Tomas Rindzevicius - DTU Orbit (14/12/2017)

Tomas Rindzevicius

Organisations

Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
30/06/2016 → present
VIP

Associate Professor, Department of Micro- and Nanotechnology
12/08/2011 → present
trin@nanotech.dtu.dk
VIP

Nanoprobes
09/06/2012 → present
VIP

Publications:

A METHOD FOR PREPARING A SUBSTRATE BY APPLYING A SAMPLE TO BE ANALYSED
The invention relates to a method for preparing a substrate (105a) comprising a sample reception area (110) and a sensing area (111). The method comprises the steps of: 1) applying a sample on the sample reception area; 2) rotating the substrate around a predetermined axis; 3) during rotation, at least part of the liquid travels from the sample reception area to the sensing area due to capillary forces acting between the liquid and the substrate; and 4) removing the wave of particles and liquid formed at one end of the substrate. The sensing area is closer to the predetermined axis than the sample reception area. The sample comprises a liquid part and particles suspended therein.

General information
State: Published
Organisations: Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics, Department of Micro- and Nanotechnology, Nanoprobes
Authors: Durucan, O. (Intern), Schmidt, M. S. (Ekstern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Publication date: 9 Nov 2017

A pseudo-Voigt component model for high-resolution recovery of constituent spectra in Raman spectroscopy
Raman spectroscopy is a well-known analytical technique for identifying and analyzing chemical species. Since Raman scattering is a weak effect, surface-enhanced Raman spectroscopy (SERS) is often employed to amplify the signal. SERS signal surface mapping is a common method for detecting trace amounts of target molecules. Since the method produces large amounts of data and, in the case of very low concentrations, low signal-to-noise (SNR) ratio, ability to extract relevant spectral features is crucial. We propose a pseudo-Voigt model as a constrained source separation model, that is able to directly and reliably identify the Raman modes, with overall performance similar to the state of the art non-negative matrix factorization approach. However, the model provides better interpretation and is a step towards enabling the use of SERS in detection of trace amounts of molecules in real-life settings.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Cognitive Systems, Department of Micro- and Nanotechnology, Nanoprobes, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and
Detection of p-coumaric acid from cell supernatant using surface enhanced Raman scattering

A standard protocol for analysis of microbial factories requires the screening of several populations in order to find the best performing ones. Standard analytical methods usually include high performance liquid chromatography (HPLC), thin layer chromatography (TLC) or spectrophotometry, which are expensive and time-consuming processes. Surface Enhanced Raman Spectroscopy (SERS), instead, is a highly sensitive spectroscopic technique for specific, fast and real-time sensing of biological samples. Here we demonstrate the use of SERS to discriminate between two different bacterial populations based on detection of p-coumaric acid (pHCA) in cell supernatant. SERS active substrates, based on leaning gold-capped silicon nanopillars, were used for detection. They were successfully used to detect culture medium spiked with pHCA, and the effect of medium dilution was studied. For analysis of biological production of pHCA, triplicate cultures of E. coli strains expressing a pHCA-forming enzyme (P) as well as of a non-producing strain (C) were grown. Then, supernatant samples were collected and their pHCA content was measured using SERS and HPLC for comparison. The intensity of the pHCA Raman mode at 1169 cm\(^{-1}\) (CH-rocking motion) showed different trends for P and C strains, similar to the results obtained using the HPLC method. Results illustrate that SERS can be used for quick and semiquantitative discrimination of pHCA concentrations in cell supernatant medium.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk Foundation Center for Biosustainability, Bacterial Cell Factory Optimization, Research Groups
Authors: Morelli, L. (Intern), Jendresen, C. B. (Intern), Zor, K. (Intern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern), Nielsen, A. T. (Intern), Boisen, A. (Intern)
Number of pages: 3
Pages: 190-192
Publication date: 2017
Conference: Biosensors 2016, Gothenburg, Sweden, 25/05/2016 - 25/05/2016
Main Research Area: Technical/natural sciences
PCB molecules within an area of high electromagnetic fields through formation of microsized nanopillar clusters, and consequently, so-called “hot spots” can be formed. In order to improve PCB detection limit, 3,3’,4,4’-tetrachlorobiphenyl (PCB77) compounds were chemically modified with a –SCH3 (PCB77-SCH3) group. Experimental and numerical analysis of vibrational modes showed only minor differences between standard PCB77 and PCB77-SCH3. Consequently, we observe significantly increased SERS signals for –SCH3 modified PCB77 while retaining most vibrational modes that characterize standard PCB77. Results point towards more efficient path for detecting different PCB congeners from real-life samples. We interpret the result as PCB77-SCH3 link to gold surface via sulfur atoms that facilitates accumulation of the modified PCB molecules on the metal surface. For similar SERS experimental conditions most spectral characteristics of PCB77 are identifiable down to concentrations of ~10-5 M while PCB77-SCH3 spectral fingerprint is retained in ~10-8 M range.
Gold Nanoparticles Sliding on Recyclable Nanohoodoo-Engineered for Surface-Enhanced Raman Spectroscopy

Robust, macroscopically uniform, and highly sensitive substrates for surface-enhanced Raman spectroscopy (SERS) are fabricated using wafer-scale block copolymer lithography. The substrate consists of gold nanoparticles that can slide and aggregate on dense and recyclable alumina/silicon nanohoodoos. Hot-spot engineering is conducted to maximize the SERS performance of the substrate. The substrate demonstrates remarkably large surface-averaged SERS enhancements, greater than $10^7$ ($>10^8$ in hot spots), with unrivalled macroscopic signal uniformity as characterized by a coefficient of variation of only 6% across 4 cm. After SERS analyses, the nanohoodoos can be recycled by complete removal of gold via a one-step, simple, and robust wet etching process without compromising performance. After eight times of recycling, the substrate still exhibits identical SERS performance in comparison to a new substrate. The macroscopic uniformity combined with recyclability at conserved high performance is expected to contribute significantly on the overall competitiveness of the substrates. These findings show that the gold nanoparticles sliding on recyclable nanohoodoo substrate is a very strong candidate for obtaining cost-effective, high-quality, and reliable SERS spectra, facilitating a wide and simple use of SERS for both laboratory and commercial applications.

