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# Biography of Ming-Chang Lin

M. C. Lin was born in the small farming village of Chao-meng (literally "the Lighted Gate") in the township of Hsin-pu (or "New Field") where the residents speak primarily Hakka, a dialect used by about 15% of the population in Taiwan. After nine years of primary and secondary education in his local schools, he passed a highly competitive entrance examination and was admitted to Hsin-chu Senior High where he was a classmate of Yuan T. Lee, a 1986 Nobel Laureate for chemistry working in the area of reaction dynamics (sharing the prize with John C. Polanyi and his mentor Dudley Herschbach).

After graduation from Taiwan Normal University (which is a preparatory college for secondary school teachers) and 2-year ROTC training, M. C. decided to go abroad for graduate studies in North America. Despite other scholarship offers in the U.S., he went to the University of Ottawa (UO) to join Prof. Keith J. Laidler's laboratory in 1962 because he enjoyed reading his book on Chemical Kinetics as an undergraduate student. In Laidler's laboratory, guided by Laidler and his then postdoctoral research fellow Margaret H. Back (wife of photochemist Robert A. Back of National Research Council (NRC) in Ottawa), M. C. thoroughly enjoyed Laidler's courses on Advanced Chemical Kinetics and Kinetics in Solution, as well as the Quantum Chemistry course given by Richard W. F. Bader. In addition, he was inspired by the many great seminars given by then well-known kineticists and spectroscopists who visited UO. M. C. also attended seminars at the nearby NRC, and the talks given by such luminaries as R. G. W. Norrish, George Porter, and G. Herzberg, among others, are still deeply engraved in his mind.

After three years of graduate work (1962−1965), M. C. chose to remain at UO for his postdoctoral research and apply the RRKM theory to interpret his experimental data on the unimolecular decomposition of ethane and ethyl radicals. With a computer subroutine generously provided by Prof. B. S. Rabinovitch of the University of Washington, he wrote a Fortran program to calculate the *P*,*T* effects on rate constants for the unimolecular decomposition of $C_2H_6$, $C_2H_5$, and $CH_2OCH_3$. The kinetics for the latter two radical reactions had been provided in detail using the mercury-photosensitization method by his contemporary in Laidler's group, Leon F. Louks. Another contemporary in Laidler's group who later became known for his work on chlorocarbene chemistry was Michael T. H. Liu. Both Liu and Louks joined the faculty of the Chemistry Department at the University of Prince Edward Island in Canada.

After M. C.'s five-happy-year stay in Ottawa (where he married J. H. (Judy) Chern soon after completion of his Ph.D. dissertation), he accepted an offer from Prof. Simon H. Bauer's laboratory at Cornell University (the Baker Laboratory) in the fall of 1967 to embark on high-temperature shock tube kinetics

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on the oxidation of CO by $N_2O$ and $F_2O$ in an attempt to produce vibrationally excited $CO_2$ for chemical laser generation. The former process was found to be too slow, whereas the latter was potentially quite likely to generate chemical laser action in both HF and $CO_2$, if $H_2$ was present through the chain processes, $F + H_2 \rightarrow HF + H$, $H + F_2O \rightarrow HF + FO$ and $FO + CO \rightarrow F + CO_2$. No attempt was made to set up an appropriate oscillatory optical cavity until M. C. left for the U.S. Naval Research Laboratory in 1970.

M. C.'s stay at the Baker Laboratory was intellectually very rewarding. Bauer's Friday brownbag lunch seminars given by students (such as Tom Baer, Mark Cardillo, Dick Hildebrandt, among others), postdoctoral research associates (C. H. Chang, Nick Zavos, and Hans Henrici), and occasionally by internationally renowned visitors such as Henry Eyring were often illuminating. In Eyring's memorable talk, he mentioned that "it is fun to be a scientist as a career. One never runs out of ideas. If it happens, go to write a book. After the completion of a book, all kinds of ideas may pop up!" An important event that occurred during the two years at the Baker Laboratory was the presentation of the Baker Lecture by G. Herzberg on the subject of alkyl radical spectroscopy, focusing on $CH_2$ and $CH_3$ at the time. The VUV Rydberg state spectroscopy of $CH_3$ in the 150 nm region was later employed as a stepping stone for its (3 + 1) REMPI (resonance-enhanced multiphoton ionization) at the Naval Research Laboratory (NRL).

In his second year at the Baker Laboratory, M. C. began to search for a research or teaching position. A couple of weeks before the interview for a job opening in Art Fontjin's group at Aerochem in Princeton, M. C. was asked by Prof. Bauer if he would be interested in a research position at NRL in Washington, D.C. to establish a chemical laser research program. The offer was delightedly accepted; it set the course of M. C.'s 18-year research career at NRL.

