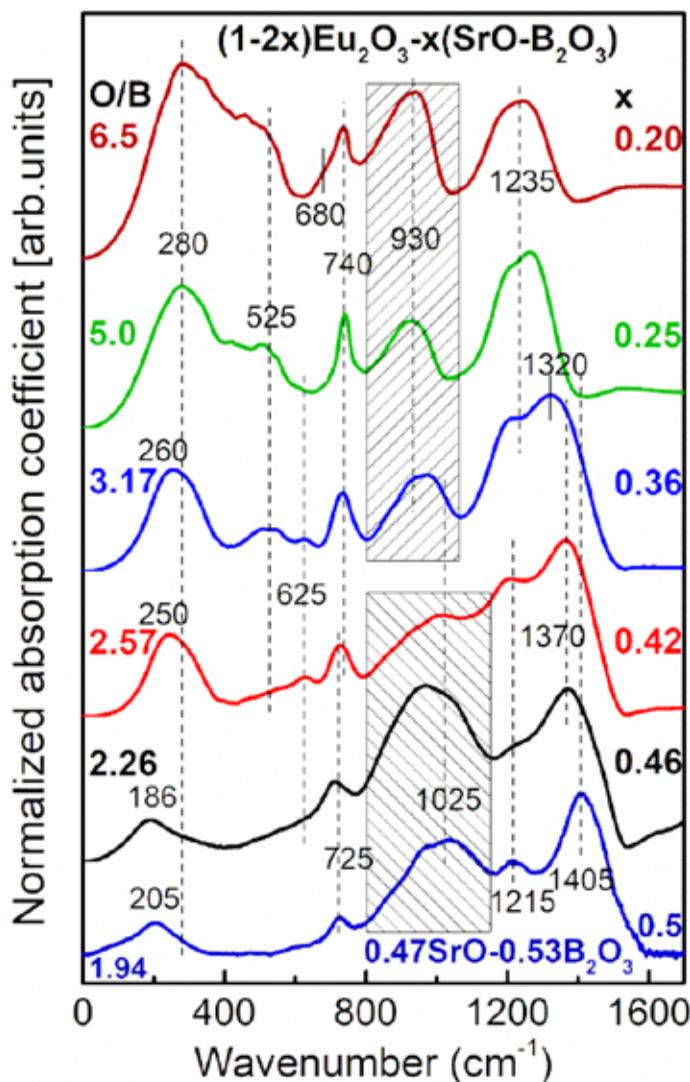


# PHYSICS AND CHEMISTRY OF GLASSES

*European Journal of Glass Science and Technology Part B*





# Physics and Chemistry of Glasses

## European Journal of Glass Science and Technology B

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9 Churchill Way  
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# Efstratios Kamitsos: Honoree of the Tenth Conference on Borate Glasses, Crystals and Melts

Steve Feller,<sup>a1</sup> George Chryssikos<sup>b</sup> & Doris Möncke<sup>c</sup>

<sup>a</sup> Physics Department, Coe College, Cedar Rapids, IA 52402, USA

<sup>b</sup> Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, Athens, 11635, Greece

<sup>c</sup> Inamori School of Engineering, New York State College of Ceramics, Alfred University, Alfred, NY 14803, USA

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The Tenth Borate Conference on Glass, Crystals, and Melts (Borate X) was held in July 2023 in Corning, NY and it honored Efstratios "Stratos" Kamitsos. He is the leading advocate for the use of infrared and Raman spectroscopy in the study of glasses, with borate glasses having received considerably more attention than other glassy systems. For forty years he made essential discoveries of atomic-level structure using these techniques in conjunction with other spectroscopies. Here, we review his personal life and present a selective, non-comprehensive summary of his scientific accomplishments and his role as a teacher, mentor, and friend.

## I. Introduction

Efstratios 'Stratos' Kamitsos has made pivotal contributions to the structural analysis of many types of inorganic non-metallic glasses, including, par excellence, the borates. At the time of writing this article (2023), Stratos had almost 250 publications listed in the Web of Science, with >10 000 citations and an impressive h-index of 52. He was the top Google scholar who identifies himself as a student of borates, among the top five glass scientists, and among the top 20 vibrational spectroscopists.

