



## Obituary

## Gene F. Dresselhaus (1929–2021) - A Tribute from the Carbon journal

We would like to share with the Carbon community the memory for Professor Gene Frederick Dresselhaus who passed away on September 29th, 2021 at the age of 91. Professor Gene Dresselhaus got a PhD from the Department of Physics at the University of California at Berkeley where he worked with A. F. Kip and C. Kittel on cyclotron resonance experiments on Si and Ge crystals by using the effective mass theory. He is also famous for investigating spin-orbit interaction in materials lacking inversion symmetry, such as zinc blende structures, which is now best known as “the Dresselhaus term” in the field of spintronics. In this content, Professor Gene Dresselhaus has got 2022 Oliver E. Buckley Condensed Matter Physics Prize shortly before his passing “for pioneering research on spin-orbit coupling in crystals, particularly the foundational discovery of chiral spin-orbit interactions, which continue to enable new developments in spin transport and topological materials”. He completed a postdoctoral work at the University of Chicago before accepting a junior faculty position at Cornell University for 4 years with A. Overhauser (see Fig. 1).

The major part of his professional career took place at MIT, first at the MIT Lincoln Laboratory and later at The Francis Bitter National Magnet Laboratory. He was a Fellow of the American Physical Society. He married Professor Mildred S. Dresselhaus and they had four children. He collaborated on carbon science extensively with Professor Mildred Dresselhaus and with many other researchers across the world (see Fig. 2). His scholarly output includes 559 publications in international peer-reviewed journals. During his career, he published 33 papers in Carbon and authored a number of books on fullerenes, carbon nanotubes, and thermo-electricity. We are confident that the tradition of excellence in the nano-carbon research established by Professor Gene Dresselhaus and Mildred S. Dresselhaus will be continued by the collaborators.

(Mauricio Terrones, Editor-in-Chief).

### 1. Morinobu Endo, Shinshu University

To visit Dresselhaus's Lab. around mid-December for me, it was annual event since 1982. We started our collaboration on pristine and intercalated graphite fibers (see Fig. 3). At that time, Millie sensei was rather busy as the director of the Center for materials science and engineering of MIT. The weekly lunch meetings of the MGM group were arranged by Gene sensei, they were very lively with about 30 students and postdocs. All of them are now very active as top scientists in diverse universities and companies around the world. When I joined to the MGM group, Profs. P. C. Eklund (University of Kentucky, Penn State University) and J-P. Issi (Université catholique de Louvain) had just left the group. The rich accumulation of excellent research on graphite of that era of

Millie and Gene sensei had led to the greatest achievements on nanocarbons. Gene sensei also belonged to the MIT Magneto-lab, and there I measured the magnetoresistance effect of graphite fibers with him. Gene sensei had always supported Millie sensei for research, student guidance and laboratory management. In the Christmas season, at their home, Gene sensei used to arrange the audio system and Mille sensei used to play music with their family. I was very impressed to see that in the car when they went back to home, Millie sensei used to knit in the backseat, in order to save time in housework. At that time, Gene sensei always drove the car very gently.

He was a great scientist, gentle and kind professor for all those who learned with him at MIT. Gene sensei had shown us that a top talented researcher should also be a great personality. Thank you very much Gene sensei, and may he rest in peace.

### 2. Toshiaki Enoki, Tokyo Institute of Technology

My interaction with Gene Dresselhaus began in 1984, in which I joined Millie Dresselhaus group, MIT, as a visiting scientist (see Fig. 3 (right)). In the mid-1980s, graphite intercalation compounds were the most popular topic in carbon science, and Millie's group worked intensively with graphite intercalation compounds and led the global community. In her labs, I worked on hydrogen adsorption in alkali-metal graphite intercalation compounds in collaboration with students. Millie and Gene supported us and gave us appropriate suggestions in every time we needed. In 1984, Millie used to be very busy and absent from the lab, as she has served as the President of the American Physical Society. So Gene took care of all the lab members in the routine from many aspects. Discussion with Gene was always exciting for me, as he let me know what I did not think about, in particular, from theoretical aspects, and inspired me to work along a new direction. One of my main experiments in Millie's lab was on Shubnikov-de Haas oscillations in hydrogen-adsorbed potassium graphite intercalation compounds. I had no experience till then in working with high magnetic field facilities, but Gene took care of me and guided me to work with the quantum oscillations in the high magnetic fields. Discussion with Gene later inspired me to conclude that metallic hydrogen atoms two-dimensionally arranged are formed in the graphitic galleries in the intercalation compounds. After I was back to Japan, we have continued our collaborations, in which nanographenes were involved as one of the targets. Actually, discussion with Millie and Gene took me to work with nanographene and to come to the first observation of isolated nanographene in 2001, Gene was a great scientist with gentle and friendly personality. I have learned a lot from him not only about scientific skill but



