Impacting human lives with paper and pencil: academic journey of Suman Chakraborty, Infosys 2022 Prize winner

Suman Chakraborty (Professor of Mechanical Engineering, Indian Institute of Technology, Kharagpur) was recently awarded the 2022 Infosys Prize in Engineering and Computer Science for his pioneering work towards 'deepening our understanding of fluid mechanics at micro- and nanoscales, and for applying this knowledge to develop a new generation of low-cost medical devices'[1]. The award citation further reads that 'Using this understanding he has helped to advance healthcare in resource-limited settings through the invention of novel low-cost medical devices for sensing, diagnostics and therapeutics[1]. Here I summarize Suman's glorious journey from a young graduate student at the Indian Institute of Science (IISc), Benglauru to an outstanding academician who has successfully taken world-class, laboratory-scale research to translational development of affordable healthcare technologies for the masses.

Suman completed his undergraduate studies from Jadavpur University in 1996 and obtained his M.E. and Ph.D. in Mechanical Engineering from IISc. He joined IIT Kharagpur in 2002 as an Assistant Professor and became Full Professor in 2008. He has received many accolades, including the Shanti Swarup Bhatnagar Prize (2013), J.C. Bose Fellowship (2018) and the G.D. Birla Award (2020). He has also been elected as a fellow of all the four national academies in India (INAE, INSA, NASI and IASc), and has received international recognition by being elected fellow of the American Society of Mechanical Engineers (ASME), American Physical Society (APS) and Royal Society of Chemistry (UK). He has also been listed as among the top 75 scientists in India across all disciplines under the age of 50 by the Department of Science and Technology, Government of India[2].

Suman's research primarily focuses on fluid flow at small length scales, ranging from exploring the physics of fluid transport at from nanometres to microns, where the dominating flow physics originates from surface effects and interfacial phenomena. Such small-scale flow phenomena are prevalent in several biological and cutting-edge technological applications such as energy, healthcare and microelectronics. In such narrow confinements, he has successfully exploited innovative ways of actuating and controlling flow such as the use of electrical fields, which led to the creation of several exciting and path-breaking technologies. Technology innovations include massive-augmentation of electrically driven pumping in nano-confined water, sticky flow of liquid water on atomically manoeuvred hydrophobic interfaces, programmable electrical modulation of droplets in directions misaligned with the electric field, generating controlled microbubbles on a portable spinning disc, and reversing the thermally driven motion of nano-droplets. His work in this field has also led to deeper understanding and novel insights into several long-standing biological and physiological mysteries in medical science. For example, he unravelled unique biophysical mechanisms responsible for puzzling antibiotic resistance in critical infectious diseases, including life-threatening variants of urinary-tract infection. His work on low-cost fabrication and analytical tools to decipher blood-flow dynamics in deformable microcirculation pathways of the human body led to the recent discovery of mechanisms of collective dynamics of red blood cells in human microvasculature. All these technological and scientific innovations have led to a plethora of high-impact seminal publications in many flagship journals.

