The Tribochemistry Award

Presented to

Dr. Stephen M. Hsu

In recognition of his outstanding contribution to tribochemistry by The Tribochemistry Technical Committee (Chair: Dr. Keiji Nakayama), Japanese Society of Tribologists (JAST) in September 2019 in “Tribochemistry Hakodate 2019”.

Dr. Stephen Hsu received BS from Virginia Tech, MS and PhD from Pa. State University. During his PhD study under Prof. Elmer Klaus, he was introduced to lubrication and Tribology. His thesis was to measure the reaction temperature under boundary lubrication conditions. Using chemical kinetics monitoring the oil soluble organometallic compounds, he was able to determine the reaction temperatures in boundary lubrication. He received the Captain Alfred Hunt Medal for his work. Ever since then, he has been intrigued with the complexity of lubrication processes. How the lubricant bond to the metal surface? How wear occurs? Upon graduation, he joined Amoco Chemicals to conduct research on lubricant additive development, additive mechanisms and how to apply additives in formulations. After four years, he joined National Institute of Standards and Technology (NIST) to lead the technical effort to establish standards to enable the use of re-refined oils in the US.. In order to link chemical composition to performance, he developed a suite of bench tests with statistical correlation to ASTM Sequence Engine dynamometer tests. The combined results of the testing provided the necessary data set to establish the equivalent Standard adopted by the US Government in 1982.

In 1983, Dr. Hsu established the Tribochemistry Group at NIST to study the molecular interactions of additive with metal surfaces. He pioneered the use of new instrumental techniques, such as laser scattering to study additive agglomeration interactions; HPLC-GFAA for quantitative measurement of organo-metallic species; Synchrotron radiation X-ray absorption spectroscopy to study molecular orientation of adsorbed species together with high resolution FTIR and Laser Raman spectroscopies to probe the basic molecular-surface interactions. These instrumental techniques provided the critical data for him to construct the sequences of boundary lubrication chemical mechanisms. He also designed and constructed a high sensitivity Chemiluminescence instrument to study the oxidation mechanisms and work

with industry to develop novel antioxidants. In the 1990s, he started to work with NSIC consortium on magnetic hard disk technology on monolayer lubrication and molecular lubrication of micro- and nano-scale devices. He conducted nano-scratch tests at that time to demonstrate the effect of plasma emission on enhanced chemical reactivity. During this time, he worked with industry, Department of Energy and Department of defense on advanced lubrication and lubricants for space, defense, and lubrication of non-conventional materials, such as coatings and ceramics.

In 1984, he was appointed the first Division Chief of Advanced Ceramics at NIST, overseeing the US National Ceramics program. In this role, he worked with DOE, DOD, Japan, Germany, and Finland under the International Energy Agency (IEA) to develop standards for ceramics to facilitate international trade of advanced materials. A total of 75 international standards were established by this activity. Besides leading the IEA effort at that time, he has continued to lead the IEA agreement on advanced materials to this date with 9 countries and 30 research institutes/universities.

While maintaining research effort in Tribochemistry, he started working on advance ceramics for adiabatic engines, wear, wear maps, wear prediction, and multilayer ceramics. He participated in the Wear conference and became the Chair in 1998. He also established an industrial consortium of artificial joints replacement materials producers for 7 years, and worked on improved materials, new test methods, surface textures, and lubrication for this industry.

In 2001, he was part of the US Nanotechnology committee ushering in the nanotech world. He developed nano-instruments to probe the physics and chemistry of nanoscale devices.

In 2008, he left NIST and spent 1 ½ years in City University of Hong Kong as Chaired Professor and Head of the Manufacturing Engineering Department, while affiliated with George Washington University where his students worked on surface texture design. In 2009, he returned to GWU to be part of the GW Energy Initiative.

Over the years, Dr. Hsu has worked with various industries in develop measurement technologies, new concepts, and innovations. Of the $25M research funding to date, some 40% came from industries directly. He has mentored over 130 students, visiting professors, and visiting scholars over the years.