General information
State: Accepted/In press
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Self-Organized Nanoporous Materials
Authors: Wu, K. (Intern), Li, T. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern), Ndoni, S. (Intern)
Number of pages: 11
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Advanced Functional Materials
Article number: 1704818
ISSN (Print): 1616-301X
Ratings:
Web of Science (2017): Indexed Yes
Scopus rating (2016): CiteScore 11.56
Web of Science (2016): Indexed yes
Scopus rating (2015): CiteScore 11.93
Web of Science (2015): Indexed yes
Scopus rating (2014): CiteScore 11.32
Web of Science (2014): Indexed yes
Scopus rating (2013): CiteScore 10.6
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): CiteScore 10.41
ISI indexed (2012): ISI indexed yes
Scopus rating (2011): CiteScore 9.47
ISI indexed (2011): ISI indexed no
Web of Science (2010): Indexed yes
Web of Science (2009): Indexed yes
Web of Science (2008): Indexed yes
Hand-Held Femtogram Detection of Hazardous Picric Acid with 2 Hydrophobic Ag Nanopillar SERS Substrates and Mechanism of 3 Elasto-Capillarity

Picric acid (PA) is a severe environmental and security risk due to its unstable, toxic, and explosive properties. It is also challenging to detect in trace amounts and in situ because of its highly acidic and anionic character. Here, we assess sensing of PA under nonlaboratory conditions using surface-enhanced Raman scattering (SERS) silver nanopillar substrates and hand-held Raman spectroscopy equipment. The advancing elasto-capillarity effects are explained by molecular dynamics simulations. We obtain a SERS PA detection limit on the order of 20 ppt, corresponding attomole amounts, which together with the simple analysis methodology demonstrates that the presented approach is highly competitive for ultrasensitive analysis in the field.

Large-scale, Lithography-free Production of Transparent Nanostructured Surface for Dual-functional Electrochemical and SERS Sensing

In this work, we present a dual-functional sensor that can perform surface-enhanced Raman spectroscopy (SERS) based identification and electrochemical (EC) quantification of analytes in liquid samples. A lithography-free reactive ion etching process was utilized to obtain nanostructures of high aspect ratios distributed homogeneously on a 4-inch fused silica wafer. The sensor was made up of three-electrode array, obtained by subsequent e-beam evaporation of Au on nanostructures in selected areas through a shadow mask. The SERS performance was evaluated through surface-averaged enhancement factor (EF), which was \( \approx 6.2 \times 10^5 \), and spatial uniformity of EF, which was \( \approx 13\% \) in terms of relative standard deviation. Excellent electrochemical performance and reproducibility were revealed by recording cyclic voltammograms. On nanostructured electrodes, paracetamol (PAR) showed an improved quasi-reversible behavior with decrease in peak potential separation (\( \Delta E_p \approx 90mV \)) and higher peak currents (\( I_{PA}/I_{PC} \approx 1 \)), comparing to planar electrodes (\( \Delta E_p \approx 560mV \)). The oxidation potential of PAR was also lowered by \( \approx 80 \) mV on nanostructured electrodes. To illustrate dual-functional sensing, quantitative evaluation of PAR ranging from 30 µM to 3 mM was realized through EC detection, and presence of PAR was verified by its SERS fingerprint.
Nanopillar Filters for Surface-Enhanced Raman Spectroscopy

We present a simple, robust, and automated molecule extraction technique based on a centrifugal microfluidic platform. Fast and facile extraction of a food adulterant (melamine) from a complex sample medium (milk) on a SERS substrate is demonstrated. The unique characteristic of the detection method is the obtained "filter paper/chromatographic" effect which combines centrifugal force and wetting properties of the SERS substrate. The work addresses issues related to SERS-based detection of analytes in complex media, which is important for realizing next generation SERS platforms applicable for a broad variety of real-life applications.

Macroscopic SERS Uniformity and Reproducibility Using Densely Clustered Nanopillars

We present a simple, robust, and automated molecule extraction technique based on a centrifugal microfluidic platform. Fast and facile extraction of a food adulterant (melamine) from a complex sample medium (milk) on a SERS substrate is demonstrated. The unique characteristic of the detection method is the obtained "filter paper/chromatographic" effect which combines centrifugal force and wetting properties of the SERS substrate. The work addresses issues related to SERS-based detection of analytes in complex media, which is important for realizing next generation SERS platforms applicable for a broad variety of real-life applications.
Optimizing silver-capped silicon nanopillars to simultaneously realize macroscopic, practical-level SERS signal reproducibility and high enhancement at low costs

The ideal surface-enhanced Raman spectroscopy (SERS) substrate should fulfil the following: (a) predictable SERS enhancement, (b) macroscale SERS signal uniformity, and (c) suitability for mass production at low costs. Macroscale SERS uniformity and reproducibility at practical levels are big obstacles, which have been preventing most SERS substrates from reliable sensing applications. We have previously shown that SERS-active nanopillar structures, fabricated by lithography-free processes, exhibit high average SERS enhancements and are mass producible. Here, we report an optimized process and show that the improved structures exhibit unrivalled macroscale SERS uniformities (RSD: ~2.5% in millimeter scale, ~7% in wafer scale) and reproducibility (RSD: ~1.5% across 3 wafers), while at the same time exhibiting a very large average SERS enhancement factor of >10^8. The obtained SERS uniformity (~2.5% RSD in millimeter scale) is the best to date measured on large-area solid SERS substrates. Fast and reproducible SERS analysis of trans-1,2-bis (4-pyridyl) ethylene down to 4x10^-13 mol is demonstrated using the optimized structures. We emphasize that achieving simultaneously macroscopic, practical-level SERS signal reproducibility and high enhancement via a lithography-free process is a notable advance towards industrialization of substrate-based SERS sensors.