The most recent overview of his work on borate glasses can be found in this issue (Kamitsos, *PCG, this issue*), and while we will highlight selected references of his work here as well, we want to focus on the person, researcher, teacher, administrator, mentor, and friend. This presentation is based on our memories from the times our paths overlapped. It is, therefore, neither complete, nor unbiased.

The paper will start with a biographical review of the early years, his education in Greece and the US, followed by his career at the National Hellenic Research Foundation (NHRF) in Athens, Greece. For many years he steered the Theoretical and Physical Chemistry Institute (TPCI) at NHRF, before passing administrative responsibilities to the next generation.

## 2. Childhood and schooling

Stratos Kamitsos (Figure 1) was born on February

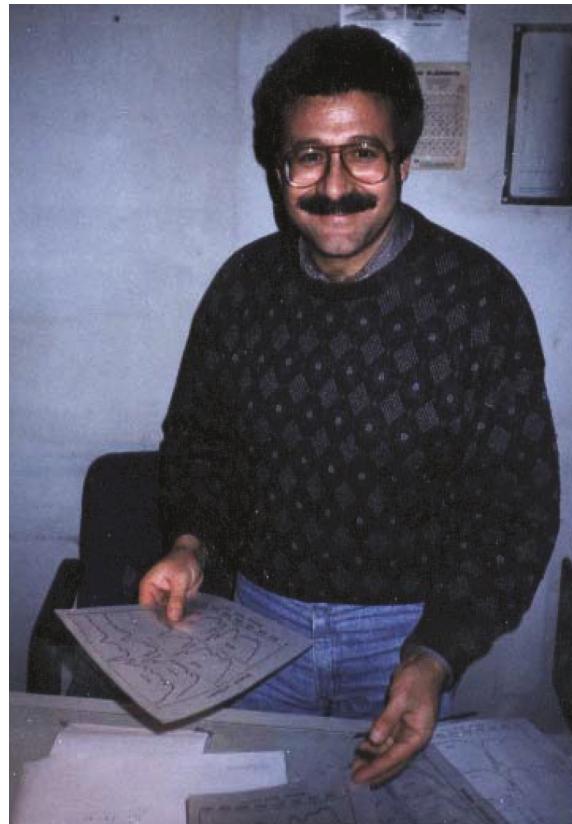


Figure 1. Efstratios 'Stratos' Kamitsos in 1990 at the National Hellenic Research Foundation in Athens, Greece (Photo Feller) [Colour available online]

24, 1955 in Napi, a small village, centrally located on the island of Lesbos, Greece (Figure 2). The family, which included his father Ioannis, his mother, Dorothea, and his older sister Maria (Figure 3) were olive

\* Corresponding author. Email SFELLER@coe.edu

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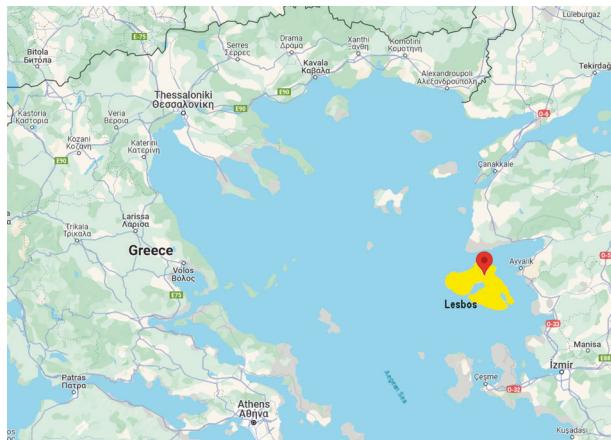


Figure 2. Map of Greece showing Stratos' home island of Lesbos (in yellow). The placemark (red) is at his home village, Napi. Athens is the home of TCPI/NHFR [Colour available online]

farmers. For Lesbos, this trade can be traced back to the Bronze Age and is still an important staple on the island.<sup>(1)</sup> (The oil from Lesbos, brightly golden-yellow coloured due to its low content of chlorophyll, has a superb taste, competing with the best Greek oils.)



