

## Professor Joseph Gyulai passed away on February 12, 2021.



Following a period of severe illness the member of the Hungarian Academy of Sciences died at the age of 88. He was, professor emeritus both of the Institute for Technical Physics and Materials Science (MFA) and of Budapest University of Technology and Economics. He was very active both domestically and internationally in different scientific and engineering boards. Most of us know him worldwide as an originally thinking, bright researcher maintaining good, even friendly relations with scientists, people in industry, and with students. Not only in the field of physics or materials characterization, but e.g. in the world of music, as well.

In fact he started his studies as a composer of classical music. Together with high-school, where he focused also on physics, mathematics and foreign languages, he continued studies at the Conservatoire in Szeged, played the piano and enjoyed composing music. Finally, he decided to move to the Science University of Szeged to study physics. After taking a degree as high-school teacher at the university he had to teach physics and mathematics in high school of his hometown, Hódmezővásárhely ("Beaverfieldmarketplace"). A year later though Joseph was offered a position at the Physics Department of the Science University of Szeged by the legendary physicist of those times in luminescence, Prof. Ágoston Budó. Here Joseph got the task to work on solid state physics and semiconductors. His first papers were published on photoelectric properties of different compound semiconductors. He proved, e.g. the existence of discrete trapping levels in crystalline GaP lying above the absolute minimum of the bandgap causing current oscillations.

A lucky moment, in fact a turning point in his career appeared, when Joseph's professor at the university arranged him a one-year scholarship to the USA. In the Communist Hungary, behind the iron curtain during the cold war it was very unusual to get a chance like that. It provided for Joseph the opportunity to join a prosperous research group in US. There was only one minor problem: Joseph did not know any scientists to contact. He knew researchers by their names only from literature. Joseph wrote letters presenting himself and his interests in semiconductor physics. Three laboratories were chosen. The letters were sent around and Joseph was waiting for an answer. The first who responded him was Jim Mayer from Caltech, Pasadena, whose work on detectors was known to Joseph. When at the end of 1969 Joseph arrived at Pasadena Jim Mayer's international research group was switching to ion implantation and Rutherford Backscattering Spectrometry (RBS). This fact became his great fortune, as his relations with Jim were not only factual, but a close friendship developed between them. Joseph was immediately accepted as it was him who figured out how to extract depth dependent chemical composition from RBS spectra of compound layers, by using an appropriate energy-to-depth conversion procedure. Just a few weeks after his arrival he already published a first-authored paper on Si-SiO<sub>2</sub> composition analysis. Thus, he joined an inspiring group with Otto Meyer, Val Rodriguez (Fairchild), Richard D. Pashley (Intel) and many other academic and industrial colleagues and PhD students.

This was the revolutionary time of the boom of electronics due to the prevailing use of various discrete semiconductor devices. The fast advancement in technology resulted in the development of integrated circuits. Jim's group at Caltech was deeply involved in the analysis and technology of silicon based

structures. At that time the main tool for investigating silicon samples was the Van de Graaff accelerator which provided the platform for the rapidly developing RBS/channeling analysis technique.

By working together with industrial colleagues Joseph studied the novel Si doping method, ion-implantation. RBS/Channeling provided the most relevant information on the depth distribution and lattice location of the implanted dopants and also on the lattice damage induced by ion bombardment.

The results of the intensive one year scholarship of Joseph yielded more than ten remarkable scientific publications. Using his expertise after his return Joseph established in Hungary an ion-implantation laboratory, which became later the core facility of the Microtechnology Department of MFA. In 1974, with Jim's and the Caltech President, Harold Brown's support a scientific cooperation and maybe the very first exchange program was initiated between National Science Foundation of the US and the Hungarian Academy of Sciences. In the coming years his young Hungarian colleagues – László Csepregi, Gábor Mezei, Péter Révész, István Krafcsik – joined the collaboration and US scientists (Jim himself and Charles A. Evans, CA Evans & Associates, Sam Matteson, TI Instruments) spent longer times in his Budapest laboratory.