General information
State: Accepted/In press
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Wu, K. (Intern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern), Thilsted, A. H. (Intern), Boisen, A. (Intern)
Number of pages: 11
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Raman Spectroscopy
ISSN (Print): 0377-0486
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.71 SJR 0.895 SNIP 1.087
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.041 SNIP 0.936 CiteScore 2.25
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.135 SNIP 1.071 CiteScore 2.53
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.032 SNIP 1.082 CiteScore 2.49
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.27 SNIP 1.084 CiteScore 2.63
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.251 SNIP 1.118 CiteScore 2.73
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.427 SNIP 1.131
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.288 SNIP 1.037
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.579 SNIP 1.076
Scopus rating (2007): SJR 1.248 SNIP 1.195
SERS detection of the biomarker hydrogen cyanide from Pseudomonas aeruginosa cultures isolated from cystic fibrosis patients

Pseudomonas aeruginosa is the primary cause of chronic airway infections in cystic fibrosis (CF) patients. Persistent infections are seen from the first P. aeruginosa culture in about 75% of young CF patients, and it is important to discover new ways to detect P. aeruginosa at an earlier stage. The P. aeruginosa biomarker hydrogen cyanide (HCN) contains a triple bond, which is utilized in this study because of the resulting characteristic C≡N peak at 2135 cm⁻¹ in a Raman spectrum. The Raman signal was enhanced by surface-enhanced Raman spectroscopy (SERS) on a Au-coated SERS substrate. After long-term infection, a mutation in the patho-adaptive lasR gene can alter the expression of HCN, which is why it is sometimes not possible to detect HCN in the breath of chronically infected patients. Four P. aeruginosa reference strains and 12 clinical P. aeruginosa strains isolated from CF children were evaluated, and HCN was clearly detected from overnight cultures of all wild type-like isolates and half of the later isolates from the same patients. The clinical impact could be that P. aeruginosa infections could be detected at an earlier stage, because daily breath sampling with an immediate output could be possible with a point-of-care SERS device.
SERS spectroscopy for detection of hydrogen cyanide in breath from children colonised with P. aeruginosa

There is a need for a fast and non-invasive tool to detect Pseudomonas aeruginosa airway colonisation in cystic fibrosis (CF) patients unable to expectorate. Fifty CF children and 19 controls aged 5–17 years were included in the feasibility study. A surface-enhanced Raman spectroscopy (SERS) nanochip optimised for detection of trace amounts of the P. aeruginosa biomarker hydrogen cyanide (HCN) was mounted inside a Tedlar bag, which the patient breathed into. The SERS chip was then analysed in a Raman spectrometer, investigating the C≡N peak at 2131 cm⁻¹ and correlated with sputum cultures. One new P. aeruginosa colonisation occurred during the trial period. The C≡N peak intensity was enhanced in this sample in contrast to the subject’s 3 other samples. Three additional patients had intense C≡N SERS signals from their breath, but no P. aeruginosa was cultured from their sputum. It is concluded that SERS spectroscopy can be developed into an easy to use hypersensitive clinical prescreening method for detection of HCN in human breath.
Surface Enhanced Raman Scattering for Quantification of p-Coumaric Acid Produced by Escherichia coli

The number of newly developed genetic variants of microbial cell factories for production of bio chemicals has been rapidly growing in recent years, leading to an increased need for new screening techniques. We developed a method based on surface-enhanced Raman scattering (SERS) coupled with liquid-liquid extraction (LLE) for quantification of p-coumaric acid (pHCA) in the supernatant of genetically engineered Escherichia coli (E. coli) cultures. pHCA was measured in a dynamic range from 1 μM up to 50 μM on highly uniform SERS substrates based on leaning gold-capped nanopillars, which showed an in-wafer signal variation of only 11.7%. LLE using dichloromethane as organic phase was combined with the detection in order to increase selectivity and sensitivity by decreasing the effect of interfering compounds from the analytes of interest. The difference in pHCA production yield between three genetically engineered E. coli strains was successfully evaluated using SERS and confirmed with high-performance liquid chromatography. As this novel approach has potential to be automated and parallelized, it can be considered for high-throughput screening in metabolic engineering.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk Foundation Center for Biosustainability, Bacterial Cell Factory Optimization, Research Groups, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Authors: Morelli, L. (Intern), Zor, K. (Intern), Jendresen, C. B. (Intern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern), Nielsen, A. T. (Intern), Boisen, A. (Intern)
Number of pages: 7
Pages: 3981-3987
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Analytical Chemistry
Volume: 89
ISSN (Print): 0003-2700
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 6.08
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 5.79
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 6.01
ISI indexed (2013): ISI indexed yes
A substrate and a method of using it
A substrate for a plurality of different measurement set-ups such as SERS, SPR and LSPR which substrate has a base and a plurality of elongate elements with metallic tips. A metallic layer is present on the base surface between the elongate elements and gaps or cavities exist between the layer and the tips or elongate elements. When the elongate elements and the base are transparent, transmission measurement set-ups are also possible.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Department of Physics, Experimental Surface and Nanomaterials Physics, Nanoprobes, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Authors: Thilsted, A. H. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Publication date: 5 Oct 2016

