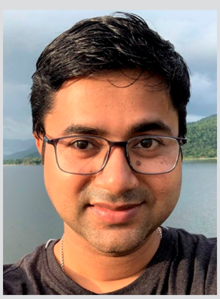
Young Career Focus: Dr. Shibdas Banerjee (Indian Institute of Science Education and Research (IISER) Tirupati, India)

Background and Purpose. SYNFORM regularly meets young up-and-coming researchers who are performing exceptionally well in the arena of organic chemistry and related fields of research, in order to introduce them to the readership. This Young Career Focus presents Dr. Shibdas Banerjee (Indian Institute of Science Education and Research (IISER) Tirupati, India).

Biographical Sketch



Dr. S. Banerjee

Shibdas Banerjee received his Master of Science in chemistry from the Indian Institute of Technology (IIT) Roorkee (India) in 2008. He then pursued his PhD in chemical sciences at the Tata Institute of Fundamental Research (TIFR), Mumbai (India), graduating in 2014 under the mentorship of Prof. Shyamalava Mazumdar. His PhD research was centered around exploring the gas-phase properties of analytes using electrospray ionization mass spectrometry, specifically targeting applications in protein engineering for cytochrome P450 biocatalysis.

Following his PhD, Dr. Banerjee joined the laboratory of Prof. Richard N. Zare at Stanford University (USA) as a postdoctoral fellow, where he advanced his expertise in microdroplet chemistry and clinical mass spectrometry.

In 2017, Dr. Banerjee accepted a position as an Assistant Professor at the Indian Institute of Science Education and Research (IISER) Tirupati, India. He was later promoted to Associate Professor, a role he currently holds. His current research at IISER Tirupati is at the forefront of developing microdroplet-based mass spectrometric methodologies and imaging techniques. These initiatives are particularly geared towards the discovery of disease biomarkers through the correlation of molecular and biological abnormalities, which are pivotal in advancing diagnostic capabilities for various diseases. Moreover, his group is recognized for discovering several unusual properties and reactivities at the air–water interface, significantly influencing the burgeoning field of microdroplet chemistry. Dr. Banerjee's contributions continue to push the boundaries of chemical and biomedical sciences, making substantial impacts on both academic and practical applications.

INTERVIEW

SYNFORM *Which field of organic chemistry are you interested in the most and why?*

Dr. S. Banerjee Our interests are multidirectional, but all are centering on an important analytical approach involving ambient mass spectrometry, which we often use to (a) capture reactive intermediate species from the reaction vial, (b) map the biomolecular distribution in human tissue or blood for development in diagnostics, and (c) induce the unusual chemical transformation in microdroplets for producing value-added chemicals. My research team is also heavily engaged in developing new synthetic strategies at the air–water interface just by spraying the aqueous solution of reactants, circumventing the need for any catalyst or reagents, an upcoming green approach in organic synthesis.

SYNFORM *Following that, what is the focus of your current research activity?*

Dr. S. Banerjee We focus on the *in situ* analysis of chemical and biological transformations in real-time, pinpointing the chemical/biochemical species associated with the transformation route (Figure 1). This helps us decipher the organic reaction mechanism and understand the disease biology by correlating molecular and biological abnormalities during the disease progression. We employ high-speed (>100 m/s) micron-sized droplets to extract the chemical/biochemical information from the sample of interest (reaction mixture, human tissue or blood, etc.), which is subsequently studied by the ambient mass spectrometry approach (a new technology).

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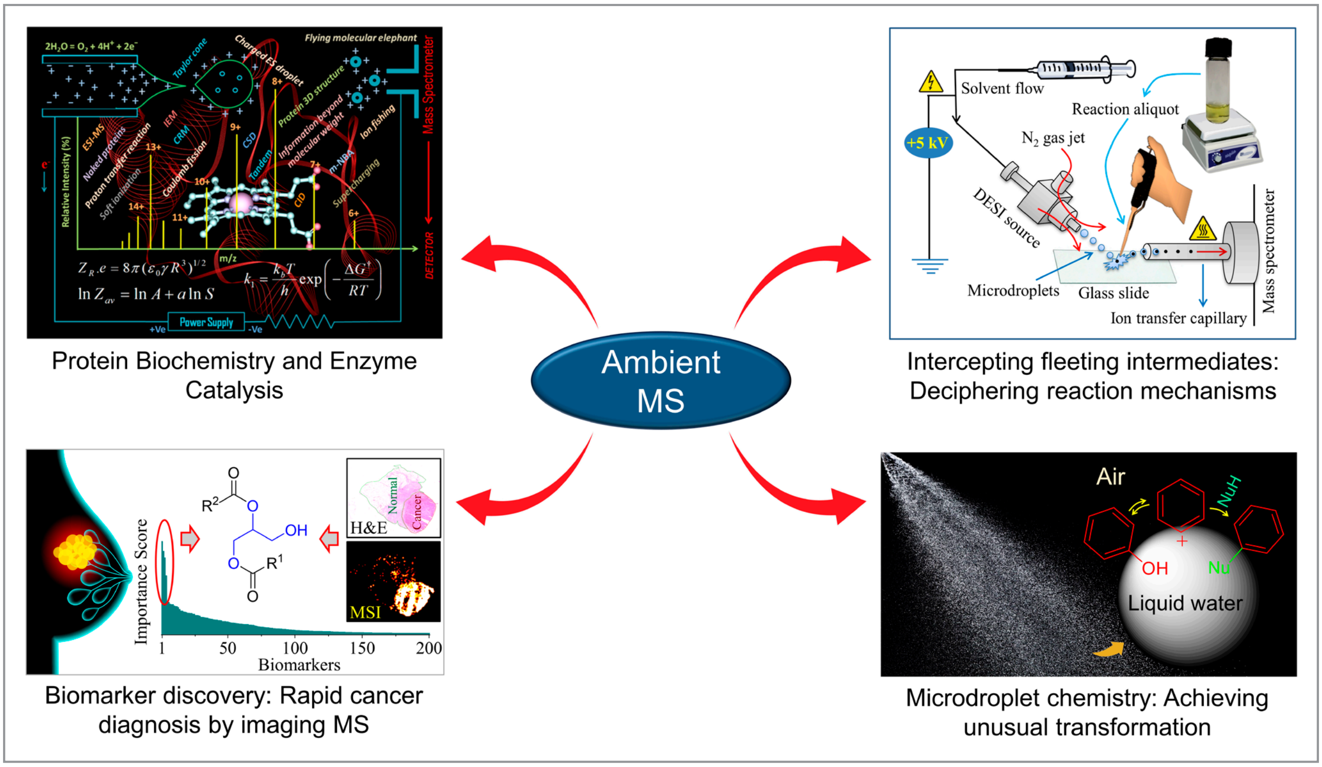