The Mayer group with more than a decade long active participation of Joseph and members of his group from Budapest (L. Csepregi, P. Révész) led to acknowledged major contributions to microtechnology, still in use in nowadays' industry:

- The exclusive use of (100) oriented Si crystals in modern microtechnology, since epitaxial regrowth and annealing properties are much better on Si wafers with this orientation compared to (111).
- Pre-amorphisation-implantation and subsequent solid state epitaxy – in order to avoid the uncertainty in the implanted profile due to the channeling effect – a basic technique to make ion implantation as well-controlled, highly reproducible industrial technique.
- Pre-amorphisation was also applied to Silicon-On-Sapphire structures improving quality and operational properties of IC-s on this substrate.

Joseph continued collaboration with Jim Mayer at Caltech and later at Cornell, as well. He met and worked together with many dominating personalities in the field of ion-implantation and ion beam analysis: W-K. Chu, Emanuele Rimini, Friedel Sellschop, S.S. Lau, Sam Matteson, Chris Palmström, Ken Purser, Lian-Sun Hung, Jim Ziegler and others. Later he was invited as visiting professor to various research groups: Groupe de Physique des Solides, Paris, France – Georges Amsel, Camille Cohen, Francois Abel and Ian Vickridge –, Friedrich-Alexander University and Fraunhofer Institute for Integrated Systems and Device Technology, Erlangen, Germany – Heiner Ryssel, Lothar Frey –, Center for Quantum Science and Technology under Extreme Conditions, Osaka University, Japan – Mikio Takai, Fujio Wakaya.

In 1978, Joseph got the support to establish and organize the first meeting of the conference series – Ion Beam Modification of Materials in Budapest. Also, he was the chairman of the International Conferences of Ion Beam Analysis, 1993, Balatonfüred and Ion-implantation Technology, 2000, in Alpbach, Austria. At that time, *he probably was the only person to organize all three major international conferences on ion-implantation and ion beam analysis*. Let's not forget, he is also a founding member of the renowned Kaiserlich-Königliche Böhmisches Physikalische Gesellschaft.

In Hungary, Joseph established the research group of ion implantation and later the Microtechnology Department (Péter Keresztes, Tibor Mohácsy, Imre Szabó, István Bársony, Csaba Dücső, Tivadar Lohner, Miklos Fried, Gábor Battistig, Nguyen Quoc Khánh and others), initiated the group of Ion Beam Analysis (Endre Kótai, Ferenc Pásztai, Manuaba Asrama, Edit Szilágyi), and chaired for 8 years the Department of Experimental Physics of the Budapest University of Technology. He was the funding

director of the Research Institute of Technical Physics and Materials Science of the Hungarian Academy of Sciences and of the Institute for Materials Technology of the leading technology development corporation of Hungary, the Bay Zoltán Applied Research Nonprofit Ltd.

He was initiator of nanoscience and technology in Hungary. Until very recently he still lectured university courses on materials science and on micro- and nanotechnology. During his long career he published or co-authored more than 400 scientific papers, 3 fundamental books and 11 book chapters, 13 patents. He gave numerous well received talks at conferences and different schools of ion-implantation and ion beam techniques (Continuing Education Institute, NATO schools, etc.).

He was a.o. member of the Academia Europea, Fellow of the European Physical Society, Member of MRS, Member of the European Materials Research Society Executive Committee, of the International Union for Vacuum Science, Technique and Application, member of the EU-MNP Committee, Senior Member of IEEE, and member of the International Union of Pure and Applied Physics.

His achievements were acknowledged a.o. by the Honorary Citizenship of Hódmezővásárhely, by the Széchenyi Prize, by the Academy Prize, by the Commander's Cross with Star of the Hungarian Order of Merit and by the Medal of the Conference Radiation Effects on Materials (REM-7).

Besides his professional and artistic activity, Joseph always made efforts to think globally, not only in organizing and making new relations within the scientific community worldwide; he also distributed new ideas and demands for sustainable development and for the establishment of closed technology cycles in energy production, conversion, waste treatment and recycling processes, burning questions for nowadays society.

We will all miss his charming personality, creative thinking, his foresight, enthusiasm and drive to advance international collaboration by building bridges and connecting actors in different fields of academia and industry worldwide. His death is a great loss not only for the Hungarian science and education, but also for the international scientific community.