Publication Information
IPC: G01N 21/ 65 A I
Patent number: EP3076161
Date: 05/10/2016
Priority date: 01/04/2015
Priority number: EP20150162286
Original language: English
Electronic versions:
Main Research Area: Technical/natural sciences
Source: espacenet
Source-ID: EP3076161
Publication: Research » Patent – Annual report year: 2016
Click chemistry based biomolecular conjugation monitoring using surface-enhanced Raman spectroscopy mapping

We describe here a novel surface-enhanced Raman spectroscopy (SERS) based technique for monitoring the conjugation of small molecules by the well-known click reaction between an alkyne and azido moiety on the partner molecules. The monitoring principle is based on the loss of the characteristic alkyne/azide Raman signal with triazole formation in the reaction as a function of time. Since these universal Raman reporter groups are specific for click reactions, this method may facilitate a broad range of applications for monitoring the conjugation efficiency of molecules in diverse areas such as bioconjugation, material science or drug discovery. Additionally, as an attractive advantage of this technique, no significant background signal is expected during the measurements, since these signals reside in a Raman silent region of 2000–2300 cm\(^{-1}\), where virtually all biological molecules are transparent.

Detection of nerve gases using surface-enhanced Raman scattering substrates with high droplet adhesion

Threats from chemical warfare agents, commonly known as nerve gases, constitute a serious security issue of increasing global concern because of surging terrorist activity worldwide. However, nerve gases are difficult to detect using current analytical tools and outside dedicated laboratories. Here we demonstrate that surface-enhanced Raman scattering (SERS) can be used for sensitive detection of femtomol quantities of two nerve gases, VX and Tabun, using a handheld Raman device and SERS substrates consisting of flexible gold-covered Si nanopillars. The substrate surface exhibits high droplet adhesion and nanopillar clustering due to elasto-capillary forces, resulting in enrichment of target molecules in plasmonic hot-spots with high Raman enhancement. The results may pave the way for strategic life-saving SERS detection of chemical warfare agents in the field.
DNA self-assembly on graphene surface studied by SERS mapping

The self-assembly of double-stranded DNA (dsDNA) segments on two variations of graphene surfaces having nano-platelets with different lateral sizes and thicknesses was investigated using surface enhanced Raman spectroscopy (SERS) and electrical impedance spectroscopy (EIS) techniques. Due to the strong local field-enhancement, the SERS signals from functional molecules bound to the graphene edges and from DNA moieties were recorded. Relative intensities of specific Raman modes were used as contrast parameters to build Raman signal intensity maps. The observed variation in the SERS signal intensity was related to the different configuration (tilted or flattened) in which dsDNA segments are assembled on the carbon surface, depending on the graphene platelet size. EIS was used to characterize the conductive properties of nano-structured films containing pristine or DNA-functionalized graphene nano-platelets. Results from the EIS analysis supported the SERS findings and confirmed that SERS mapping is a reliable method for a rapid monitoring of the procedures used to interface DNA with graphene surfaces. The present study, linking DNA anchoring morphology to the conductive properties of nano-structured hybrid films, contribute to define a new approach in the optimization of biosensor design.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Italian National Agency for New Technologies, University of Rome La Sapienza, Horiba Italia
Authors: Botti, S. (Ekstern), Rufoloni, A. (Ekstern), Laurenzi, S. (Ekstern), Gay, S. (Ekstern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern), Santonicola, M. G. (Ekstern)
Number of pages: 10
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Carbon
Volume: 109
ISSN (Print): 0008-6223
Ratings:
BFI (2017): BFI-level 1
Engineering Plasmonic Nanopillar Arrays for Surface-enhanced Raman Spectroscopy

This Ph.D. thesis presents (i) an in-depth understanding of the localized surface plasmon resonances (LSPRs) in the nanopillar arrays (NPs) for surface-enhanced Raman spectroscopy (SERS), and (ii) systematic ways of optimizing the fabrication process of NPs to improve their SERS efficiencies. This Ph.D. project is part of the NAPLAS - NAanoPLAsmonic Sensors project, funded by The Danish Council for Independent Research. LSPRs in silver capped silicon NPs are studied using numerical simulations and dark-field scattering microscopy. Simulations show that a standalone NP supports two LSPR modes, i.e., the particle mode and the cavity mode. The particle mode can be hybridized via leaning of pillars. The LSPR wavelength of the cavity mode is dominant only by the diameter of the Si pillar. The presence of a substrate
dramatically changes the intensities of these two LSPR modes, by introducing constructive and destructive interference patterns with the excitation fields. Experimental scattering spectra can be interpreted using theoretical simulations. The processes, which affect the SERS efficiencies of the silver NPs, are systematically evaluated. Short exposures to the O2-plasma and the use of 1-3 nm Cr adhesion layers are advantageous for reducing the SERS background signals. Influence of the NP height and silver deposition thickness on SERS intensities is also investigated. Using an optimized recipe, the measured SERS enhancement factor (EF) reaches 108, and the SERS signal intensity exhibits a standard deviation of ~14% (660 data points) across a 5 x 5 mm2 surface area. Lastly, a further improved process shows that high-density NPs exhibit unrivalled macroscale SERS uniformities (RSD: ~2.5% in mm scale, ~7% in inch scale) and SERS reproducibilities (RSD: ~1.5% across three wafers), while at the same time displaying a very large average SERS EF of >108. From a practical point of view, the developed SERS substrates are particularly interesting, since they are easy to handle and store and the fabrication is scalable, facilitating a wide and simple use of SERS in sensing applications.
Lithography-Free Fabrication of Silica Nanocylinders with Suspended Gold Nanorings for LSPR-Based Sensing

