

2. Analysis of the Raman bands of carbon nano-materials using the WITec Project and WITec Project Plus Software

Besides generating Raman images of graphene flakes, the WITec data analysis software provides algorithms which are useful for a detailed analysis of 2D Raman spectral arrays. As reported in the papers published on data obtained with a WITec alpha300 R microscope (see appendix), the Raman spectra of graphene provide precise information on the crystal structure, electronic band structure, the phonon energy dispersion, and the electron-phonon interaction in sp^2 carbon systems. By monitoring the position, width, integrated intensity and line shape of the Raman features of the graphene layers, the number of layers, the linear dispersion of electronic energy, the crystal orientation, the doping, the defects, the strain, and the thermal conductivity can all be probed.

The most prominent peaks in the Raman spectrum of graphene are the G and G' bands, which are associated with the double degenerate in plane transverse optical phonon mode (TO) and longitudinal optical phonon mode (LO).

The intensity of the G band is directly proportional to the number of graphene layers and is thereby a measure for the number of layers in a graphene flake. By fitting a Lorentzian curve to the G band, a shift towards lower wavenumbers is observed with an increase of graphene layer numbers (Fig. 2).

The G' band is described by a single Lorentzian fit in the case of exfoliated graphene monolayer (Fig. 3a), whereas four Lorentzian curves are required for the fit of this Raman band in the case of bi- and multilayer (Fig. 3b and 3c) revealing the interplane phonon interaction.

Fig. 2: Variations in G-band position and G-band intensity in comparison with the height profile of the AFM topography image.

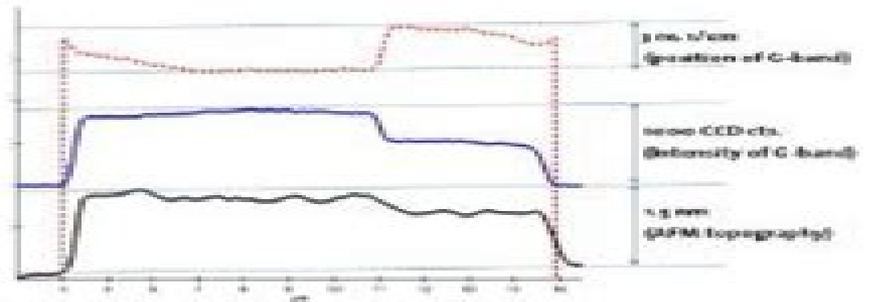
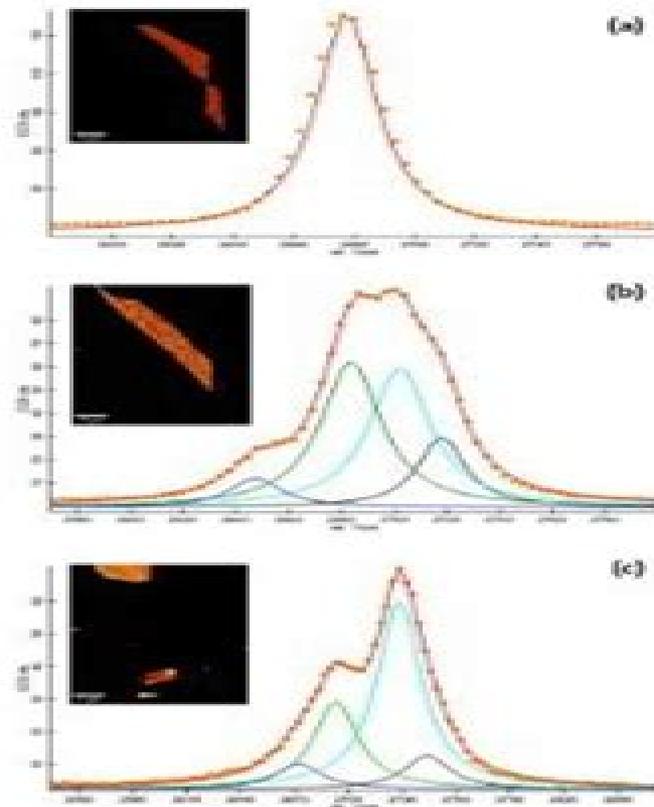


Fig. 3: Line shape of the G' band and Lorentzian fit of the 2D spectral array for (a) monolayer, (b) bi-layer, (c) multilayer of graphene.