Figure 3. Stratos (around 4 years old) with his parents Ioannis and Dorothea and sister Maria (Photo Kamitsos)



Figure 4. Elementary School in Napi, Lesbos, Greece, attended by Stratos 1961–1967. (Photo Kamitsos) [Colour available online]

It is worthwhile to expand even more on the historic link of olive oil and the history of the island to better understand Stratos' upbringing. In particular, the 'People's Machine' ('του Κοινού η Μηχανή'), the communal olive press of Agia Paraskevi,<sup>(2)</sup> is located near his home. This communal olive press, founded around 1910 by the farmers of the region, combined the most modern technological methods of that time with socialist ideas, cutting out the middleman, and as such increasing the earnings for the local farmers and also, providing communal services including good schools for the children of the area around Agia Paraskevi.

Stratos enrolled in the small school of Napi (depicted in Figure 4) from 1961–1967 before attending the impressive gymnasium (1967–1970) in Agia Paraskevi, Figure 5, and finally transferring to a second high school (1970–1973), in the town of Kalloni, a 10 km bike ride that included some stony, steep roads and a bike that had no gears. The activities of the communal olive press were greatly impeded in 1967, as the military junta dismissed most of the communal council's members, including Stratos' father who had been serving as president of the council in Napi for some time. The repercussion of these actions impacted Stratos' family directly and also meant that Stratos, an excellent student, was given a warning by well-meaning teachers to keep his head down and stop asking any critical questions, if he wanted to graduate from school.

### 3. University (1973–1983)

After graduation, Stratos moved to Athens, starting his university degree in chemistry, see Figure 6. He used to tell friends that one condition for his studies in Athens were monthly appearances at a local police station as the military junta was unsure of the threats posed by the socialist background of his family. The junta was overthrown in 1974, so that by the time Stratos finished his chemistry degree in 1978, he was able to apply for a PhD scholarship to the USA.

From January 1979 to March 1983 Stratos attended



Figure 5. High school ('Gymnasium') in Agia Paraskevi, Lesbos, Greece, attended by Stratos from 1967–1970. (Photo Möncke, 2010) [Colour available online]

chemistry graduate school at Brown University in Providence, R.I., USA and worked on his PhD thesis in Physical Inorganic Chemistry with William M. (Bill) Risen, Jr, see Figure 7.

His work at Brown was split between Raman and optical studies of metal-organic films<sup>(3–8)</sup> and glass science. The latter included diverse hot topics such as the Brillouin scattering of alkali silicate glasses,<sup>(9)</sup> the vibrational study of single and mixed alkali pentasilicates,<sup>(10)</sup> as well as LiF-containing ionic-conducting glasses.<sup>(11)</sup> Stratos published nine papers based on his work at Brown and defended successfully his PhD thesis 'Spectroscopic investigations of charge-transfer materials and mixed alkali glasses' in 1983.

On the private side, the years in the United States were characterised by important events, as Stratos married Tina in 1980 and their first son Ioannis (John) was born in the United States.

Though there was a small overlap at Brown University between Steve Feller and Stratos Kamitsos, Steve finished his PhD at Brown in July 1979, in



Figure 6. Stratos (circled) as an undergraduate in a chemistry lab at the University of Athens [Colour available online]

the physics department with Phil Bray, Stratos and Steve never met there and only became close friends later on.



Figure 7. Faculty, staff and graduate students of the Chemistry Department, Brown University (Sciences Library, Oct. 1980). Stratos is above Bill Risen, both circled



Figure 8. The National Hellenic Research Foundation (NHRF) in Athens, Greece (Photo Feller, ca. 2016) [Colour available online]

#### 4. The early years at NHRF (1985–2000)

Following a government change in 1981, Greece was redrafting its research policy by establishing a network of national research institutes outside its universities. This was done by expanding existing Institutes in Athens and creating new ones in the periphery. Numerous promising young Greek scientists from the best universities abroad found an opportunity to apply for the newly opened positions and returned to Greece. Among them was Stratos, who returned from Providence in December 1983 and joined as a lecturer the Theoretical and Physical Chemistry Institute of the National Hellenic Research Foundation in the center of Athens in March 1984, see Figure 8.

