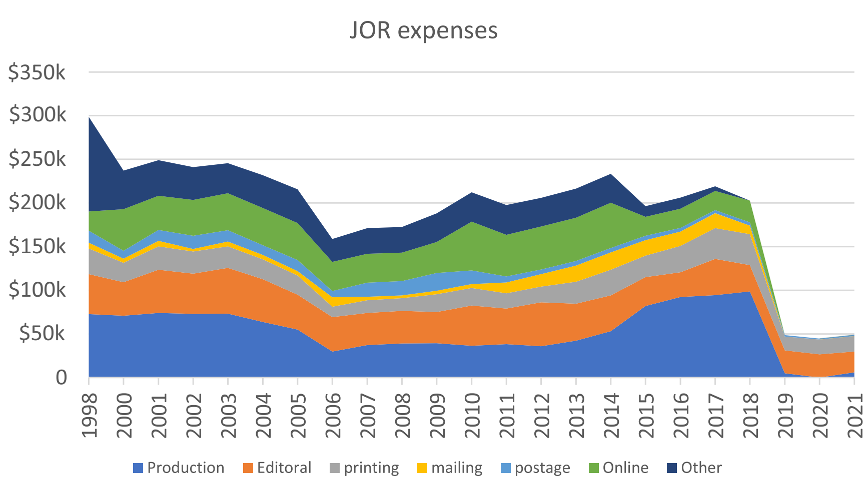


FIGURE 3. Journal of Rheology expenses from 1998-2021.

from two sources: membership dues and interest on reserves. The dues revenue has remained flat or decreased from 1998-2016. A modest dues increase was proposed and approved in 2016, resulting in an annual increase in revenue from ~$60K to ~$80K. The interest on the reserves, a feature of the revenue from 1998-2007 was basically eliminated as a source of revenue until a modest return in 2018. In 2021, this revenue collapsed temporarily due to a sudden drop in interest rates.

The expenses associated with running SOR have shown an unrelenting five-fold increase from 1998-2021. The average increase in expenses is over $7K/yr. over this period. After 2007, the SOR has effectively depended on an annual subsidy from JOR because the SOR annual expenses exceed the SOR annual revenue. It is reasonable to assume that the expenses associated with SOR operations will continue to increase with no offsetting increase in revenue. Besides these historically increasing annual operating expenses, there are several significant, anticipated increases in expenses expected soon.

Society Meetings

The meetings we have grown accustomed to attending are not feasible at locations such as Chicago, Austin, and even Santa Fe without some financial subsidy or a significant increase in registration fees. Estimates for this subsidy have exceeded $100K/meeting. SOR takes on significant liability in hosting these meetings. SOR narrowly avoided paying out on the liability of a $300K contractual obligation in order to cancel the planned February 2021 Austin meeting. Typically, SOR has four or five such contracts for future meeting spaces at any given time. This total exceeds $1M in contracted liability for future meetings. While the probability of losing this substantial outlay due to unforeseen circumstances is small, 2020 has demonstrated that it is a possible outcome. This potential liability is covered only by our reserves.

Professional Services

SOR is the smallest of the AIP societies. We are the only AIP Member Society that has no professional staff. Everything SOR does is based on the efforts of volunteers. THANK YOU! Increasingly, as these responsibilities grow, these volunteer efforts are being replaced with

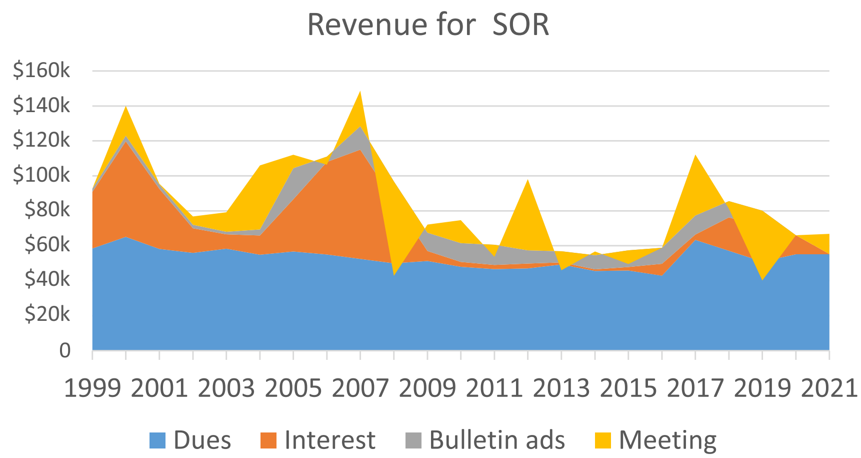


FIGURE 4. Revenue from SOR without the Journal of Rheology from 1999-2021.