However, the real impact of Suman's contribution goes much beyond awards and usual quantitative indices such as papers, *h*-index, number of patents, etc. His contributions have been unique in terms of their scientific path-breaking nature as well as having immense practical and social relevance. For instance, his collaborative research with a Japanese team concerned the first-ever introduction of microneedles for blood extraction and drug delivery by mimicking the blood sampling mechanism of mosquitoes[3]. Another significant contribution involved pioneering work on establishing the electro-kinetics of blood in micro-capillaries, with particular emphasis on the role of the included cellular matter, plasma proteins, amidst dynamically evolving contact angles. Based on the underlying scientific foundation on realizing the coupling of electrically modulated interfacial phenomena and dynamic capillarity of complex biological fluids, he laid the foundation of his pioneering innovation – 'paper and pencil microfluidics' technology, which successfully led to the development of a new class of electrically manipulative, miniaturized device that deploys a simple paper cartridge having pencil-sketched electrodes controlling fluid flow in 2D-printed channels[4]. In addition to the scientific breakthrough involving insight into the complex multi-scale, multi-physics fluidics in a hierarchical random porous structure, this innovation led to the foundation of 'fabrication free', electrically manipulated analytics and sensing as a more economical alternative to the conventional resource-intensive lithography or laser-mediated procedures. He further developed a bioengineered microfluidic platform through surface-functionalization technologies to mimic human microvascular functionalities, which is potentially suitable for probing cellular dynamics as well as offering critical insights into cancer and cardiovascular diseases, thus partially offsetting the requirements of *in vivo* trials[5]. He also pioneered the development of biomimetic slippery interfaces on a paper matrix, leading to significant augmentation of energy-harvesting efficiency through co-operative harnessing of slip and capillarity on the device strip. This laid the foundation of a cellulosic platform for medical diagnostics, energy harvesting[6] and water desalination[7]. He reached an important milestone in his dream journey towards the development of affordable healthcare technology for the masses through the timely invention of COVIRAP, during the peak of the COVID-19 pandemic, which came as a spin-off technology originating from his disruptive inventions for pathological testing using a drop of finger-pricked blood on a frugal paper strip kit. COVIRAP which is a first-of-its-kind, ultra-low-cost, rapid and yet highly accurate point-of-care nucleic acid test applicable for the detection of a variety of infectious diseases and already has a worldwide impact[8].

On a personal front, I am extremely delighted that my former-student has received this special recognition. To me, however, Suman has been much more than a former student. We say that a good teacher has positively influences students, but we often overlook the fact that a teacher can also learn a lot while working with a student. When we met each other for the first time in 1997 (when Suman joined IISc for the Masters in Engineering programme), both of us were coincidentally at the beginning of our respective academic lives – I was starting my academic career in India and Suman was at the beginning of his research career. It was a journey we started travelling together, having ups and downs, as we ventured into the interdisciplinary topic of solidification research which was new to both of us. There were many challenges to overcome, and eventually Suman created history at IISc by completing his Ph.D. in less than a year after his masters. I have rarely come across a person who is so self-motivated and passionate about research, and at the same time, extremely talented. While Suman is exceptionally gifted and a high achiever, people who know him closely are familiar with his pleasant personality and humility. In spite of being extremely busy with academic research and administration, he always has time for everyone – for his family, friends, students and colleagues. With such a personality, he draws respect from his juniors as well as seniors.

Suman started microfluidics research at IIT Khraragpur independently. This work did not have much correspondence with his Ph.D. or initial postdoctoral work. It is worth mentioning here, that just after he joined IIT Kharagpur as a faculty, he received timely mentorship and support from the then Director, Amitabha Ghosh, to enable him to build India's first microfluidics laboratory. During those initial years, Ghosh also led an Indo-US Research Network Program with the support of the Indo-US Science and Technology Forum, which fostered Suman's advancement in microfluidics in the global research arena under the mentorship of Marc Madou, a leading global exponent in microfabrication and microfluidics from the University of California at Irvine, USA. After he developed a world-class laboratory on microfluidics, Suman indeed connected it effectively with medical applications, thereby bringing in his technological pursuits for the benefit of the underserved. Together with the on-field implementation partner Foundation for Innovations in Health[9] led by Satadal Saha (FRCS, UK), the interdisciplinary team collaborated towards developing frugal healthtech innovations that solve real-life health issues of significance and also build capacity among rural youth as community health workers who are digitally literate and able to operate healthtech devices. Thus, the digital clinic programme and the R&D of frugal healthtech represent an integrated ecosystem that, at scale, promises to make a transformational impact in resource-poor parts of the world.

In summary, Suman has indeed emerged to be a rare researcher who combines the highest quality fundamental research with its translation into the realm of deployment in resource-limited settings, with an unprecedented fusion between scholastic pursuits in deep science and compelling responsiveness for public health. Most importantly, we are all proud that throughout his career, his deep and impactful work has originated entirely in India and made a real difference in those fields at the highest international level.

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