He has published over 250 papers, a dozen of books/NIST Special publications, and invited chapters. He has received 10 US patents and has filed 4 world patents which are pending. He has published 3 best of the year papers. And he has delivered over 60 plenary/keynote lectures on various subjects that he is engaged in. He has received many awards, including US Department of Commerce Bronze Medal, Silver Medal, STLE International Award, Captain Alfred E. Hunt Memorial Medal, Al Sonntag Award, and he is a Fellow of STLE and ASME. He serves as Foreign Expert Reviewers on major programs for 7 countries.

Dr. Hsu has contributed to the ITCs and WTCs satellite forums on Tribochemistry for long years from the first time in Tokyo 1995 to Hakodate 2019.

He is indeed a worthy recipient of the world's highest honor in tribochemistry – The Tribochemistry Award for 2019.

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Dr. Jean-Michel Martin

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Jean Michel Martin was born in Burgundy, France, in 1948. From 1968 to 1973 he read from

University of Lyon as a chemical engineer and then as a surface chemist. He joined the Laboratory of Tribology at Ecole Centrale de Lyon in 1974 in the Material Sciences Department. He studied for a PhD under the supervision of Professor Jean-Marie Georges. He obtained his PhD in 1978 for a research entitled “*Anti-wear chemistry of zinc dithiophosphates*”. He has continued to teach and conduct research in boundary lubrication and becomes a full Professor in 1988 and a distinguished Professor in 2008. He became a member of the “University Institute of France” in 2001.

His career has been entirely devoted to tribology. He has more than 45 years of extensive experience in fundamental and applied research in tribology of thin films, gas phase lubrication, diamond-like coatings, boundary lubrication, anti-wear and extreme-pressure additives, friction modifiers and surface chemical analysis.

As a surface chemist, Professor Martin first research topic was the anti-wear mechanisms of zinc dithiophosphate. Since his PhD on this topic in 1978, He never stopped continuing this research field. In 1999, He introduced the Chemical Hardness concept to explain how abrasive wear is inhibited by the tribochemical reactions of ZDDP in steel contacts. Later, He studied multi-additive lubricants, friction modifying additives (MoDTC), overbased detergents and synergistic and/or antagonist effects between all these different additives.

In 1993, He discovered superlubricity of pure molybdenum disulphide MoS_2 in ultrahigh vacuum. Since this date he never stopped studying how to reach superlubricity (friction coefficient below 0.01) in practical situations, including in presence of a liquid lubricant

under boundary conditions. In 2004, a new discovery was made of superlubricity of diamondlike coatings in presence of ester of polyols.

Professor Martin has developed a new lubricant technology containing no heavy metals, no phosphorous and sulfur and no toxicity. Green lubricants were optimized for DLC coatings (mainly ta-C). Results lead to several papers and 8 patents in collaboration with Japanese companies. The result was the mass production of such carbon coatings for the Asian market (more than one hundred millions engine parts coated since 2006).
A book "superlubricity" was edited in 2007 on this topic (with Ali Erdemir from Argonne USA) and a second edition will be delivered in 2019.

In the 2000's, Professor Martin studied nanoparticles as lubricant additives because they do not need temperature to be activated. Many materials were systematically investigated: bucky balls, nanotubes, carbon onions, fullerenes etc. Mechanisms of action of nanolubricants were optimized for industrial applications. A book on this topic "Nanolubricants" was co-edited with Nobuo Ohmae from Kobe University.

From his education as a surface chemist, Professor Martin tried to implement new analytical techniques for tribofilm analyses (XPS/AES/ToF-SIMS, XANES, Raman etc.). He published the first paper using synchrotron radiation applied to lubrication studies.

In 2005, He pioneered the use of computer simulations in lubrication studies and particularly molecular dynamics (MD) coupled with quantum chemistry (QM). He has developed several collaborations with Japan (Tohoku University), Italy (University of Modena) and US (Caltech). Nowadays, computer simulations are routinely used in papers dealing with tribochemistry.

Since his retirement from ECL in 2012, Professor Martin is an emeritus professor who never stopped research so that he has several PhD students under his supervision.