Tunable plasmonic platforms are important for a variety of applications such as photovoltaics, LED's, optoelectronics, medical research, and biosensors. In particular, development of label-free plasmonic biosensors is one of the key research areas that utilizes plasmonic nanostructures for detection of biologically relevant molecules at low concentrations. The authors have developed a cost-effective, fast, and lithography-free method to fabricate transparent fused silica nanocylinders. The technique allows tuning of nanocylinder height, diameter, and density and can be scaled to large surface areas, such as 8 in. wafers. The authors demonstrate that gold coated nanocylinders support localized surface plasmon resonances (LSPR) from visible to near infrared wavelengths. The plasmonic platform can be characterized as suspended gold nanorings and exhibits a sensitivity of 658 nm RIU⁻¹ with a figure-of-merit of 10, comparable to other state-of-the-art LSPR sensing platforms that utilize more complex nanofabrication pathways. It was observed that the LSPR peak positions can be controlled by varying the geometry of the nanocylinders. The authors illustrate surface functionalization, biosensing, and surface regeneration properties of the platform using thiols and detection of bovine serum albumin (BSA). The observed LSPR shifts for 11-mercaptoundecanoic acid and BSA was 12 and 26 nm, respectively.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Authors: Thilsted, A. H. (Intern), Pan, J. Y. (Intern), Wu, K. (Intern), Zor, K. (Intern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern), Boisen, A. (Intern)
Number of pages: 8
Pages: 6745–6752
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Small
Volume: 12
Issue number: 48
ISSN (Print): 1613-6810
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 8.11 SJR 3.324 SNIP 1.505
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 3.249 SNIP 1.624 CiteScore 8.11
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 3.118 SNIP 1.668 CiteScore 7.74
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.576 SNIP 1.672 CiteScore 8.13
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 4.471 SNIP 1.9 CiteScore 8.17
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 4.122 SNIP 1.83 CiteScore 8.15
ISI indexed (2011): ISI indexed yes
Macroscale SERS Uniformity and Reproducibility Using Densely Clustered Nanopillars

Orientation of Pterin-6-Carboxylic Acid on Gold Capped Silicon Nanopillars Platforms: Surface Enhanced Raman Spectroscopy and Density Functional Theory Studies

The orientation of pterin-6-carboxylic acid on gold nanopillars was investigated by surface enhanced Raman spectroscopy and density functional theory methods. The experimentally vibrations from pterin-6-COOH free and attached to the Au surface display vibration features indicating chemical interaction of the pterin with the metal surface. The spectral feature evidenced that the pterin would adsorb on gold surface with a "lying down" configuration through the high intensity vibration of NH scissoring and rocking OH modes. The orientation study of pterins on gold nanopillars presented herein is believed to lead to new applications in biosensing field for detecting pterins of physiological importance.
Plasmonic nanopillar structures for surface-enhanced raman scattering applications

Noble metal nanostructures support localized surface plasmon (LSPR) resonances that depend on their dimensions, shapes and compositions. Particle LSPR's can be used to spatially confine the incident light and produce enormous electromagnetic (EM) field enhancement spots, i.e. hot spots. Hot spots have been utilized in surface-enhanced Raman spectroscopy (SERS) for biological and chemical sensing. We present Au nanopillar (NP) SERS structures that are excellent for molecular detection. The NP structures can be fabricated using a simple two-step process. We analyze NP optical properties experimentally and theoretically. Simulations show that that a single Ag-coated NP supports two LSPR modes, i.e. the particle mode and the Ag cap resonant cavity mode. The Ag cap resonant cavity mode contributes most to the enhancement of the Raman scattering signal. The electric field distribution calculations show that the EM hot spots are located at the bottom of the Ag cap which is important observation for practical SERS sensing. Reproducible and repeatable SERS signal intensities can be obtained across large surface areas (>mm²). Application examples include detection of TAMRA-labeled vasopressin and cyanide (KCN).

General information
State: Published
SERS detection of pneumonia in breath of children with cystic fibrosis

Cystic fibrosis (CF) is the most frequently inherited disease in the Western world, and also the one with the highest morbidity and mortality. The main reason is chronic lung infections caused by the pathogenic bacterium Pseudomonas aeruginosa, which is well-adapted to the thick and dehydrated mucous in the CF airways. Established methods to detect P. aeruginosa in young CF children are invasive and lack sensitivity, which is why novel approaches are being investigated. P. aeruginosa emits hydrogen cyanide (HCN) gas, which can possibly be used as a biomarker for early P. aeruginosa colonisation, if it can be detected in the breath. It was investigated if a nanopillar substrate for surface-enhanced Raman spectroscopy (SERS), developed in the Nanoprobes group, could be optimised for gas phase detection of HCN. The project consisted of 3 steps, of which the first was to establish a chemical method to detect cyanide on the substrate in relevant concentrations, preferably in gas. Step I was split up into two parts; one for HCN detection in the gas phase, and one for detection of potassium cyanide (KCN) in serial dilutions to reach sufficiently low CN concentrations and verify the limit of detection. Once this was done, Step II was to measure HCN(g) from emissions of P. aeruginosa; first from the established reference strain, the wild type PAO1. Secondly, it was relevant to study clinical P. aeruginosa strains, isolated for the first time from CF children (the wild type-like strains), and then compare to SERS measurements on later strains, isolated from the same patients after their infection became chronic and the P. aeruginosa had mutated in the lasR gene, which is essential to HCN production. Step III was a clinical trial, where children with CF would blow into a bag containing the SERS substrate, which was then measured, to see if HCN was detected when a new P. aeruginosa colonisation occurred; and data was correlated to culturing of sputum from the patient's lungs.