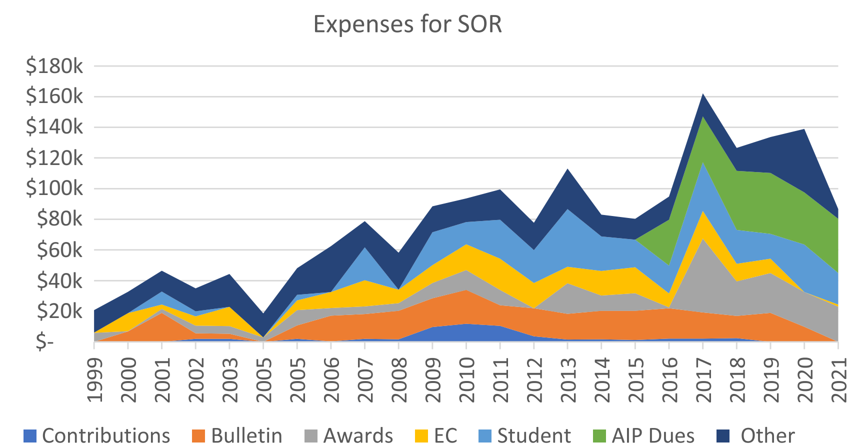


FIGURE 5. Operating expenses for SOR (without JOR) from 1999-2021, there has been a five-fold increase in expenses over this period.

TABLE 3. Sources of Revenue for Journal of Rheology. Notice the shift in revenue sources in 2019–2021.

Journal of Rheology	***2021***	***2020***	**2019**	***2018***	**2017**
Advertising Sales			$ 4,313	$ 27,085	33,000
Royalties			$ 3,709	$ 18,285	22,000
Single-Copy Sales			$ 2,863		
Consortium Access Fees			$ 5,000	$ 54,432	53,169
Consortium Subscription			$ 94,025	86,663	
Subscriptions			$ 17,591	$ 112,083	100,340
AIPP Guarantee	$ 100,000	$ 100,000	$ 100,000		
AIPP Profit sharing	$ 139,613	$ 139,813	$ 145,000		
Total Revenue	**$ 239,613**	**$ 239,813**	**$ 275,613**	**$ 308,773**	**$295,172**

subsidized positions. For example, the successful operation of JOR requires two subsidized Editors, the bulletin editor has transitioned to a subsidized Communications Coordinator. Albert has done a great job with our website for many years. Eventually, the demands on the website will outstrip even Albert's ability to meet our collective expectations. Effective and professional websites require significant investment, which would increase the Society's annual expenses. Even the sharing or hiring of a single paid full-time staff for SOR could wipe out any projected annual net surplus. There are always significant unanticipated expenses, for example, in 2020 there was an unanticipated $18K in legal fees to ensure compliance with data privacy laws in Europe. The liability and requirements for legal counsel continue with funds expended in 2022.

Reserves

Where did the SOR financial reserves come from? The reserves shown in the balance sheet are a result of planned net revenue from the SOR for the period 1929-2004 and then net revenue from JOR for the period 2005-2021. By 1997, SOR had accumulated $777K in reserves by generating revenue streams (primarily dues) greater than expenses. The reserves, as currently envisioned, anticipate a one-year shock to the system with a return to previous conditions. For example, having to pay $300K to cancel a single meeting (such as we nearly had to do in 2001 in Bethesda or the 2021 Austin meeting) completely depletes the funds in the meeting reserve. This model does not anticipate long-term changes in the revenue and expense model for JOR. Our history has shown that the current profitability of JOR is not fixed. Our performance also shows that the expenses associated with running SOR will continue to increase and therefore rely more and more on the uncertain subsidy provided by JOR.

Our reserves allow time for future Executive Committees to respond to these one-time or systemic changes. The reserves provide future executive committees the opportunity and flexibility to consider new innovative initiatives or just to keep the Society running in times of crisis. Because of our reserves, we were able to pay the deposits for the future Bangor and Chicago meetings and support student participation in the ICR while faced with the possibility of a large penalty for breaking contracts for Austin, instead of having to make tough choices due to a limited budget.

The reserves also offer the opportunity to buffer the uncertainty associated with the subsidy required by JOR revenue to keep SOR running. Establishing interest revenue and using a portion of that interest income to fund SOR operations is a path that has been used in the

TABLE 4. Journal of Rheology expenses and net revenue. The years 2019-2021 show significant decrease in the expenses associated with producing the journal.

	2021	2020	2019	2018	2017
Revenue	**$239,613**	**$239,813**	**$ 275,613**	**$ 308,773**	**$295,172**
Fixed cost			$ 31,854	$ 126,818	$122,492
Print			$ 17,454	$ 49,071	$64,000
Online			$ 24,772	$22,250	
Total Expenses	**$ 47,563**	**$ 44,707**	**$ 49,308**	**$ 200,661**	**$208,742**
NET	**$192,068**	**$195,106**	**$ 226,305**	**$ 108,112**	**$86,430**

past (pre-2007). To increase the return on investment requires exposure to downside risk on our principal. The finance committee is charged with making recommendations to the executive committee around this balance between risk to principal and return on investment. The reserves function like that of an endowment for SOR operations to offset future expenses and financial shocks.