Fig. 1. Gene Frederick Dresselhaus.

also on how we should work as a scientist. I would express many thanks to Gene for what he inspired us in our scientific activities.

### 3. Jean-Christophe Charlier, University of Louvain

In summer 1989, I arrived at MIT as a visiting undergraduate student in the group of Millie and Gene Dresselhaus. Millie was abroad for a scientific conference somewhere around the world ... and Gene welcomed me in his office of building 13. I explained him that Jean-Paul Issi (a long-standing friend) was sending me to MIT to help me to decide between theory and experiments for my PhD. Gene directly told to me “In the next couple of days, I will show you how to change the oil of the vacuum pumps in the lab, and for sure, you'll choose THEORY !” ... When Millie came back, she proposed me to measure weak localization effects in fluorinated carbon fibers, which was a very hot topic. But at the end, I followed Gene's advice ... I have always really enjoyed his particular sense of humor

and had a strong friendship relation with Gene. He was the only person I know to directly detect a problem in an electronic band structure or a phonon spectrum thanks to group theory. Gene was really a world expert in that field. During 30 years, I have had so many scientific discussions with Gene and Millie especially when they were coming to visit our group in Louvain. Gene was always curious, supportive, trying to understand every piece of the puzzle when we were investigating complex scientific phenomena in carbon nanostructures. We have all been extremely lucky to have met Gene (and Millie) along our scientific journey ...

### 4. Riichiro Saito, Tohoku University

It was exactly thirty years ago on Oct 1st, 1991, Professor Gene Dresselhaus picked up me and my wife at Logan airport to welcome us at MIT for ten months stay. Before going to MIT, I wrote to Professor Gene Dresselhaus in which I asked him to become a host professor at MIT. When the visit was scheduled, many senior professors in Japan congratulated me on going to MIT by telling me that Professor Gene Dresselhaus was a famous professor in semiconductor physics in 1960's. In fact, my supervisors, Prof. Y. Uemura and Prof. H. Kamimura invited Professor Gene Dresselhaus as a distinguished professor of the University of Tokyo in 1960's and the whole Dresselhaus family came to Japan for a couple of months, which includes Professor Mildred Dresselhaus who was invited to Aoyama Gakuin University at the same time. When I arrived at MIT, he proposed me to calculate the electronic structure of carbon nanotube which we called “graphene tubule” at that time, which was lucky for me to have such a great subject for my research life. During the 10 months, we have published 10 papers, which was really successful.



Fig. 2. Prof. Gene Dresselhaus with Prof. Mildred Dresselhaus (left) at the Carbon conference in 2004 and (right) in Oslo in 2012. (A colour version of this figure can be viewed online.)



Fig. 3. Gene and Millie sensei at Endo's office for discussion, 1989. (right) In the house of Millie and Gene Dresselhaus with Enoki's family, 1984.

Since then, I tried to find any research money to visit MIT in the summer time to continue the collaboration of the research with Professor Gene Dresselhaus and Prof. Mildred S. Dresselhaus (MGM group, see Fig. 4). They always accept me in very exciting and really warm way. During one month for each year, staying the vacant summer dormitory of MIT that Laura-san found for me, I got many home works with the visitors of the year which were solved in the remaining eleven months. Professor Gene Dresselhaus was a brain of the MGM group and he taught me group theory and solid state physics. Whenever he told me “This paper is important”, the paper always became important for the field of carbon nanotubes and the paper was later cited many times.

