

## Mihir Chowdhury (1937–2017): scientist and teacher extraordinaire

*Scientific and technical biography throwing light on how Mihir Chowdhury's research interest evolved during his active years in science and how he innovated in both teaching and research.*

Henry Smith wrote 'A teacher can affect eternity; he does not know when his influence comes to an end'. The sad demise of Professor Mihir Chowdhury (formerly Head, Department of Physical Chemistry, Indian Association for the Cultivation of Science (IACS), Kolkata) on 28 March 2017 brought to the fore the deep truth of Smith's observation<sup>1</sup>. Protracted and debilitating illness kept him away from active science for over a decade or so; yet the news of his passing away evoked a spontaneous and acute sense of loss among his numerous students, colleagues and admirers spread all over the country. It was the end of an era, many felt; but as a teacher he had kindled so many young minds and shaped their destiny that his subtle influence, they hoped, would live on, enduring the test of time.

### The man

To the discerning and perceptive observer, Chowdhury appeared to be poised between two worlds – one tradition and old values, and another of pure reason and rationality. The former made him the unmistakable aristocrat that he was; a towering personality without the imperiousness generally characteristic of such personages. He was kind and benign and refused to stoop low, no matter what the provocation was. The latter helped him imbibe the qualities of a great scientist and teacher who could kindle the spirit of enquiry in young minds, encourage them to question, debate and discover the sheer pleasure of learning. As a scientist he was an explorer of innovative ideas, who would never settle for anything that was ambiguous, imprecise or inaccurate.

When Chowdhury came to head the Department of Physical Chemistry at IACS in 1976, he faced a formidable challenge – he was leaving the niche he had carved out for himself in the famous Presidency College (now Presidency University), Kolkata, his alma mater, where he became professor of chemistry at a young age of 28, and where his legendary teaching skill grew and attained stellar heights during the ten years

(1966–76) of his tenure there. At the same time, he was moving to IACS to succeed Professor S. R. Palit, the undisputed emperor of polymer chemistry in India in those days. The Department was indeed well known for its contributions to polymer and solution chemistry. Chowdhury's task was cut out: he would have to reshape, remodel and refashion the Department into a modern centre of physical chemistry. He had the clear vision and meticulous planning that the task called for. He also had the innate ability to spot and nurture talent. No wonder he was able to transform the



Department into a vibrant centre of excellence where atomic and molecular spectroscopy, photochemistry, photodynamics and theoretical chemistry flourished in all their splendour. Under his able leadership of two decades and a half, the Department reached the zenith of its reputation both in the national and international arena of modern physical chemistry. Chowdhury not only believed that a scientist must be able to think and grow freely, but also practised it with the sincerity of a true believer. The freedom that he gave to his students, the spirit of enquiry that he fostered among his colleagues, and the lively interest that he always displayed in any new development are examples of qualities rarely met in these days of quick results and fashionable pursuits. The depth and the breadth of expertise that the department acquired during his tenure is not just a testimony to his qualities, but a tribute to his astute guidance which inspired through personal example. Chowdhury was a born teacher and did not give up

teaching even during the busiest part of his career as a scientist. He was no orator; it was the depth of his analysis and crisp logic-based articulation of a subject from scratch that enthralled the students and made the classroom alive.

### The scientist

The research activities of Chowdhury were varied, full of ingenuity, novelty and imagination. They reveal a sharply analytical and creative mind. He was a spectroscopist in the classical mould, and elegantly focused on both linear and non-linear domains to probe the systems he worked on. His penchant for working on 'clean' systems and 'precise' measurements naturally drew him to low-temperature spectroscopy of single crystals doped with transition metal or rare earth (RE) ions.

### *Low-temperature single-crystal spectroscopy*

During the initial days of his research career in India, Chowdhury was a full-time professor of chemistry in Presidency College, Kolkata, teaching a host of subjects (thermodynamics, spectroscopy, group theory, quantum mechanics) at the UG and PG levels, and shared time between his laboratory in the College and the one in the erstwhile Department of Magnetism in IACS (now the Department of Solid State Physics), where he spent two years as a CSIR pool officer (1964–66) after returning from USA. His focus was on low-temperature polarized one-photon absorption (OPA) and emission (OPE) spectroscopy of single crystals of transition metal complexes like  $K_3Cr(CN)_6$ ,  $K_3Mn(CN)_6$ ,  $Co^{+3}$  doped in  $CsCdCl_3$ , etc. Several spin-forbidden transitions in potassium chromicyanide ( ${}^4A \rightarrow {}^2A_2$ ,  ${}^2E$  and  ${}^2T_1$ , for example) were located and analysed in the low symmetry field and  $g$  value in the  ${}^2E$  state was determined accurately<sup>2–5</sup>. It was clear that Chowdhury intended to blend experiments with appropriate theoretical calculations to remove any ambiguity in