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Clemens Wendtner



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Developments in Surface Contamination and Cleaning, Volume 12 Rajiv Kohli, K.L. Mittal, 2019-06-08 Developments in Surface Contamination and Cleaning Methods for Assessment and Verification of Cleanliness of Surfaces and Characterization of Surface Contaminants Volume Twelve the latest release in the Developments in Surface Contamination and Cleaning series provides best practices on determining surface cleanliness Chapters include an introduction to the nature and size of particles a discussion of cleanliness levels detailed coverage of measurement methods characterization methods and analytical methods for evaluating surfaces and an overview of analysis methods for various contaminants As a whole the series creates a unique and comprehensive knowledge base for those in research and development in a variety of industries Manufacturing quality control and procurement specification professionals in the aerospace automotive biomedical defense energy manufacturing microelectronics optics and xerography industries will find this book to be very helpful In addition researchers in an academic setting will also find these volumes excellent source books Includes an extensive listing with a description of available methods for the assessment of surface cleanliness Provides a single source of information on methods for verification of surface cleanliness Serves as a guide to the selection assessment and verification of methods for specific applications

Applications of Vibrational Spectroscopy in Food Science, 2 Volume Set Eunice Li-Chan, John M. Chalmers, Peter R. Griffiths, 2010-11-01 Bringing several disparate aspects of food science and analysis together in one place Applications of Vibrational Spectroscopy to Food Science provides a comprehensive state of the art text presenting the fundamentals of the methodology as well as underlying current areas of research in food science analysis All of the major spectroscopic techniques are also covered showing how each one can be used beneficially and in a complementary approach for certain applications Case studies illustrate the many applications in vibrational spectroscopy to the analysis of foodstuffs

Oral Controlled Release Formulation Design and Drug Delivery Hong Wen, Kinam Park, 2011-01-14 This book describes the theories applications and challenges for different oral controlled release formulations This book differs from most in its focus on oral controlled release formulation design and process development It also covers the related areas like preformulation biopharmaceutics in vitro in vivo correlations IVIVC quality by design QbD and regulatory issues

A Practical Guide to Geometric Regulation for Distributed Parameter Systems Eugenio Aulisa, David Gilliam, 2015-06-18 A Practical Guide to Geometric Regulation for Distributed Parameter Systems provides an introduction to geometric control design methodologies for asymptotic tracking and disturbance rejection of infinite dimensional systems The book also introduces several new control algorithms inspired by geometric invariance and asymptotic attraction for a wide range of dynamical control systems The first part of the book is devoted to regulation of linear systems beginning with the mathematical setup general theory and solution strategy for regulation problems with bounded input and output operators The book then considers the more interesting case of unbounded control and sensing Mathematically this case is more

complicated and general theorems in this area have become available only recently The authors also provide a collection of interesting linear regulation examples from physics and engineering The second part focuses on regulation for nonlinear systems It begins with a discussion of theoretical results characterizing solvability of nonlinear regulator problems with bounded input and output operators The book progresses to problems for which the geometric theory based on center manifolds does not directly apply The authors show how the idea of attractive invariance can be used to solve a series of increasingly complex regulation problems The book concludes with the solutions of challenging nonlinear regulation examples from physics and engineering

Instrumental Analytical Chemistry James W. Robinson, Eileen M. Skelly Frame, George M. Frame II, 2021-06-29 Analytical chemistry today is almost entirely instrumental analytical chemistry and it is performed by many scientists and engineers who are not chemists Analytical instrumentation is crucial to research in molecular biology medicine geology food science materials science and many other fields With the growing sophistication of laboratory equipment there is a danger that analytical instruments can be regarded as black boxes by those using them The well known phrase garbage in garbage out holds true for analytical instrumentation as well as computers This book serves to provide users of analytical instrumentation with an understanding of their instruments This book is written to teach undergraduate students and those working in chemical fields outside analytical chemistry how contemporary analytical instrumentation works as well as its uses and limitations Mathematics is kept to a minimum No background in calculus physics or physical chemistry is required The major fields of modern instrumentation are covered including applications of each type of instrumental technique Each chapter includes A discussion of the fundamental principles underlying each technique Detailed descriptions of the instrumentation An extensive and up to date bibliography End of chapter problems Suggested experiments appropriate to the technique where relevant This text uniquely combines instrumental analysis with organic spectral interpretation IR NMR and MS It provides detailed coverage of sampling sample handling sample storage and sample preparation In addition the authors have included many instrument manufacturers websites which contain extensive resources

Undergraduate Instrumental Analysis Thomas J. Bruno, James W. Robinson, George M. Frame II, Eileen M. Skelly Frame, 2023-07-31 Analytical instrumentation is crucial to research in molecular biology medicine geology food science materials science forensics and many other fields Undergraduate Instrumental Analysis 8th Edition provides the reader with an understanding of all major instrumental analyses and is unique in that it starts with the fundamental principles and then develops the level of sophistication that is needed to make each method a workable tool for the student Each chapter includes a discussion of the fundamental principles underlying each technique detailed descriptions of the instrumentation and a large number of applications Each chapter includes an updated bibliography and problems and most chapters have suggested experiments appropriate to the technique This edition has been completely updated revised and expanded The order of presentation has been changed from the 7th edition in that after the introduction to spectroscopy UV

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