Even when Professor Mildred Dresselhaus became incredibly busy after 2000 that no one could imagine how busy she was, Professor Gene Dresselhaus supported her for writing papers and books, accepting many visitors, and everything of the MGM group in an intelligent way with many humors, from which I learned how to behave as a researcher. I think that Professor Gene Dresselhaus and Professor Millie Dresselhaus are now enjoying the weekend walking in the countryside of the heaven and playing music together after eating the poppy seed bagels with cream cheese and the Wilson's farm sliced onion and tomato.

### 5. Marcos A. Pimenta, Universidade Federal de Minas Gerais

My first contact with the Dresselhaus couple was through articles published in the literature on Raman spectroscopy of fullerenes, where only the initials appeared (M.S. and G.) and I didn't know which was the wife and which was the husband. I wrote a message to them in 1996 and was accepted to spend a sabbatical year at MIT. I met Millie and Gene in August 1997 in large room 3005 in building 13 at MIT which was already a very messy room, with piles of papers and books strewn all over the space. Gene was responsible for the computer system and network of the MGM group and for the latex edition of the group's articles and books. I received from Gene's hands a sample of single-wall carbon nanotubes resonant spectroscopy measurements at the MIT Spectroscopy Laboratory. I regularly presented my measurement advances at the weekly MIT meetings, Millie was thrilled with the results, but Gene was more skeptical and rigorous, always suggesting new experiments and posing new questions to be answered. We were able to show that the Raman spectrum of metallic nanotubes was different from that of semiconductor nanotubes, and I made a model to explain the results that was fitted by only one parameter, the tight-binding constant  $\chi_0$  of graphene. I got the value of 2.95 eV



**Fig. 4.** 40th Anniversary of wedding of Professor Gene Dresselhaus with Professor Mildred Dresselhaus who visited to Tokyo on May 1998 with R. Saito and his two daughters. The daughters considered them as “American grandparents”. (A colour version of this figure can be viewed online.)

for this constant through my measurements and, when Gene saw this result, he was very excited and started to believe in my results.

Back in Brazil, in 2000 I organized the Carbon Brazil 2000 meeting and invited Gene to visit UFMG and make a presentation at the conference in the city of Ouro Preto. I took Gene to meet the president of UFMG, who was very excited about the visit of such an illustrious person to our university, but on the way out, Gene made the following comment to me: “he doesn't know he was talking to the wrong Dresselhaus”, revealing his sense of humor. I see today that the two Dresselhaus were always right, and Gene's support for Millie allowing her to make several trips a year, and taking care of the group at MIT during her absence were key to MGM's success. Gene also had the opportunity to dedicate himself to his children's education and leisure, having taken trips with them as in the Brazilian Amazon, in addition to being the organizer and distribution of the scores in the string quartet sessions in the evenings at the Dresselhaus home. Gene was born and raised in Panama and always liked the tropical climate and the heat. May the success of the Dresselhaus couple serve us as an example of companionship and solidarity.

### 6. Ado Jorio, Universidade Federal de Minas Gerais

From December 1999 to December 2001, as a post-doc at MIT, I had the opportunity to share my everyday working hours with Gene (see Fig. 5). During these two years, I would meet Gene and Millie from Monday to Saturday (the one not working on Sunday was me). Gene would be in his office (see Fig. 6(a)) during all day, sometimes during the day going to stretch the legs and complain about the air conditioning inside the MIT building 13: “It is too cold!”. As everyone is ready to recognize, Gene had an odd sense of humor, his comments were always unexpected and funny. Gene and Millie arrived every day at 5am at MIT, and departed 5pm, except on the weekends, when they leaved around noon, always going home carrying a bag full of papers to read and correct at night. Gene's office was also the place to make tea: “You have to hydrate!”. If Gene was not at his office, he was at the MGM group meeting room (see Fig. 6(b)). Everyone in the group knew he liked the pizza with pepperoni. Gene's warm and kind behavior made the group to work as a family.