Professor Martin had had many international collaborations and research contracts with car manufactures: Renault (France), Ford (US) Nissan and Toyota (Japan) and with lubricant suppliers: Total (France), Idemisu and Nippon Oil Co., (Japan).

Throughout his carrier Professor Martin has published more than 300 referred papers and has received the "Bunshan Award "at ICMCTF in San Diego and the Carlos Gohn Award in 2007 He has written 10 book chapters and has 12 international patents.

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Dr. Hugh Alexander Spikes

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Hugh Alexander Spikes was born in London in October 1945 and grew up in Birmingham in central England. From 1965 to 1968 he read Natural Sciences at the University of Cambridge, with a focus on Chemistry, before joining the Lubrication Laboratory in the Mechanical Engineering Department at Imperial College London in 1968 to study for a PhD under the supervision on Professor Alastair Cameron. He obtained his PhD for research entitled *Physical and Chemical Adsorption in Boundary Lubrication* in 1972 and then worked as a research assistant on the design of helicopter lubricants and other projects before joining the staff of the Mechanical Engineering Department as a Lecturer in 1978. He has continued to teach and to supervise research in Tribology at Imperial College ever since, becoming Reader and joint Head of the Tribology Group in 1992 and Professor and Head of the Group in 1996. In 2011 he retired from the academic staff and was reemployed as a Senior Research Investigator and Emeritus Professor to focus on Tribology research, continuing to serve as Head of the Tribology Group until 2016. Under his guidance the Tribology Group has grown to five full time academic staff and more than 50 current PhD students and postdoctoral research assistants and fellows. Professor Spikes still supervises PhD and postdoctoral research within the Tribology Group at Imperial College

The focus of Professor Spikes’ research has been on the molecular origins of the behaviour of lubricants and has spanned all the lubrication regimes from hydrodynamic through to boundary lubrication. Two particular fields of research interest have been the development of new experimental techniques and tribochemistry.

In 1989 Professor Spikes and his team extended the optical interferometry method to measure very thin films, down to about one nanometer. This enabled boundary lubricant films to be studied *in situ* in high pressure contact for the first time and has led to major advances in our understanding of thin film lubrication. The ultrathin film interferometric test apparatus

developed by Professor Spikes is currently in routine use in numerous oil and additive companies and several academic establishments around the world.

Professor Spikes has worked extensively in the study of film-forming lubricant additives and their influence on friction and wear. His work on thin film lubrication has helped resolved the long-standing debate about the thickness of organic friction modifier films and has led to new strategies for the development of fuel-efficient engine oils that are now widely used by the additive industry. His research on ZDDP and other phosphorus-based antiwear additives provided the first definite evidence of the thick film, solid-like nature of the films formed by such additives during rubbing and the consequent origins of their antiwear performance. Recently he highlighted the importance of mechanical stress in controlling the rates of many tribological processes and has demonstrated conclusively that some lubricant additive reactions are driven by shear stress and are thus a manifestation of mechanochemistry.

An important feature of Professor Spikes' research is that much of it, despite being fundamental in nature, has been carried out in collaboration with industry. This is reflected in more than 120 joint publications with collaborators from more than 30 companies. This close industrial connection has also ensures that Professor Spikes research has had strong impact not only within the academic tribology community but also within industry.

Throughout his career Professor Spikes has published more than 300 refereed research papers and has received ten best paper awards, from the Institution of Mechanical Engineers (IMechE), the American Society of Mechanical Engineers (ASME) and the Society of Tribologists and Lubrication Engineers (STLE). In 2004 he was awarded the International Award from STLE, the Mayo D Hersey Award from ASME and the Tribology Trust Tribology Gold Medal for his research contributions to Tribology. He is a Fellow of the IMechE and of the Royal Academy of Engineering.

Dr. Spikes has contributed to the ITC and WTC satellite forums on Tribochemistry for many years including the very first one in Tokyo 1995.

He is indeed a worthy recipient of the world's highest honor in tribochemistry – The Tribochemistry Award for 2019.