Part of the deal was that the newcomers would (should) establish new research directions and were given the opportunity to apply for some seed funding. This seed funding is very relevant to the Borate Conference honoring Stratos almost 40 years later in 2023, as Stratos, who had mastered vibrational spectroscopy during his PhD years (see Figure 9) was aware of the NMR work on glass by Phil Bray *et al* across the street from the chemistry department, now proposed to launch a systematic structural vibrational investigation of ionic conducting glasses, starting with borates.<sup>(11)</sup>

Stratos secured funding for a new mid-far infrared spectrometer and a high-temperature furnace, but after he sent out the orders, he had to go off to serve the army, which is still mandatory in Greece. On his way back in April 1985, he had a second son (Yiorgos), a new spectrometer (one of the first IFS 113v's made by Bruker), a furnace, his first PhD student (Michalis Karakassides, now a professor of Materials Science and Engineering in the University of Ioannina) and was ready to start work. At about the same time, George Chryssikos joined the team for half a year as a travelling scholar from Brown, before getting a tenure-track position in 1987, mostly thanks to Stratos.

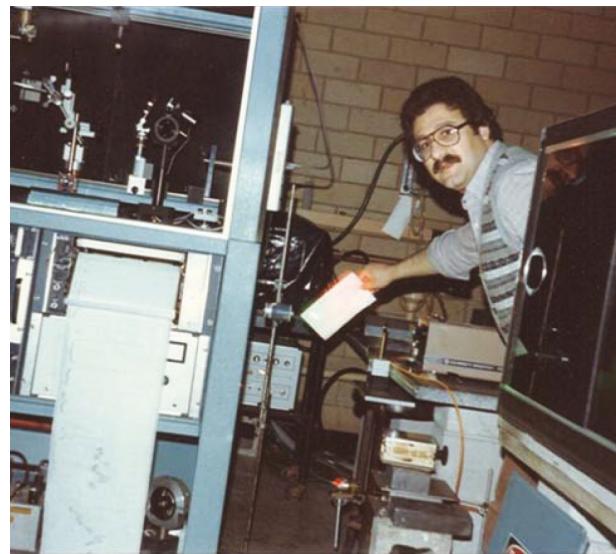


Figure 9. Measuring Raman spectra of glasses at Brown University, ca. 1983 [Colour available online]

The spectroscopic infrastructure involved the new FTIR spectrometer and a pre-existing Raman instrument. The Bruker 113v was a vacuum instrument with an innovative design allowing for changing up to five beam splitters without breaking the vacuum and offering continuous coverage in the mid and far-infrared, down to  $\sim 30\text{ cm}^{-1}$ . This spectrometer is still in the lab today, and could be operated, albeit with some effort. The Raman spectrometer was older but also of top class: a double monochromator Jobin Yvon HG2S with a Spectra Physics 5W Argon laser purchased in 1977. The water pressure on the third floor of NHRF was not sufficient for running the excitation laser over the long times needed to measure borate glass. A 2 m<sup>3</sup> tower tank was constructed to buffer the water supply. To save money, Stratos and the group applied themselves the necessary anticorrosive coatings in the early days and had some monumental

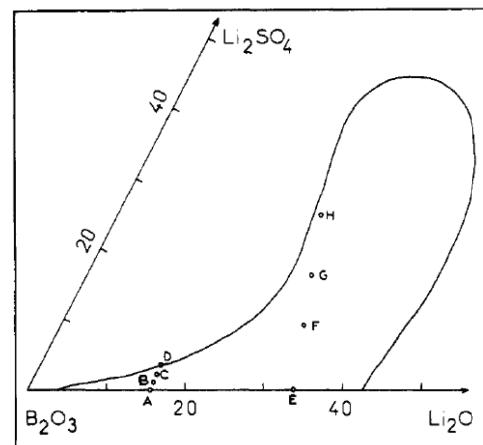


Figure 1. Glass formation region of the system  $x\text{Li}_2\text{O}\cdot y\text{Li}_2\text{SO}_4\cdot \text{B}_2\text{O}_3$ . The ternary glasses studied in this work are indicated; for exact compositions see Table I.

Figure 10. The first figure of Stratos' first glass paper at NHRF<sup>(12)</sup>



Figure 11. Group picture for 50 years NHRF / TCPI 2008, Stratos is centered in the first row, including international collaborators Doris Möncke (red jacket behind Stratos), Marc Dussauze, Guillaume Guimbretiere standing on the right, and glass colleagues, George Chryssikos, yellow top left half of last row, Manos Simantiras (left of GC), and Christos Varsamis (2 right of GC), Aliki Vegiri (3 right of GC), Dimitris Palles (left of DM) [Colour available online]

failures before mastering the art.