Our collaboration continued for over a decade after my departure from the US. In 2004, I was visiting MIT and Gene drove all the group (including me) from Boston to Montreal, in a big van, to attend the APS March Meeting. Gene was such a great scientist with a very deep understanding of materials science. It was a privilege to work with him on many papers and books, especially on the “Group Theory” book, built based on a course Gene and Millie developed over decades of teaching. Gene was an example of a man ahead of his time when addressing ethics and humility. No matter your level of knowledge, the MGM group was always with



**Fig. 5.** The photo is taken in Boston in 2010. From left to right: Philip Kim, Mauricio Terrones, Ado Jorio, Gene Dresselhaus, Millie Dresselhaus, Riichiro Saito, Antonio G. Souza Filho, Marcos A. Pimenta.



**Fig. 6.** (a) Gene in his office, MIT, 2001. (b) Dresselhaus, Ado Jorio, Oded Rabin, Victor Brar, Marcie Black, Elena Rogacheva (standing), two visitors, Yu-Ming Lin, Stephen Cronin and Gang Chen. Antonio G. Souza Filho is taking the picture. (A colour version of this figure can be viewed online.)



**Fig. 7.** Prof. Gene Dresselhaus with Prof. Mildred Dresselhaus with MGM group at MIT, in summer of 2008. The right side of Gene Dresselhaus is Jing Kong. (A colour version of this figure can be viewed online.)

open arms for you to build your best. I feel orphan, but still happy for the science family I inherited from Gene and Millie. And now they rest in peace.

### 7. Antonio G. Souza Filho, Universidade Federal do Ceara

It is clear in my memory the day (November 2nd, 2000) I arrived at MIT as visiting Ph.D. student. I was very excited about such opportunity to join the well-known Dresselhaus group at MIT. Of course, I was kind of nervous as well about facing that challenge, since it was the first time I was going to work in another country and my English was indeed poor. I knocked on the door of room 13–3005 and, the first person I met was Gene Dresselhaus. I felt very welcomed by his welcome words said with his typical sense of humor. “Welcome to MGM group. We liked very to work in Brazil (they spent some time in Campinas in the late 70’s), and we like much more the Brazilians working here”. He got a key and set me a desk in the office and clearly told me two things: “Please use only Linux on this computer. Start to work because the former Brazilians did very well, so we expected the same for you.” Apart from the physics lessons I learned from him, sometimes with hilarious criticism (or sarcasm) on figures or interpretations of the results, I have good memories of Gene helping us editing the papers, answering referees, organizing group meetings. We shared good jokes and laughs protesting against the freezing weather of the winter days in the Boston area. The Dresselhaus couple taught me many valuable lessons not only for science but also for life;

some led by words, some by actions, and some just by the way they were themselves. It is sad to say goodbye to them; it is fortunate to keep them in the best memories.

### 8. Humberto Terrones, Rensselaer Polytechnic Institute

I started to collaborate with Mildred Dresselhaus group around 2002 and I had the pleasure of meeting Gene Dresselhaus in person around 2005 when a group of Mexican students and researchers (including me) visited the Massachusetts Institute of Technology (MIT) as part of a collaboration program supported by MIT. I recall that Gene was a very active member of Millie’s group, making always good suggestions and knowledgeable comments about carbon research which at this time was about graphene, carbon nanotubes and exotic carbons, but he also knew how to catch the attention of people in other subjects. I recollect that MIT reserved the hotel for our group and we were not very familiar with the city of Boston: When talking informally during our first day lunch in the conference room, Gene mentioned that our hotel was very close to Fenway Park (the famous stadium of the Red Sox, baseball team), immediately attracted the attention of our Mexican students and researchers, including me, because we did not know about this and some of us followed the Red Sox team. When we arrived back at our hotel, someone from our group pointed out “Prof. Gene Dresselhaus was right, from my room I can see the Fenway Park stadium!”. Unfortunately, no game during our stay, but Gene was correct, and also his research suggestions made to our group during our memorable visit to MIT.

### 9. Jing Kong, Massachusetts Institute of Technology

Before I came to MIT, I already read an article written by Gene about Millie, I enjoyed the stories told by him. After started at MIT in 2004, each time coming back with Millie from lunch meetings to their office, we often were welcomed by Gene bringing a cup of tea to Millie. It was my great fortune seeing their life example as I was starting my career (see Fig. 7). Each day ~5pm Millie and Gene would home together, walking along the hallway, greeting everyone and saying goodbye. I had also heard that they came in together at 5am. This was how Gene put it: “you know, when I was retired, Millie asked me if I want to come to her lab and work part time. I only discovered part time is 12 hrs a day.” Gene’s sense of humor had filled our time in building 13 with many laughter. For example, when I was going on my first trip with Millie to Brazil, Gene told me about the story he and Millie went to Brazil before. Gene said the president of the university spent a lot of time talking to him and then found out that there were two Professor Dresselhaus’ ...