assignments and construction of energy-level diagrams of the transition metal ions in different chemical environments. During this period, he succeeded in setting up a pulsed magnetic field (7–8 tesla) generator (locally fabricated) and integrated it with a Karl Zeiss spectrograph. He leveraged the integrated system to measure Zeeman splittings of several transition metal and rare earth single crystals<sup>6</sup> at low temperatures.

### *Spectroscopy of multichromophoric organic molecules (phase I)*

Chowdhury also started taking interest in the low-lying excited states of organic molecules containing multiple chromophores such as 2,2'-pyridil, mesityl, benzil, indantrione, alloxan, etc. Vicinal di and polyketones were convenient examples of molecules with several low-lying  $n\pi^*$  states, which provided the opportunity to gain insight into the fine balance between the 'through-bond' and 'through-space' interactions that shaped the dispositions of these electronic states. Here too, Chowdhury displayed his basic ambidextrous disposition. He deftly combined available theoretical tools with polarized (one-photon) absorption and emission spectroscopy to locate the electronic states responsible for the observed absorption and emission spectra<sup>7–9</sup>.

### *Spectroscopy of rare earth single crystals*

Even at low temperatures (liquid N<sub>2</sub>, liquid O<sub>2</sub>), the single crystals of transition metal complexes produced absorption bands that were too broad for Chowdhury's comfort. Since f-electrons in lanthanides are not as much exposed to the immediate chemical environment, the forbidden  $f^n-f^n$  one-photon transitions produced much sharper line shapes by forced electric dipole mechanism. Such transitions yielded valuable information about the odd and even components of the crystal or the ligand fields. Pr<sup>3+</sup> (HAPI) and Nd<sup>3+</sup> (HAPI) single crystals were the first rare earth systems to be studied by his group in IACS, that unearthed valuable information relating to the energy levels, selection rules, mechanism of intensity generation, etc. in rare earth single crystals, centrosymmetric or non-centrosymmetric<sup>10,11</sup>.

### *Two-photon spectroscopy*

The advent of lasers opened up new avenues for probing the rare earth systems by making use of nonlinear spectroscopy. The simplest nonlinear tool that Chowdhury and his associates exploited for  $f^n-f^n$  transitions was two-photon absorption (TPA) spectroscopy.  $f^n-f^n$  transitions are intrinsically two-photon allowed. If the crystal was centrosymmetric, TPA would allow them to locate the phonon free '0–0' bands exactly. In addition, the different selection and polarization rules operative for two-photon transitions could allow them to locate a term or its crystal field components missed out in one photon absorption (OPA) spectrum. The two-photon spectra of single crystals of gadolinium-DG (non-centrosymmetric)<sup>12</sup> and Gd-elpasolite (centrosymmetric)<sup>13</sup> provided valuable information about states not seen in the OPA spectrum. The initial foray into two-photon spectroscopy excited his keen interest in polarized two-photon absorption, wherein selection and polarization differentials could be expected to shed light on the nature of the electronic energy levels more completely. Chowdhury turned his attention to double and triple molecules in which two or more  $\pi$ -chromophoric units weakly interact causing splittings in the energy levels<sup>14</sup>. The double molecules and the exciton splitting displayed by them were well known. Little was known at that time about the splitting patterns in triple molecules like triptycene, in which the basic  $\pi$ -chromophores are benzene  $\pi$ -systems, three of them being weakly coupled. Group theoretically the lowest <sup>1</sup>B<sub>2u</sub> states of benzene would be expected to split into E' and A<sub>1</sub>' states due to excitonic interactions among the three benzene units under D<sub>3h</sub> symmetry. One photon absorption spectroscopy allowed them to see only the E' state. Was there another state hidden under the rather strongly allowed one photon transition? His group tried to provide a definite answer to the query by resorting to two-photon absorption spectroscopy with linearly and circularly polarized light. Elementary group theory suggests that the one-photon transition to state A<sub>1</sub>' is forbidden in linearly polarized light, while transition to the E' state is allowed in both x and y polarizations. In TPA, on the other hand, A<sub>1</sub>' is strongly allowed in linear polarization while E' is rather weakly allowed.