The new group could work and publish unobstructed by other duties and quite independently. Glass samples with systematically varying compositions were quenched and studied by mid- and far-infrared, as well as Raman spectroscopies. Target glass families were fast-ionic conductors, selected because they were known to display non-monotonic variations of properties (ionic conductivity,  $T_g$ , etc.) as a function of composition. The name of the game was to explore the spectral systematics by careful measurements and establish correlations between the structure of the glass network, the cation-site dynamics and the properties of interest. Borates were chosen because they were known to express non-monotonic structural variations by changing the coordination number of B, as discovered earlier by the seminal  $^{11}\text{B}$  NMR work of Bray *et al.* Steve had a significant share in the NMR studies of borates, which explains the onset of his relation to Stratos.

The first glass paper of Stratos' Greek period appeared in late 1986.<sup>(12)</sup> It was about the mid-infrared and Raman study of  $\text{LiSO}_4$ -based fast ionic conducting glasses and it explored the unusually shaped glass-forming range of the ternary  $\text{Li}_2\text{O}-\text{Li}_2\text{SO}_4-\text{B}_2\text{O}_3$  system, see Figure 10. Fibres were drawn for the Raman measurements and KBr pellets were used for the mid-infrared.

It was soon followed by several papers including three on  $\text{Na}_2\text{O}-\text{MgO}-\text{B}_2\text{O}_3$  ternaries,<sup>(13–17)</sup> which included the first far-infrared investigation of cation-site interactions in such borate systems. These early far-infrared spectra were obtained by dispersing powdered glass in a low-density polyethylene film.<sup>(14)</sup> The next major experimental advance came in 1990 on the  $\text{Li}_2\text{O}-\text{B}_2\text{O}_3$  binary glass system<sup>(18)</sup> when specular

reflectance was introduced, par excellence, to collect infrared data with five beam splitters, seamlessly down to the far-infrared. The data, free from particle-size, ion-exchange and hydrolysis artefacts, were then subjected to a Kramers–Kronig transformation to yield the complex dielectric permittivity, refractive index and absorbance spectra. This was a signature paper of Stratos<sup>(18)</sup> opening new ways in the vibrational characterisation of glass and, despite its age, is still highly quoted and his most cited work. Ref. 18 has more than 770, closely followed by Ref. 17 with over 730 citations at the time of writing.

Accessing the outcome of the early period (1985–2000) shows that Stratos managed to jump-start glass research in Greece, and he did that at the highest international caliber. Four PhD theses (Karakassides, 1990; Kapoutsis, 1998; Patsis, 1999 and Yiannopoulos, 2000), numerous publications and the first international collaborations with Steve Feller from Coe College in Iowa and the Aberdonians (Malcolm Ingram, John Duffy, John Hutchinson), all mark this period. Over the time, more researchers of TPCI became involved with glass science in collaboration with Stratos: Christos Varsamis (now professor at the University of West Attica), Aliki Vegiri, Manos Simandiras and Dimitris Palles, to name a few with the longest involvement (Figure 11).

## 5. Director of TPCI (1997–2020)

Although this is the occasion for honoring Stratos' seminal contribution to borate glass science, this presentation would be incomplete without paying tribute to his critical involvement in the management of his Institute, see Figure 11 especially because these duties were competing with and taking precious time

from his personal research.

The growth of the Greek research infrastructure in the 1990s and the maturing of EU research policies inevitably made the funding of research much more competitive at both, the national and international levels. Money stopped flowing from high above and its internal distribution could no longer be controlled by the leader. Instead, it was directed towards innovative proposals along priority topics by individual applicant groups. Obviously, this had a profound effect on the way an institute is managed, and the transition was not without friction.

In 1997, an external electorate committee elected unanimously Stratos as the new director of the Institute. Their decision was based on his proven scientific merit and also, in anticipation of a more modern peer-to-peer style of management. At that time, the Institute consisted of about twenty researchers and a handful of students spread thinly over eight research fields, both experimental and theoretical. Orchestrating the fragmented efforts towards a cohesive outcome required diplomatic skills and managerial guts. It became obvious that Stratos had both. He was re-elected another three consecutive times and remained the director of the Institute until May 2020, while serving as the president of the whole Foundation during 2012–2013, the worst period of the recent debt crisis and recession in Greece.