The SERS substrate was optimised, and setups were developed for HCN(g) detection, for SERS detection of HCN from bacterial volatiles, and for collection and SERS substrate exposure to human breath. Five ppm HCN was successfully detected in gas phase, and KCN was detected down to 10⁻⁶ M. HCN detection was demonstrated from cultures of P. aeruginosa wild types, starting from the end of exponential / beginning of stationary growth phase. HCN was also detected from lasR mutated clinical P. aeruginosa strains isolated from the airways of children with CF, when the mutation was located at the 5' terminal (downstream) of the gene. P. aeruginosa isolates with a mutation at the 3' terminal of the lasR gene (upstream) did not emit detectable HCN. Application for ethics' committee was submitted and permission granted to conduct a 4 months' clinical pilot study at Rigshospitalet, including 50 CF patients aged 5-17 years and 19 age-matched control subjects. One CF patient had a new P. aeruginosa lung colonisation during the trial, and it was probably detected on the SERS substrate, which had an increased HCN signal compared to the patient's other visits. Additional cases of increased SERS cyanide signal were seen in the breath of some of the children, and it was speculated if they could come from prolonged exposure time or from children being exposed to passive smoking at home. The SERS substrate has a background peak in the Raman spectrum, which needs to be addressed, because it is located very close to the cyanide peak.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk AS
Authors: Lauridsen, R. K. (Intern), Boisen, A. (Intern), Rindzevicius, T. (Intern), Molin, S. (Ekstern)
Number of pages: 160
Publication date: 2016

Publication information
Publisher: DTU Nanotech
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Untitled.pdf

Relations
Supercritical impregnation of polymer matrices spatially confined in microcontainers for oral drug delivery: Effect of temperature, pressure and time

The present study is aimed to enhance the oral bioavailability of ketoprofen by inserting it into the matrix of poly(vinylpyrrolidone) (PVP) K10 spatially confined into microcontainers, by means of supercritical CO2-aided impregnation. Microcontainers are cylindrical reservoirs, with typical sizes in the micrometrarrange, with a cavity open on one side, where the drug formulation is loaded. Differently to traditional tablets, microcontainers have a higher surface area per unit volume, and release the drug only in one direction. This design is meant to enhance the absorption of problematic drugs, like those with poor solubility in water. In a previous study we introduced a novel technique for drug loading of microcontainers, based on inkjet printing and supercritical impregnation (SCI). We showed that SCI produces accurate and reproducible drug loading for large arrays of microcontainers. In the attempt of enhancing the throughput of the loading methods, we propose the replacement of polymer inkjet printing with an easier manual compression of the PVP powder into the microcontainers. As the second step, the polymer powder-filled microcontainers were submitted to SCI. The separate role of different impregnation parameters (temperature, pressure, time, drug concentration in the supercritical phase) was elucidated with respect to the loading capacity. The microcontainer filling was observed by means of optical macroimaging, X-ray microtomography and scanning electron microscopy. The physical state of the drug was investigated by means of Raman spectroscopy and compared with selected representative PVP-ketoprofen physical mixtures. Finally, the drug loading was estimated by means of in vitro dissolution tests. The characterization study shows that the present loading method is a valuable alternative to the one previously described. The drug loading can be controlled with high accuracy and reproducibility and the impregnated drug is in amorphous state. These results demonstrate that SCI can be used as a high-throughput loading technique for microfabricated devices for oral drug delivery.
Surface Enhanced Raman Spectroscopy detection of p-coumaric acid from cell supernatant using gold-capped silicon nanopillar substrates

A standard protocol for analysis of microbial factories requires the screening of several populations in order to find the best performing ones. This is done with standard analytical methods (e.g. HPLC) with an expensive and time-consuming process. Surface Enhanced Raman Spectroscopy (SERS) is a highly sensitive spectroscopic technique which only requires drying a small volume of solution on an active substrate, with an analysis time of few minutes. Here we demonstrate the use of SERS to discriminate between two different bacterial populations based on detection of p-coumaric acid (pHCA) in cell supernatant. pHCA is a valuable secondary metabolite of genetically modified E. coli[1]. It is produced through deamination of tyrosine, and it has strong Raman and SERS activity[2],[3]. Gold capped silicon nanopillars were used as sensing substrates[4]. At first, they were successfully used to detect pHCA spiked in culture medium, in the same concentration range \(10^{-4} - 10^{-5} \) M commonly found in cell supernatant. For supernatant analysis, triplicate cultures of FjTAL modified (P strains) and control (C strains) E.coli strains were carried out according to the methods described by[5] and shown in Fig.1. Samples of cell supernatant were extracted from each culture at 0, 3, 24 and 48 h post seeding and their pHCA content was measured with HPLC[5]. For SERS analysis, aliquots of supernatant were diluted 10-fold with MilliQ water, and 1 μL droplets were dried on the SERS substrates. A MatLab analysis was performed to extract the height of the significant peak at 1169cm\(^{-1}\), with the results shown in Fig.2. The amplitude of the peak shows a different trend for P and C strains. A similar trend is obtained from HPLC. These promising results open up new possibilities for the use of SERS for high-throughput and automated evaluation of bacterial factories, allowing parallel analysis and discrimination of different strains.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk Foundation Center for Biosustainability, Bacterial Cell Factory Optimization, Research Groups
Surface Enhanced Raman Spectroscopy detection of p-coumaric acid from cell supernatant using gold-capped silicon nanopillar substrates