NRL's academia-like environment for mission-tailored basic research, similar to DOE's national laboratories, with an attractive postdoctoral program managed by the National Research Council, offered a great opportunity for the pursuit of fundamental scientific research. M. C.'s career at NRL covered a wide variety of interesting subjects: chemical lasers (with Si Bauer, Lou Brus, Bill Green, Teman Burks, and Laura Colcord), state-to-state chemistry ($NO + O_3(001)$ with Bob Gordon, $O + HCl(v = 1)$ with Geoff Smith and Jim Butler, $O(^1D) + CO(v = 0)$ with Bob Shortridge, $Na(^2P_J) + CO(v = 0)$ with David Hsu), combustion chemistry (with David Hsu, Walter Shaub, C.-Y. Lin, Tarun Choudhury, and Bill Sanders), Jovian atmosphere chemistry (with Jim Butler, Jim Fleming, Mike Berman, Dan Lichtin, and Steve Zarbanick), free radical REMPI spectroscopy (with Tom DiGiuseppe, Jeff Hudgens, and Chuck Dulcey), and the formation and reactions of free radicals in gas−surface reactions studied by laser-induced fluorescence and REMPI-MS (with Larry Talley, Gary Selwyn, Dave Hsu, Mark Hoffbauer, David Squire, John Dagata, Chuck Dulcey, and Jim Horwitz). The latter three projects were densely packed in the early 1980s when all of the talented and devoted NRC Research Associates arrived from the nation's top institutions. The appearance of Lou Brus, a truly original thinker, at NRL in early 1970s is worth noting. Lou spent five years at NRL for his ROTC-related service. Initially, Lou carried out an interesting study of the reactions of $O_3$ with Si surfaces. The collaboration of M. C. with Lou Brus began when Lou visited M. C.'s laboratory and became interested in M. C.'s chemical laser project. Their work together resulted in a couple of papers. Lou then embarked on the laser-induced $SO_2$ fluorescence and energy-transfer work with Jimmy McDonald, who had a very successful research career at NRL before he retired as Head of the Optical Diagnostics Branch a few years ago.

Among the several new initiatives in the 1980s, three studies are particularly noteworthy. After the arrival of Tom DiGiuseppe from Boston College, M. C. became interested in REMPI spectroscopy for "dark" radical detection by mass spectrometry, which affords both wavelength and mass selectivities. With the consent of Jeff Hudgens, who was then a staff member in the Mass Spectrometry Section headed by Jim DeCorpo under Fred Saalfeld (an outstanding administrator who later became Technical Director of the Office of Naval Research), Tom and Jeff jointly embarked on the REMPI spectroscopy of several prototypical radicals; heading the list were $CH_3$, $^3CH_2$, $C_2H_3$, and $C_6H_5$, all of which are key combustion species whose direct optical detection by laser excitation was still elusive at the time. Among the radicals originally tried with Hudgen's high-power manually tunable dye laser (the only suitable instrument then available in the entire Chemistry Division), $CH_3$ REMPI was successful. Tom's skill and persistence allowed him to obtain many detailed spectra by manual scanning. Jeff and his collaborators later extended the studies to many other substituted alkyl radicals in a series of elegant experiments.

At the same time in another lab, Mike Berman and Jim Fleming initiated a series of CH radical kinetic measurements for a NASA-sponsored project. CH was known as a key radical in the Jovian atmosphere produced by solar photolysis of $CH_4$ and was assumed to react with H-containing species (R−H) by an insertion mechanism that produced hot $RCH_2$ radical adducts. Mike carried out a series of studies that included the reactions of CH with $H_2$, $CH_4$, $C_2H_6$, $C_2H_2$, $C_2H_4$, $NH_3$, CO as well as $N_2$. RRKM analyses of the kinetic data confirmed the insertion/stabilization−decomposition-type mechanism. The results for the reactions of CH with $H_2$ and $N_2$ revealed strongly V-shaped Arrhenius plots, reflecting the dominating stabilization mechanism at low temperatures with a negative *T*-dependence and the decomposition of adducts at high temperatures by overcoming exit barriers that lie above the reactants. The observed V-shaped Arrhenius plots, although quite rare then, were fully explained by RRKM theory. The reaction of CH with $N_2$ at high temperatures also turned out to be of great importance in combustion chemistry, being responsible for the formation of prompt NO in flames.

Concurrently in another laboratory, Larry Talley and later David Hsu were successfully characterizing the rotational and vibrational energies of OH radicals desorbing from polycrystalline Pt surfaces under low-pressure flow conditions. The experiment was later moved to an ultrahigh vacuum system constructed by David Hsu and Mark Hoffbauer. The system was utilized for studies of OH as well as NO molecules formed in Pt(111) catalyzed reactions (e.g., oxidation of $H_2$ and $NH_3$). Interestingly, the well-known rotational cooling was detected more pronouncedly in NO than OH and the extent of cooling in NO was quite similar to that observed in beam-surface scattering studies reported by the laboratories of Dick Zare (on Ag(111)) and G. Ertl and G. Somorjai (on Pt(111)) around the same time.