As director of TPCI, Stratos slowly steered the Institute towards Materials Science. He was not given new openings, but he filled vacancies by hiring new, very competent researchers. These were selected in order to introduce new fields that could bridge with existing skills, thereby having a multiplicative effect on the research outcome. He encouraged international collaboration, as the only means to achieve scientific critical mass and maintain high standards. He promoted direct research links with industry, a by no means obvious standpoint in a purist fundamental research environment. He guided the Institute through four external evaluations by international committees, with excellent outcomes, and he made sure that the benefit was shared fairly through the Institute.

## 6. International collaboration

By 1989 Steve became aware of new papers on borate glass structure coming from the newly established glass group in Athens. He contacted Stratos at NHRF and soon arranged for a sabbatical visit with George and Stratos. The first visit sparked intense discussions that bore fruits for the separate research on both sites of the Atlantic, followed by many more semiregular return visits (not untypical when working with Stratos), see Figure 12. A series of American undergraduate students followed Steve's lead, coming to Athens, Greece for various research projects and many joint



Figure 12. Steve Feller and Stratos Kamitsos arguing about glass structure at NHRF, Aliko Vegiri and Christos-Platon Varsamis (both NHRF) are seen in the background [Colour available online]

papers ensued from this collaboration.<sup>(19–24)</sup>

Throughout his career Stratos has always collaborated within the glass community and shared his broad knowledge of glass structure. He has a wonderful knack of getting to the bottom of scientific questions and he is tenacious at the same time (the quality of a publication beating quantity any time). This resulted in a large group of collaborations in Europe (Bulgaria, France, Germany, Sweden, UK, ...), the US (Alfred, Coe, Lehigh, Lawrence Livermore, ...) and all the way to Brazil, Egypt and Japan (see Figures 13–15). Any attempt to compile a complete list of collaborators is futile, many can be researched in Stratos list of publications, but close friendships do not necessarily translate into joint projects.

## 7. Teacher and mentor in research

Stratos is a gifted teacher and mentor. In his career he supervised five undergraduates that led to honors theses, 12 graduate students who earned their



Figure 13. Halifax Borate Conference 2011, Stratos is with Doris. Ladislav Koudelka is left back, honoree of the Phosphate Conference 2023, and Richard Brow is at centre back [Colour available online]



Figure 14. 8th Otto Schott Colloquium, Jena, Germany, 2006, Fuchsturm, from left to right Christos-Platon Varlamis (standing), Adrian Wright and Natasha Vedishcheva (seated front), Leonie Velli, Stratos Kamitsos, Ladislav Koudelka (back), Christian Rüssel (and wife) seated front, DM walking in back [Colour available online]

PhDs, and 19 post-doctoral research fellows. Stratos welcomed students from all over the world for short to long term visits and mentors them like his own advisees, several times ending up on their thesis committees.

We have watched Stratos with students, see Figure 16, a snap-shot of recent NHRF Postdocs, with visiting Coe College undergraduate students. The long tradition of visiting undergraduates from Coe College, resulted in several joint publications, including lead borate and lead silicate glasses as well as going full circle back to lithium borates.<sup>(19-24)</sup>

Stratos always treats all ideas with respect, he answers all questions posed to him as best he can, and he is kind to new scientists. A typical example occurred during the ICG meeting in Prague, where he dedicated over two full hours during the lunch break to discuss the work of one student he had never met before.

Doris briefly met Stratos at the ICG in Edinburgh in 2001. More impactful, however, was that subsequent meeting at the Borate Conference 2002 at Coe College in Iowa, when a discussion following her presentation on the same borosilicate glass system resulted in a subsequent three month long visit in Athens, the first of many stays, the longest extending four years, from 2007 to 2011 as Marie Curie Fellow. In the German tradition, Doris Ehrt is considered



Figure 15. During the International Congress on Glass, 2004 (a) Stratos with his wife Tina, and Himanshu Jain at the Golden Temple in Kyoto, Japan, (b) Stratos Kamitsos with Giuseppe Dalba. (Photo provided by Kamitsos) [Colour available online]



Figure 16. Stratos with N. Tagiara, K. Chatzipanagis, M. Jesuit (Coe College) & M. Boyd (Coe College) (Photo Feller) [Colour available online]

Doris' Doktormutter, and consequently, Stratos Kamitsos became her Postdoc-father and might now be considered a scientific grandfather to several of her PhD students, partaking in at least two thesis committees (Anja Winterstein-Beckmann<sup>(25)</sup> and Brian Topper<sup>(26)</sup>).