The purpose of the project is to use Surface Enhanced Raman Spectroscopy (SERS) to discriminate between two different bacterial populations, based on their p-coumaric acid (pHCA) production. The pHCA concentration is measured in a droplet of diluted supernatant dried on SERS substrates, using a Raman microscope. By analyzing the SERS signal of pHCA from the supernatant, considering the peak height at the characteristic frequency (1169 cm⁻¹) it is possible to distinguish between a producing and control strain, as also confirmed by HPLC analysis.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk Foundation Center for Biosustainability, Bacterial Cell Factory Optimization, Research Groups
Number of pages: 1
Publication date: 2016
Main Research Area: Technical/natural sciences
Electronic versions:
bios2016_poster_v1_KZ_LM.pdf
Publication: Research - peer-review › Poster – Annual report year: 2016

Transparent Substrates for Plasmonic Sensing by Lithography-Free Fabrication

This Ph.D. thesis presents fabrication and optimization of transparent plasmonic substrates that can be used for biological and chemical sensing by surface enhanced Raman spectroscopy (SERS) sensing and localized surface plasmon resonance refractive index (LSPR RI) sensing. These substrates are: glass nanopillars with gold caps for SERS sensing; polymer nanopillars with gold caps for SERS sensing; transferred gold nanocaps to polymer foil for SERS sensing; and glass hollow-core nanocylinders with gold nanorings for LSPR RI sensing.

These substrates were achieved using lithography-free fabrication methods, and resulted in large-area, high throughput and low cost production techniques. The fabrication techniques consisted of using aluminum patterned areas and reactive ion etching (RIE) to achieve nanopillars or nanocylinders in glass; using RIE to achieve nanopillars in silicon as a mould for polymer injection; and using RIE and imprinting to transfer gold nanocaps to a polymer foil.

The SERS substrates showed a 91%, a 94% and 8% Raman signal intensity compared to gold-capped silicon nanopillars for the glass nanopillars, the polymer injected nanopillars and the transferred gold nanocaps, respectively. As the substrates were transparent, measurements from the backside were possible, showing a 44%, 1.7% and 71% Raman signal intensity in comparison to the measurements from the front, for the glass nanopillars, the polymer injected nanopillars and the transferred metal nanocaps, respectively.

For LSPR, the glass hollow-core nanocylinders with suspended gold nanorings showed a sensitivity of 658 nm RIU⁻¹ with a gure-of-merit of 10. The LSPR wavelengths could be shifted by tuning the plasma etching parameters.

Due to the low electrical conductivity of glass substrates, electrodes could be incorporated onto the glass nanopillars, resulting in a device that could be used for both electrochemistry and SERS measurements. The polymer injected nanopillars used an industrial high throughput and robust fabrication technique. The substrate was integrated into high throughput fluidic devices for in-situ SERS measurements. The fabrication methods presented in this Ph.D. thesis are scalable, high throughput and low cost, and result in high performance plasmonic surfaces for sensing.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Thilsted, A. H. (Intern), Boisen, A. (Intern), Rindzevicius, T. (Intern), Schmidt, M. S. (Intern)
Number of pages: 158
Publication date: 2016

Publication information
Publisher: DTU Nanotech
Original language: English
Main Research Area: Technical/natural sciences
Wafer-Scale Nanopillars Derived from Block Copolymer Lithography for Surface-Enhanced Raman Spectroscopy

We report a novel nanofabrication process via block copolymer lithography using solvent vapor annealing. The nanolithography process is facile and scalable, enabling fabrication of highly ordered periodic patterns over entire wafers as substrates for surface-enhanced Raman spectroscopy (SERS). Direct silicon etching with high aspect ratio templated by the block copolymer mask is realized without any intermediate layer or external precursors. Uniquely, an atomic layer deposition (ALD)-assisted method is introduced to allow reversing of the morphology relative to the initial pattern. As a result, highly ordered silicon nanopillar arrays are fabricated with controlled aspect ratios. After metallization, the resulting nanopillar arrays are suitable for SERS applications. These structures readily exhibit an average SERS enhancement factor of above $10^9$, SERS uniformities of 8.5% relative standard deviation across 4 cm, and 6.5% relative standard deviation over $5 \times 5 \text{mm}^2$ surface area, as well as a very low SERS background. The as-prepared SERS substrate, with a good enhancement and large-area uniformity, is promising for practical SERS sensing applications.
A method for the chemical modification of polychlorinated biphenyls for improved affinity towards noble metal surfaces.

The present application discloses a method for the modification and analysis of a field sample suspected of containing contaminant(s) like polychlorinated biphenyls (PCBs). The invention also relates to a corresponding kit for the modification of samples suspected of containing such contaminant(s).