In circularly polarized light, however, E' is strongly allowed while A<sub>1</sub>' remains only weakly allowed in two-photon absorption. By comparing polarized one- and two-photon absorption spectra of triptycene, Chowdhury and associates succeeded in locating two excited electronic states, one at 2500 cm<sup>-1</sup> above the other<sup>15</sup>.

### *Jet-cooled molecular spectroscopy*

In the 1980s, laser-induced fluorescence spectroscopy of molecules cooled in supersonic jets grew into a powerful method of probing vibrational-level structures and intramolecular dynamics. In the rarefied atmosphere following expansion in a jet and the resultant cooling, the molecules are not only isolated but also have very low vibrational and rotational temperatures. The state in which molecules are prepared is well defined. The spectrum is free of hot bands and is therefore amenable to clear assignments. Chowdhury's attention was focused on the possibility of using the jet expansion technique to probe low-frequency, highly anharmonic, large amplitude motion of nuclei and exploiting the information to construct the excited state potential energy surfaces on which the nuclear dynamics took place. To achieve this objective he needed a supersonic jet expansion set-up, which was designed and fabricated in the IACS workshop. The vacuum was maintained at 10<sup>-4</sup> torr. The samples (dihydroanthracene, 9,10-dihydrophenanthrene, etc.) were expanded against the vacuum with He or Ar as carrier gas through an orifice of 0.5 mm in a homemade, magnetically controlled, pulsed nozzle valve. It had a repetition rate of 10 Hz. The fluorescence spectrum of dihydroanthracene, for example, could be mapped onto an excited-state double minimum potential with a barrier height of 94 cm<sup>-1</sup> (ref. 16); also see for additional examples of laser-induced fluorescence spectroscopy of jet cooled molecules undertaken by Chowdhury and associates<sup>17–22</sup>. We may mention their study of butterfly inversion of perfluoronaphthalene, ring inversion of dihydronaphthalene, low-frequency vibrations in S<sub>0</sub> and S<sub>1</sub> states of 1,2,3,4-tetrahydronaphthalene<sup>20</sup>, and THIQ in supersonic jet<sup>22</sup>. His group members carried the work forward in other institutes and broke new grounds.

*Magnetic field effects in chemistry*

Chemists have long been fascinated by the possibility of low external magnetic fields affecting the outcome of a chemical event. After an initial spate of controversies and doubtful explanations for the observed effects, it has now been accepted as something real and interesting. It is firmly established that chemical processes involving radical-pair intermediates can be influenced by external magnetic fields which act upon the system to alter the rates of processes, their yields and product distributions. The most completely understood and thoroughly studied among the magnetic field effect (MFE) has been the effect of low magnetic fields on the spin rephasing dynamics of a solvent-separated radical pair generated in a spin-conserving process. In the absence of an external magnetic field, the singlet ( $S_0$ ) radical ion pair (a non-stationary spin state) evolves reversibly into each component of the degenerate triplet ( $T_0, T_{\pm}$ ) and vice versa, due to electron–nuclear hyperfine interaction. The low field lifts the triplet degeneracy and blocks the  $S_0 \leftrightarrow T_{\pm}$  interconversion. The net outcome is an altered steady-state distribution of triplet and singlet radical pairs, which affects photophysical and photochemical outcomes that critically depend on this distribution. Chowdhury and his associates began looking into the effects of low magnetic fields on the pyrene-N,N-dimethyl aniline exciplex luminescence in methanol. They did not use the procedure of Weller, who followed the triplet yield by measuring triplet–triplet absorption or delayed fluorescence. Instead, they decided to follow the exciplex luminescence by an improved phase-sensitive, indigenously developed detection method (see ref. 23 for details of circuitry and instrumentation). The idea was that the external magnetic field lifts the triplet degeneracy and lowers the triplet yield while simultaneously increasing the complementary exciplex fluorescence yield. The  $B_{1/2}$  values measured by Chowdhury and his associates<sup>24</sup> ( $B_{1/2}$  value represents the strength of the magnetic field at which half the saturation is reached and gives a good measure of the hyperfine strength) are in very good agreement with those of Weller *et al.*<sup>25</sup>. The technique was extensively used to probe MFE on exciplex luminescence, for example, from 9-

