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Fourier Transform Infrared Spectroscopy: Applications in Medicine

Shalmoli Bhattacharyya*

Department of Biophysics, Post Graduate Institute of Medical Education and Research, Chandigarh, India

Fourier transform infrared spectroscopy (FTIR) is rapidly gaining ground in modern clinical research. This technique is useful for understanding a wide variety of applications ranging from characterization and quality control of various compounds to biomedicine. Importantly, biological materials like proteins, carbohydrates, lipids and nucleic acids have unique structures so it is possible to obtain spectral fingerprints corresponding to their functional groups. FTIR spectroscopic techniques generate an immediate appeal in the field of biology and medicine because of their fast and non-invasive nature. It allows easy visualization of cellular components based on their intrinsic properties and chemical composition. It provides a potential route to screen diagnostic markers for diseases like cancer. FTIR spectroscopy is also considered as a useful tool for analysis of the chemical composition of human calculi. Analysis of stone samples from recurrent stone formers by FTIR may provide a clue to effective prevention of stone recurrence [1].

Fourier transform infrared (FT-IR) spectroscopy has proven to be a fundamental and valuable technique in biology and medicine due to its high sensitivity to detecting changes in the functional groups belonging to tissue components such as lipids, proteins and nucleic acids [2]. Infrared spectra of human and animal tissues could provide information on the molecular structure of tissues. FT-IR has been extensively applied for the determination of a biochemical metabolite in biological fluids. Diagnosis of various types of malignancies such as lung, breast, skin, cervical and colon cancers is already reported in the literature. The spectra are analysed for changes in levels of molecules such as RNA, DNA, phosphates, and carbohydrates. Variation of the RNA/DNA ratio as measured at 1121/1020 cm^{-1} generally show higher ratio for malignant tissues compared to their non-malignant counterpart. Changes in the spectra of malignant samples were also observed in the symmetric and asymmetric stretching bands of the phosphodiester backbones of nucleic acids, the CH stretching region, the C-O stretching bands of the C-OH groups of carbohydrates and cellular protein residuals, and the pressure dependence of the CH_2 stretching mode [3]. The changes in the FTIR spectra correlate to modification of bases and sugars, and redistribution of the H-bond network. The loss/change in the covalent bonds due to damage in the primary, secondary and tertiary structure of nucleic acids can be observed in the spectra. These changes involved the phosphate and C-O stretching bands, the CH stretch region, and the pressure dependence of the CH_2 bending and C=O stretching modes. FTIR micro spectroscopy has also been used as a fast diagnostic technique to identify drugs targeting specific molecular pathways causing chronic myeloid leukaemia. Chemometric data analysis was used to assess drug compounds in ex vivo cancer cells [4].

Substantial progress has been made in incorporating advances in computational methods into the system to increase the sensitivity of the entire setup, making it an objective and sensitive technique suitable for automation to suit the demands of the medical community.

FTIR spectroscopy provides the possibility of obtaining information on molecular composition and structure at the level of single cell within a time-scale of few seconds-minutes and to perform qualitative and quantitative multi-component analyses. It helps in automated pattern recognition and objective classifications of samples with minimal and label-free sample treatment. The technical improvements will progressively increase the number of potential applications of micro FT-IR to cancer research and clinical diagnosis. It may be hoped that the future pre-clinical and clinical trials will include sample evaluation utilizing this technique in order to obtain data necessary to validate the use of micro FT-IR spectroscopy in a clinical context. In fact, this appears to be the most important way to reduce the high level of skepticism of many biologists and pathologists about an old technology that has been designed and improved mainly for applications in clinical diagnosis including cancer research.

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***Corresponding author:** Shalmoli Bhattacharyya, Room No. 518, Fifth Floor, Research Block-B, Post Graduate Institute of Medical Education and Research, Chandigarh 160 012, India, E-mail: shalmoli2007@yahoo.co.in

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