How large a reserve should SOR maintain? As our past has shown, the current net revenue from JOR is not assured, yet the expenses of running SOR continue to increase. As the revenue from SOR remains flat, any financial shocks or increased future operating expenses must be paid from these reserves. There are significant future expenses that will require funds. In this uncertain future, the current temporary surplus from JOR should be considered a safeguard against future unexpected expenses and liability exposure. The presence of the reserves allow SOR and the Executive Committee to focus on our mission, to expand the knowledge and practice of **rheology** through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what **rheology** is, and how it impacts humanity and the world.

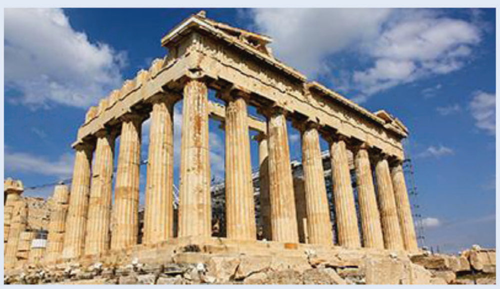
TABLE 5. Balance sheet for SOR from 2017-2021

The Society of Rheology, Inc. Balance Sheet	**2021**	**2020**	**2019**	**2018**	**2017**
Assets					
Cash in checking account(s)	$ 142,871	$ 47,741	$ 46,727	$ 27,774	$ 7,096.35
Balance in AIP account	$ 608,866	$ 449,440	$ 354,665	$ 862,081	$ 850,906
Schwab (Reserve1)	$ 945,384	$ 947,471	$ 942,513	$ 1,018,793	$ 1,003,872
Schwab (Reserve2)	$ 608,866	$ 608,604	$ 602,731		
Accounts Receivable	$ 1,654	$ 88,151	$ 129,885	$ 1,197	
Prepaid Expense	$ -	$ (8,500)	$ 36	$ 36	$ 36.00
Total Assets	**$ 2,307,641**	**$ 2,132,907**	**$ 2,076,557**	**$ 1,909,880**	**$ 1,861,911**
Liabilities and Net Assets					
Liabilities					
Deferred revenue	$ 13,166	$ 32,245	$ 126,398	$ 122,190	$ 140,325
Venture Capital Fund	$ 26,900	$ 27,000			
Total Liabilities	$ 40,066	$ 59,245	$ 126,398	$ 122,190	$ 140,325
Net Assets					
Publication reserve	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000
Student travel grant reserve	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
Annual Meeting reserve	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
Operating reserve	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000
Unrestricted	$ 1,143,662	$ 1,020,159	$ 859,439	$ 791,586	$ 743,857
Net Revenue	$ 193,913	$ 123,503	$ 160,720	$ 66,105	$ 47,729
Total Net Assets	$ 2,267,575	$ 2,073,662	$ 1,950,159	$ 1,787,690	$ 1,721,586
Total liabilities and net assets	**$ 2,307,641**	**$ 2,132,907**	**$ 2,076,557**	**$ 1,909,880**	**$ 1,861,910**

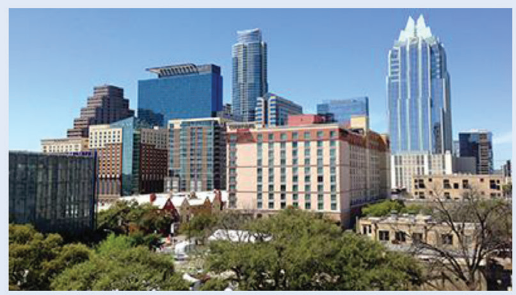
Future Meetings & Workshops

8th Pacific Rim Conference on Rheology
May 15 – 19, 2023
Vancouver, Canada

Workshop on Ring Polymers
June 14-16, 2023
Monash U. Prato Centre
Prato, Italy

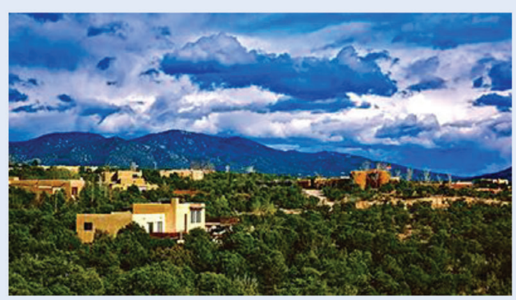


19th International Congress on Rheology
July 29 - August 4, 2023
Athens, Greece



95th SoR Annual Meeting
October 2024
Austin, Texas

Annual European Rheology Conference (AERC)
Spring, 2024
Leeds, UK



96th SoR Annual Meeting
October 19-23, 2025
Santa Fe, New Mexico

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