cyanophenanthrene-trans anisole system<sup>26</sup>, to analyse typical and atypical effects of solvent dielectric constant on the MFE in exciplex emission<sup>27</sup>, anisotropy in MFE on the DPH–DMA exciplex luminescence in viscous media<sup>28</sup>, time-resolved analysis of MFE on exciplex luminescence, solvent dependence of MFE in polymer-linked DA system<sup>29</sup>, MFE in a polymer-chain linked donor–acceptor systems<sup>30</sup>, magnetic field-mediated control of back electron transfer following photoinduced electron transfer in biphenyl pyrylium in SDS micelles<sup>31</sup>, and many others. The work of Chowdhury and his associates on MFE in chemistry was noticed, and soon the laboratory became an important and integral part of the global network of spin chemistry or spin dynamics centers.

*MCD, CD and ORD spectroscopy*

Chowdhury had an abiding interest in chirality and the magnetic field. After experimenting with his pulsed magnetic field set-up for measuring Zeeman splittings of energy levels of transition and rare earth ions, he turned his attention to magnetic circular dichroism – the differential absorption of left and right circularly polarized light in non-chiral samples induced by a strong magnetic field applied in a direction parallel to the direction of light. His interest was in detecting transitions that are too weak to be seen in normal absorption spectra, and determine the symmetry of the energy levels associated with metal ion sites. His group also started measuring the circular dichroism (CD) and optical rotatory dispersion (ORD) spectra of chiral samples. Although CD and ORD were already established as modern spectroscopic tools, magnetic circular dichroism (MCD) discovered by Michael Faraday was not really recognized as a useful form of spectroscopy before 1960s – it was relegated to the realm of mere scientific curiosity. Chowdhury and his associates fabricated and set up an MCD unit from scratch, standardized the technique and started doing serious experiments<sup>32</sup>. The absorption, CD and MCD spectra of rare earth carboxylates (Pr : DG)<sup>33,34</sup>, and optical activity of rare earth crystals (Eu : DG) were recorded and explained in detail<sup>35–37</sup>. Circular dichroism in Gd–DG single crystals<sup>38</sup>, of  $\text{Eu}^{3+}$  and  $\text{Nd}^{3+}$  in  $\text{K}_3\text{Nd}_2(\text{NO})_3$  single crystals<sup>39</sup>, resonance

effects in second Harmonic generation in lanthanide crystals: Gd–DG (ref. 40), chiro-optical activity of  $^8s \rightarrow ^6p$  transition in Gd : Pg and low-temperature phase transition in crystals of an optically active complex are some of the other interesting works in this area that reveal his depth and versatility. His group identified  $\Delta J = 0, \neq 1$  transition in  $\text{La}^{3+}$  in Er : DG and  $\text{Er}^{3+}$  PG single crystals<sup>41</sup> through deft use of circular dichroism. Linear dichroism spectra of cubic sodium uranyl acetate single crystals and direction-dependent circular dichroism in the same system<sup>42,43</sup> are two other examples of his mastery over the technique. The contribution of electric quadrupole mechanism to the chirality of optically active cubic sodium uranyl acetate single crystals was estimated by his group by measuring the direction dependence of circular dichroism spectra of the crystal. They found that the CD bands for the  $E_g^+ \rightarrow \Delta_g$  transition were direction-dependent, while the bands for  $\Sigma_g^+ \rightarrow \Pi_g$  were direction-dependent for light propagation direction  $k$  parallel to the (100) and (111) directions of the cubic cell. It was estimated that the contribution of the electric quadrupole mechanism to chirality relative to that of magnetic dipole mechanism was approximately 20%. The  $A_1 \rightarrow A_1$  transition in trigonal Pr : DG single crystals ( $\text{Na}_3\text{Pr}(\text{C}_4\text{H}_4\text{O}_5)_3 \cdot 2\text{NaClO}_4 \cdot 6\text{H}_2\text{O}$ ) is forbidden. Chowdhury and his associates found that the transition could be intensified and located by the application of a high magnetic field that causes mixing of electronic states, allowing the transition to gain intensity<sup>44</sup>. His work on the use of lanthanide chirality as a tool for identifying a magnetic dipole transition in Tm : PG stands out in novelty<sup>45</sup>.