While the aforementioned reaction kinetics, free radical REMPI, and gas−surface reaction dynamics were progressing robustly in the laboratories by many talented collaborators, M. C. headed for Germany in the fall of 1982 with his entire family for his one-year sabbatical in G. Ertl's labortatory, then at the University of Munich, supported by a Guggenheim Fellowship and a Humboldt Senior U.S. Scientist award. M. C. helped the

group set up an excimer pumped dye laser system for studies of $NO_2$ scattering from Au and Ge surfaces. He and his family had a most memorable stay in the beautiful and orderly city of Munich and made tours of several Western European countries.

M. C.'s move to academia had been percolating in his mind since the mid-1980's after his sabbatical. His move to Emory as Robert W. Woodruff Professor of Physical Chemistry should be credited to Joel Bowman who invited M. C. to visit the university campus and present a departmental seminar in the fall of 1986. The location and environment of the university and its ambitious plan to build the Chemistry Department gave M. C. "a love at first sight" feeling after he had earlier visited the University of Iowa and the San Diego State University for the potential move. M. C. completed his move to Emory University in the fall of 1988 after his years of challenging but enjoyable civil service at NRL. His stay at Emory University has undoubtedly been the most productive and intellectually rewarding period of his research career through productive collaborations with his colleagues (such as Joel Bowman and Keiji Morokuma) and numerous creative and hard-working students and postdoctoral research associates. M. C.'s commitment to education was reflected by his enthusiasm for teaching. Although the terms of his appointment did not obligate him to do so, M. C. consistently accepted a full teaching schedule. During the period of M. C.'s tenure at Emory, 1988−2005, he and his group produced roughly 270 refereed papers. This work spanned the fields of gas-phase reaction dynamics, combustion chemistry, gas−surface interactions and thin-film deposition. M. C. pioneered the use of cavity ring-down spectroscopy as a means for studying the kinetics of reactive intermediates. This technique was used to explore a wide range of reactions of the phenyl radical, many of which are important in the early stages of soot formation during hydrocarbon combustion. Another major contribution to combustion research was M. C.'s discovery of the mechanism for prompt NO formation. This was one of the results from M. C.'s new thrust in computational chemistry that he embarked on after his arrival at Emory. M. C. fully recognized the power of theoretical ab initio calculations when applied to chemical kinetics, in particular when they are combined with RRKM theory for prediction of accurate reaction rate constants and product branching ratios at different pressures and temperatures. His "love affair" with quantum chemistry started from his fruitful collaboration with Carl Melius (Sandia National Laboratory). In the mid-1990s, together with Keiji Morokuma, he developed new theoretical schemes for reliable calculations on radical reactions. He successfully employed the ab initio/RRKM theoretical approach to characterize a wide variety of combustion processes, ranging from the reactions of vinyl and phenyl radicals involved in the formation and growth of aromatic compounds to $NO_x/NH_y$ reactions critical for the $DENO_x$ and $RAPRENO_x$ processes. In recent years, M. C. has extended his theoretical ab initio/RRKM studies to aid in the interpretation of experimental crossed molecular beam measurements by the groups of Y. T. Lee, Y.-P. Lee, C.-K. Ni, and J.-J. Lin.

M. C. has received numerous awards during his career, including the Hillebrand Prize, Chemical Society of Washington (1975); Physical Sciences Award, Washington Academy of Sciences (1976); Pure Science Award, Sigma Xi, NRL Chapter (1978); Navy Meritorious Civilian Service Award (1979); John Simon Guggenheim Fellow (1982−1983); Alexander von Humbolt Award, Bonn, Germany (1982); Taiwanese-American Foundation Prize for Science & Technology (1989); and the Robert Dexter Conrad Award for Scientific Accomplishment (U.S. Navy, 1998). He is a member of the National Academy, Taiwan (Academia Sinica).

On September 1, 2005 M. C. became "Woodruff Emeritus Professor" and also a "Woodruff Senior Research Associate". While maintaining a research group at Emory, M. C. currently holds multiple positions in Taiwan. He is the director of the Center for Interdisciplinary Molecular Science, TSMC (Taiwan Semiconductor Manufacturing Co.) Distinguished Professor, NSC (National Science Council) Distinguished Visiting Professor, and University Distinguished Professor at National Chiao Tung University, Hsinchu, Taiwan. His research program is stronger than ever, and we are sure that he will continue to enrich both the field of Physical Chemistry and the community of scientific scholars for many years to come.

**Joel M. Bowman**
**Michael C. Heaven**
**Yuan-Pern Lee**