Figure 1 Schematic overview of the research foci of Banerjee's group, centered on ambient mass spectrometry (MS). Figures are in part adapted from the following publications: *J. Am. Chem. Soc.* **2021**, *143*, 2459–2463; *J. Am. Chem. Soc.* **2023**, *145*, 15674–15679; *Anal. Chem.* **2023**, *95*, 8054–8062.

SYNFORM *What do you think about the modern role and prospects of organic chemistry?*

Dr. S. Banerjee Organic chemistry is abundant and lucrative in the modern age, whether in the medicine/pharma industry, energy, environment, agriculture, or fundamental understanding of natural and biological processes. It has transcended the boundary between the reaction vial and the living cell/organism. To advance in creating new drugs, laboratory medicines, biochemical tests, bioimaging techniques, and all that requires not only a strong understanding of the molecular makeup and mechanism of transformation of biological molecules *in situ*, but also the expansion of the efficient synthetic toolbox to deliver the need-based selectivity and specificity in the biological world. Another obvious prospect in organic chemistry is sustainable development, aiming to use natural resources in an environmentally benign fashion. This should be fostered by the upcoming revolution in green chemistry for making value-added chemicals.

SYNFORM *Which difficulties are there for young upcoming chemists in your field? Do you have any tips?*

Dr. S. Banerjee Young and enthusiastic minds are always the catalyst for any new advancement. Chemistry is now being applied beyond reaction vials to the living realm. For example, I see a bright future of biorthogonal chemistry. Sometimes, I find that the young chemists appear with preconceived notions and are reluctant to collaborate, or they are not much encouraged for interdisciplinary collaboration, which is much needed to bridge between different fields/techniques to solve a problem. Engaging in scientific endeavors is not a competitive situation with winners and losers but a collaborative effort where all participants benefit from each other's achievements. For example, we are developing a next-generation histopathology technique for intraoperative cancer margin analysis. This project is being pursued by strong synergistic efforts across different fields like mass spectrometry, biochemistry, surgical oncology, pathology, and machine learning. We cannot succeed without such collaboration.

I also want to mention that big scientific discoveries and breakthroughs are often accidental. The probability of meeting such accidental discoveries depends on persistent efforts, scientific temperament, and critical analysis of the data if unfavorable to the anticipated outcome.

SYNFORM *Could you tell us something about yourself outside the lab, such as your hobbies or extra-work interests?*

Dr. S. Banerjee Well, I enjoy outings in nature. When I get time, I do that with my family, research group, or friends. I enjoy watching films from different continents, as those expose me to a wide range of cultures and landscapes from various nations. I also enjoy music during my leisure time.

SYNFORM *What is your most important scientific achievement to date and why?*

Dr. S. Banerjee I think I have participated in the pioneering process of an emerging field called microdroplet chemistry. Back in 2011, during my PhD, we revealed that microdroplets in the air can cause unusual chemical reactions that may not be possible by conventional bulk-phase chemistry (*J. Am. Soc. Mass Spectrom.* **2011**, *22*, 1707–1717). In the same year, a report from the Cooks lab (Purdue University) showed the acceleration of chemical reactions in microdroplets (*Chem. Sci.* **2011**, *2*, 501–510). These two reports mark the beginning of the field. After that, I moved to the Zare lab (Stanford University) and continued working in the field along with others. After starting my independent research career at IISER Tirupati in 2017, my research group focused on taming micron-sized water droplets to capture and stabilize reactive intermediate species such as carbocations, carbanions, and protein-unfolding intermediates, followed by detecting those species using mass spectrometry. Generally, transient intermediate species in the reaction medium have such a short lifetime that conventional spectroscopic techniques fail to detect them because the measurement duration is longer than their lifespan. However, our finding that the air–water interface of microdroplets can enhance the lifetime of reactive intermediate species for their direct detection represents an important milestone of microdroplet chemistry, which is now apparently multifaceted with diverse applications. We are now translating this success to utilize the chemistry of such reactive species in aqueous microdroplets, especially for advancing sustainable organic synthesis in aqueous medium. As we have discovered that water microdroplets facilitate unusual reactions at the air–water interface, we are also currently exploiting such interfacial reactions for advancements in disease detection (diagnosis). I am very much optimistic about the promising future of microdroplet chemistry. It will likely significantly impact molecular/material synthesis, comprehension of reaction mechanisms, disease diagnostics, disinfections, environmental studies, and other areas in the future.