*Spectroscopy of multichromophoric organic molecules (phase II)*

Spectroscopy of organic chromophores containing weakly coupled multiple electronic systems, or molecules with multiple carbonyl groups has been a recurrent theme for Chowdhury's research. Recording and interpreting the spectrum of benzil<sup>46</sup> and then deciphering the 6500 Å transition of thiobenzene<sup>47</sup> marked the beginning, and with the advent of lasers was followed up by investigations into the possibilities of conformational relaxation in the excited states of benzil and naphthil<sup>48</sup>, analysis of fluorescence

from the relaxed and unrelaxed excited states of benzil<sup>49</sup> interpreting the nature of level splitting in one- and two-photon spectra of trans-dimer of acenaphthylene<sup>14</sup>. His emphasis was on completely understanding the nature and dynamics of excited states. The interest took him naturally to explore, as we have already described, laser-induced fluorescence spectroscopy of organic molecules in cooled supersonic jets in order to obtain information about the excited state potential energy surfaces of these molecules. Chowdhury was deeply interested in setting up a UV-IR double resonance system in IACS, but rapidly declining health prevented him from pursuing the project further. Unusual emission from molecules attracted his attention, for example, S<sub>1</sub>, S<sub>2</sub>, T<sub>1</sub> emissions from 3,6-diphenyl S-tetrazin<sup>50</sup>, n- $\pi^*$  fluorescence of pyridazino-pyridazine<sup>51</sup> in apparent exception to El-Sayed's rule. In each case, his work led to proper understanding of the mechanisms that induce the exceptional behaviour. Chowdhury was interested in the dynamics of the excited states following photoexcitation. Excited-state proton transfer kinetics of carbazole<sup>52</sup> equilibrium P<sub>k</sub>\* of carbazole<sup>53</sup>, excited state deprotonation reactions of aromatic amines<sup>54</sup>, and inclusion effect on excited state proton transfer kinetics<sup>55</sup> are some of the problems that interested him.

#### *Instrumentation and Equipment building*

Chowdhury had an endless fascination in all kinds of toys – mechanical, electrical or electro-optical. Perhaps, it is this interest in toys that enthused him to take up the challenge of fabricating equipment for his research. In 1976, Chowdhury and his associates built a nitrogen laser from scratch, making use of the transformer of an abandoned X-ray machine, mylar sheets and brass plates. It was not just a toy laser for demonstration – he used it for studying conformational relaxation of Benzil in excited states and published the work in a journal of repute. Earlier, with his students he built a double-beam recording spectrophotometer with a lamp used in automobiles and an audioamplifier used in public address systems<sup>56</sup>. In those days when foreign exchange for importing equipment was hard to come by, he set up a pulsed high magnetic field system for studying the Zeeman splitting of en-

ergy levels of transition metals and rare earth ions doped in single crystals. His tryst with equipment building did not end there. An apparatus for recording magneto-optical rotatory dispersion spectrum was fabricated out of an old oscilloscope, two split magnetic coils and nicol prisms picked up from discarded equipments lying in the junkyard, and was used for actual measurements<sup>32</sup>. We have already referred to the phase-sensitive recorder developed by his group to measure accurately the magnetic field-induced small changes in exciplex luminescence. Later, in late 1980s, his team developed a cheap and efficient gating technique and computer-controlled data acquisition system for pulsed-laser experiments (eliminating problems arising from pulse-to-pulse intensity fluctuation, scattering of original laser light, lack of adequate wavelength discrimination, etc.)<sup>57</sup>. Indeed Chowdhury was a giant among the rapidly vanishing tribe of experimental physical chemists who would design and fabricate the equipment required for specific problems – probably the last among the Mohicans, so to say – rather than be limited by the demands of an imported equipment, quick results and still quicker publications.