**Fig. 8.** E-mail from Gene Dresselhaus, 2012.

When my lab renovation was finished, it was Gene who suggested that I should have a lab warming party. When we finish the food and drinks and come to the newly renovated lab, Gene declared “Now Millie shall give the blessings to this lab.” At that time, at the beginning of my career, I was struggling even with the thesis topic of the present students, I had never thought there could be many fruitful researches to come as Millie said in her blessing. It was not just our lab, but more so for my heart, that being warmed and touched so much by their kindness and encouragement.

I had learned many things from Gene, for example, “MGM” means “millie group meeting”, in fact I enjoyed the way Millie runs her group meeting very much and our two groups had always run group meetings together. Gene told me “Millie is very good at converting her students from experimentalist to theorists”. Though I was laughing at that time because of Gene’s humor, that was so helpful, nowadays I gradually realized how important it is to distill the experimental observations into theoretical formalisms. When I was with Millie, Millie would give me her aspect of how she guided different students. I felt so fortunate I had Millie and Gene in my life, truly gifts from heaven, that is so dear to my heart.

I still remembered the time when Gene was strong and helped Shoshi move when she was at Brandis. I also remember when we were proud of MIT, Gene used his humor again and remarked, “guess what, we have two kids went to MIT and another one went to Harvard. But it was the Harvard one earns the most money”. I still remember the excitement of me and my husband when we found out Millie and Gene also took the detour back from the airport to avoid the toll. I also remember the “wow”, when I found out the “Dresselhaus effect” in solid state physics was named after Gene ... On the board outside my office, there are many photos of Millie and collaborators, each time when we sent to Millie our photos, either baby, or graduation, it used to be

Gene who would print them out and hang outside Millie’s office proudly. Now these have become treasures in our memories.

Each thanksgiving, it used to be that Millie and Gene would come to school, and check out who is still in the lab, and bring them home to celebrate thanksgiving. Students told me their wonderful time with Millie and Gene. Just in 2019, before the pandemic shutdown, we saw someone left a note on the board outside Millie’s office: “Millie, thank you for taking me to your home to Thanksgiving when I had no place to go.” Of course, Gene was there also, with his big support.

Dear Gene, thank you so much for all your kindness, your help, your encouragement. The impact you and Millie has given us have become treasures for us to pass on to the future generation.

## 10. Mauricio Terrones, the Pennsylvania state University

It is very sad to see Gene’s departure. He was an excellent physicist, father, husband, grandfather, and mentor. Millie and Gene Dresselhaus were always one entity, as they complemented and supported each other. I remember Millie mentioning to me that her success in science was due to all the help received from Gene since they got married. Everyday, they started working at MIT since 5:30 a.m. and worked there from Monday to Saturday; science was their passion! Gene was characterized by his sense of humor, generosity, and empathy. During my visits to MIT, Gene always made me feel at home and helped me to navigate around. As part of his generosity, he gave me rides to Logan airport before traveling, making also sure I was always well fed. Gene and Millie also invited me to stay at their place and I had wonderful dinners, conversations, and music. It is also important to mention that Gene was the one who informed me about Millie being awarded the Kavli Prize for nanoscience in 2012. It was during a 2D workshop in Washington, DC, organized by the National Science Foundation (NSF) and the Air Force Office of Scientific Research (AFOSR), when Gene sent me an email in the middle of the workshop (May 3rd, 2012), asking me to contact Millie immediately to phone Norway. It was great to know her award before Millie (see Fig. 8).

That morning, Millie had issues with her email and she did not have handy cell phone. Gene and Millie also visited Penn State in 2010 and we enjoyed their visit and discussions. Gene always supported our students and made sure they felt at home. Gene, thanks for all your contributions and support; we will miss you!

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