Doris and Stratos have by now more than 50 joined publications, starting with the early collaborations applying Raman and infrared studies to the (fluoride) phosphate glasses of Doris Ehrt,<sup>(27-29)</sup> to archeological glass samples.<sup>(30-34)</sup> The enigma of the three-thousand-year-old Mycenaean glass samples was eventually



Figure 17. 25th International Congress on Glass, Boston MA, USA June 2019, Steve Feller (left), Stratos (center) and Adrian Wright, all honorees of previous Borate Conference, and all three pivotal scientific mentors of the current glass faculty at Alfred University [Colour available online]

resolved, as the infrared spectrum was found surprisingly close to that of a low alkali borosilicate glass.<sup>(34)</sup> For the key scientific findings in borate research, we refer to the review paper by Stratos in this current issue. Some data collected in the 2010s needed until the 2020s to be published.<sup>(35–36)</sup>

Figure 17 shows three honorees of various Borate Conferences, Stratos was selected for the 2020 conference at Corning NY, USA, but due to the pandemic had to wait until 2023 for the honours, Steve Feller (2017, Oxford, UK) and Adrian Wright (2008, Himenji, Japan), all three of them were supervisors of current Glass Engineering Science faculty at the New York State College of Ceramics in Alfred, NY.

Figure 18 depicts Tina Kamitsos, Stratos Kamitsos, Barbara Feller and Steve Feller in the beautiful mountain village of Elafos near Larissa in the spring of 2023.

## 8. Final notes – summary - outlook

We would be amiss if we did not mention all the other lifetime achievements of Stratos.

However, listing of funding, publications, conference presentations (more than 75 invited talks), conference organisations, membership in national and international professional organisation, advisory boards, expert committees, are too plentiful to list, and any selection can only be arbitrary, thus we want to limit this paper to exemplary examples. In 2004, Stratos and many colleagues at TCPI organised the ESG conference in Athens, Greece. Stratos was Principal Investigator or Project Coordinator of many projects, large and small, by Greek and/or European or collaborative international programs. During the economic crisis in the early 2010s, when jobs were hard to come by, TCPI seemed to be even more crowded than usual, every available desk was occupied by students and postdocs, researching and publishing, adding to their CVs until the job market opened up again.

Most recently Nagia Tagiara, see Figure 16, successfully defended her PhD on tellurite glasses in 2021. During her PhD she published 14 papers with Stratos,<sup>(20,23,35,37–47)</sup> and, of course at least four of these are focused on boro-tellurites or borates.

In what seems to be a decadic cycle, Stratos revisits research on tetrahedral orthoborate glasses,<sup>(45,48–52)</sup> only this year [2023], both at the GOMD meeting of the American Ceramic Society, as well as the Borate Conference – other research groups are suddenly also discussing these materials.

With his most recent scientific grandchild, Brian Topper, Stratos revisited orthoborates and other unfinished glass questions from the far infrared, thermal poling or modifications in ULE glasses,<sup>(35,45,52–55)</sup> and even now, Nagia, Brian, Doris and Stratos are still collaborating on the interpretation of Raman and infrared data of more glasses.



Figure 18 (left to right). Steve Feller, Barbara Feller, Tina Kamitsos, and Stratos Kamitsos in Elafos, Greece, May, 2023. Elafos is a beautiful village in the hills surrounding Larissa [Colour available online]

In summary, Stratos Kamitsos is a most deserving honoree for Borate X. His contributions to the science of borates are legion. He has superbly mentored the next generation of borate glass scientists.

Perhaps more importantly, Stratos is now spending a lot of prime time with his true grandchild, Stratos Jr., and seems to enjoy it very much, perhaps more than the borate anomaly.

## 9. Acknowledgements

The authors acknowledge Stratos' family, colleagues in Greece and abroad, his friends and Dr Nagia Tagiara (his latest PhD student) for sharing their memories, pictures and anecdotes. SAF acknowledges the US National Science Foundation for supporting this work under grant number DMR-RUI 22033142.

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