#### *Spectroscopy of intermolecular charge-transfer complexes*

Sadhan Basu, Chowdhury's Ph D adviser, initiated him into the field of spectroscopy CT complexes, which were then just discovered by R. S. Mulliken and interpreted by a valence bond theory of CT complex formation. There was a lot of excitement and curiosity about these molecular complexes. Chowdhury quickly picked up the problem and completed a number of investigations with amazing speed, which included a study on I<sub>2</sub> – hydrocarbon CT complex formation<sup>58</sup>, CT interaction between TCPA and aromatic molecules<sup>59</sup>, CT interaction in quinine – aromatic system<sup>60</sup> and CT complexes of tetrachlorophthalic anhydride and azahydrocarbons<sup>61</sup>. Later, with Lionel Goodman (Pennsylvania State University, USA) he wrote an interesting paper on the polarization of CT band<sup>62</sup>. After returning to India, Chowdhury did not pursue spectroscopy of CT complexes with that much vigour. A couple of publications addressing the issue of thermal effects on the CT band of methiodides of some nitrogen heteroaromatics<sup>63</sup> and geometrical aspects of methio-

ides of some heteroaromatics<sup>64</sup> indicate the direction that his investigations on the CT complexes would perhaps have taken had his interest in the subject not waned.

#### *Theoretical research*

Chowdhury had a natural interest in analytical theory as opposed to computation or large-scale calculations. His grounding in quantum mechanics, perturbation theory, angular momentum algebra and group theory was solid. As a Ph D student, he suggested a simple perturbation method for the calculation of  $\pi$ -electron energy, investigated the nature of intermolecular forces in quinydrone and calculated binding energies of quinine – hydrocarbon complexes (1961–62). After his return to India, his group started looking theoretically into second- and third-order optical and magneto-optical activity of molecules or crystals, presumably with an eye on setting up experimental facility to measure any novel properties that such theories might predict. Chowdhury with his associates succeeded in showing perturbatively that the optical and magneto-optical rotation would reveal a dispersion anomaly at the second harmonic frequency corresponding to the biphotonic absorption band, if the photon density could be made high enough. Their theory further predicted that a magneto-optical rotation of the second harmonic may be observed in specific cases due to the production of the second harmonic light polarized perpendicular to the incident beam, when an intense polarized beam of light containing only a small amount of coherently matched and similarly polarized second harmonic radiation is passed through the medium in a direction perpendicular to the direction of the external magnetic field<sup>65</sup>. Later on, he tried to measure the predicted higher-order magneto-optical response (two-photon optical activity) experimentally. Unfortunately, the signal turned out to be too weak for error-free detection with facilities then available. Non-radiative relaxation is an important mode of energy disposal in the excited states of rare earth single crystals. While Judd-Ofelt theory provided a fairly good description of the radiative relaxation rates and accounted for the hypersensitivity of certain f<sup>n</sup>–f<sup>n</sup> transitions to the ligands (chemical environment), the dependence of non-radiative rates in the same systems on various ligand attributes

and system parameters was an open question, except for the exponential dependence of the non-radiative rate on the energy gap between the states involved. Chowdhury with his Ph D student developed a detailed theory of the ligand-induced relaxation in rare earth crystals within the framework of the dynamic coupling model. The theory predicted correctly how the non radiative  $f^n-f^n$  transition rate would be modulated by states of opposite parity, symmetries of the initial and final states of the rare earth ion, energy gap between the states involved, symmetry of the crystal field, internal promoting and accepting modes of the ligands, and dipole moment and polarizability of the ligands<sup>66</sup>. The predictions have been corroborated by experimental observations.

In rare earth, the interactions among f-electrons and ligands are weak. Perturbation theory is thus generally adequate to model ligand-induced perturbation on the  $f^n-f^n$  transitions or  $f^n-f^n$  state properties. The interactions among d-electrons and ligands in transition metal complexes are much stronger and more covalent than ionic, making the perturbative approach inadequate for describing ligand modulation of  $d^n-d^n$  transitions or properties of the states involved. Chowdhury with his Ph D student developed an approximate self consistent field molecular orbital (SCF MO) theory capable of modelling many properties of transition metal complexes dominantly shaped by charge transfer interactions. The MO theory developed by them corrected the 'imbalance' present in the then prevailing 'zero differential overlap' methods and succeeded in 'avoiding' ab initio calculations involving transition metal atoms needed for fixing crucial parameters, which was difficult in those days<sup>67</sup>. Chowdhury was clearly of ambidextrous disposition, equally adept at marshalling experimental tools and theoretical apparatus for handling a problem. Unfortunately, he gave up his quest for new theoretical developments a few years after moving to IACS, perhaps in order to pay undivided attention to the experimental projects that were then taking concrete shapes.

#### *Innovative teaching*

Chowdhury loved to experiment with teaching techniques. One good example of his innovation in teaching can be

found in a lucid article that he had published<sup>68</sup>. Here he invoked the principle of conservation of total symmetry of the initial state in the final state arrived at by photon-molecule (atom) interaction to deduce the selection rules for one-photon absorption (both by electric and magnetic dipole mechanisms), two-photon absorption, second harmonic generation and optical activity along with angular momentum selection rules. (Naturally, he took into account symmetry of both the molecular and photon wave functions.) His approach bypassed the standard route involving perturbation theory and lengthy calculation of various transition matrix elements. The intuitive symmetry-based and largely pictorial approach was extremely well received by the UG students.

#### *A biographical sketch*

It is interesting to trace the academic and professional trajectories that Chowdhury's life took since childhood. He was the younger son of Jogendra K. Chowdhury and Indira Chowdhury, born on 15 July 1937 in Dhaka (now the capital of Bangladesh). His father was a professor of chemistry in Dhaka University. He received his early education in the famous St Gregory High School, Dhaka. When his parents moved to Calcutta after the partition of India, Chowdhury was sent to the Scottish Church Collegiate School to complete his school education. He had been a bright student throughout his school days and with people like Satyendra Nath Bose around, the ambiance in Dhaka was intellectually electrifying. It certainly shaped his 'no-nonsense, strictly academic' disposition. He did his B Sc with Honors in Chemistry from Presidency College, Calcutta and M Sc with specialization in physical chemistry from the University of Calcutta in 1957. He began his research career under the inspiring and formidable tutelage Sadhan Basu (Calcutta University). He completed his Ph D in chemistry in three years (1960) and went for two brief stints of postdoctoral research in USA – first with Professor Lionel Goodman (Pennsylvania State University; 1961–62) and then with Professor Donald McClure (Chicago University, 1962–64). While Basu introduced him to the then emerging field of spectroscopy of intermolecular charge transfer complexes, Goodman initiated him into the field of fluorescence

spectroscopy, of which he became a master. McClure made Chowdhury interested in excitons and excitonic processes – ideas which left a lasting impression on him. The rest belongs to history.

Chowdhury received numerous awards, honours and recognitions. He was recipient of the Shanti Swarup Bhatnagar Prize in Chemistry (1977), the Gold and Silver Medal of the Chemical Research Society of India, Bengaluru (2000), the Lifetime Achievement Award of the Indian Society of Radiation and Photochemical Sciences, the Rangadhama, and the Sadhan Basu Memorial awards of INSA, to name a few. He had been elected fellow of a number of scientific societies, including the Indian Academy of Sciences, Bengaluru, Indian National Science Academy (INSA), New Delhi, and the Laser and Spectroscopy Society of India. He had been invited to deliver special lectures such as UGC National Lecture (1980), R. P. Mitra Memorial Lecture of Delhi University (1985), Rangadhama Rao Lecture, INSA (1988), J. C. Ghosh Memorial Lecture, Indian Chemical Society (1997), the Travers Memorial Lecture, Indian Institute of Science, Bengaluru (1998), the DAE C. V. Raman Lecture of Indian Physics Association (1998), the Baba Kartar Singh Memorial Lecture, Punjab University (1999), and many others.

Chowdhury served on many academic and professional bodies and societies in various capacities. He was a Council member of INSA; President of the Indian Society for Radiation and Photochemical Sciences; Chairman of the PAC for Physical Chemistry, DST, Government of India (GoI); a Member, PAC, Council of Scientific and Industrial Research, GoI; Member, PAC, Department of Atomic Energy, GoI; and was appointed the Indian Nominee to the Committee for Spectroscopy, IUPAC, to name a few.

He served on the editorial boards of a number of journals, including the *Indian Journal of Chemistry*, *Proceedings of the Indian National Science Academy*, *Materials Science* (Wroclaw, Poland), *Proceedings of Indian Academy of Sciences*, *Current Science*, *Resonance*, etc.

Chowdhury was indeed a very busy scientist, yet he was always available to his students and colleagues for discussions. His unhurried manner, infinite patience, the depth and breadth of his knowledge, his unusual common sense, and incisive analysis earned him the

sobriquet 'a gentle colossus'. The academia is distinctly poorer without him.

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