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Rindzevicius, T. (Intern), Boisen, A. (Intern), Schmidt, M. S. (Intern), Barten, J. A. (Ekstern), Vorobiev, M. (Ekstern)
Publication date: 17 Dec 2015

Publication information
IPC: G01N 33/00 A I
Patent number: WO2015189262
Date: 17/12/2015
Priority date: 10/06/2014
Priority number: EP20140171743
Original language: English
Electronic versions:
WO2015189262A1.pdf
Main Research Area: Technical/natural sciences
Source: espacenet
Source-ID: WO2015189262
Publication: Research – Patent – Annual report year: 2015

Adsorption and Vibrational Study of Folic Acid on Gold Nanopillar Structures Using Surface-enhanced Raman Scattering Spectroscopy

This paper presents a study of adsorption and vibrational features of folic acid, using surface-enhanced Raman scattering (SERS). A gold-capped silicon nanopillar (Au NP) with a height of 600 nm and a width of 120 nm was utilized to study the vibrational features of FA molecules adsorbed on the nanopillars within the high electromagnetic field areas. The adsorption behaviour of folic acid and the band assignment of the main vibrations together with the optimized geometry of folic acid and folic acid in the presence of a cluster of 10 gold atoms were assessed using the density functional theory (B3LYP(6-31G(d))) and the scalar relativistic effective core potential with a double-zeta basis set (LANL2DZ). The vibrations obtained from the solid-state folic acid and the folic acid on a gold cluster were in accordance with those observed experimentally. The analysis of the main vibrations indicated that the interaction of folic acid with the Au NP occurred primarily through the nitrogen atoms, from their pteridine ring. Finally, the obtained adsorption isotherm for folic acid was deduced from the analysis of the SERS spectra and it followed a negative cooperative binding model.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Universidad Santo Tomas, Universidad Industrial de Santander
Authors: Castillo, J. J. (Ekstern), Rindzevicius, T. (Intern), Rozo, C. E. (Ekstern), Boisen, A. (Intern)
Number of pages: 7
Publication date: 2015
Main Research Area: Technical/natural sciences
In this work we present high-aspect ratio carbon pillars (1.4 μm in diameter and ~11 μm in height) on top of interdigitated electrode arrays to be used for electrochemical applications. For this purpose, different types of 2D and 3D pyrolysed carbon structures were fabricated and characterised including surface- and microstructure, electrical and electrochemical properties. A pre-treatment of oxidised Si wafers is introduced to eliminate electrode delamination and ensure structure stability in water during long time-experiments. Additionally, a heat treatment method is reported for regeneration of pyrolysed carbon films with increased film resistance due to oxidation during storage.
Detection of bacterial metabolites through dynamic acquisition from surface enhanced raman spectroscopy substrates integrated in a centrifugal microfluidic platform

In this work we present a novel technology that combines the advantages of centrifugal microfluidics with dynamic in-situ Surface Enhanced Raman Spectroscopy (SERS) sensing. Our technology is based on an automated readout system that allows on-line SERS acquisition on a rotating centrifugal microfluidic platform with embedded gold nanopillar substrates. While spinning, the disc platform enables dynamic SERS acquisition of multiple chips, significantly reducing time-to-result and improving the reproducibility of the acquired spectra, reducing the fluctuation by a factor of 2.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Durucan, O. (Intern), Morelli, L. (Intern), Schmidt, M. S. (Intern), Burger, R. (Intern), Rindzveicius, T. (Intern), Boisen, A. (Intern)
Number of pages: 3
Pages: 1831-1833
Publication date: 2015
Exploring Plasmonic Resonances of Silver Capped Silicon Nanopillars

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Fluidic Array Systems and Technology
Authors: Wu, K. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Mogensen, K. B. (Intern), Boisen, A. (Intern)
Number of pages: 1
Publication date: 2015

Host publication information
Title of host publication: Proceedings of the 7th International Conference on Surface Plasmon Photonics
Main Research Area: Technical/natural sciences
Conference: 7th International Conference on Surface Plasmon Photonics, Jerusalem, Israel, 31/05/2015 - 31/05/2015
Electronic versions:
Kaiyu_SPP7_ABSTRACT_v1_mssc_comments.pdf
Source: PublicationPreSubmission
Source-ID: 110867882
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2015

Explosive and chemical threat detection by surface-enhanced Raman scattering: A review
Acts of terror and warfare threats are challenging tasks for defense agencies around the world and of growing importance to security conscious policy makers and the general public. Explosives and chemical warfare agents are two of the major concerns in this context, as illustrated by the recent Boston Marathon bombing and nerve gas attacks on civilians in the Middle East. To prevent such tragic disasters, security personnel must be able to find, identify and deactivate the threats at multiple locations and levels. This involves major technical and practical challenges, such as detection of ultra-low quantities of hazardous compounds at remote locations for anti-terror purposes and monitoring of environmental sanitation of dumped or left behind toxic substances and explosives. Surface-enhanced Raman scattering (SERS) is one of today's most interesting and rapidly developing methods for label-free ultrasensitive vibrational "fingerprinting" of a variety of molecular compounds. Performance highlights include attomolar detection of TNT and DNT explosives, a sensitivity that few, if any, other technique can compete with. Moreover, instrumentation needed for SERS analysis are becoming progressively better, smaller and cheaper, and can today be acquired for a retail price close to 10,000 US$. This contribution aims to give a comprehensive overview of SERS as a technique for detection of explosives and chemical threats. We discuss the prospects of SERS becoming a major tool for convenient in-situ threat identification and we summarize existing SERS detection methods and substrates with particular focus on ultra-sensitive real-time detection. General concepts, detection capabilities and perspectives are discussed in order to guide potential users of the technique for homeland security and anti-warfare purposes.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Chalmers University of Technology, Swedish Defence Research Agency
Authors: Hakonen, A. (Ekstern), Andersson, P. O. (Ekstern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Käll, M. (Ekstern)
Pages: 1-13
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Analytica Chimica Acta
Volume: 893
ISSN (Print): 0003-2670
Ratings:
BFI (2017): BFI-level 2
Mathematical model for biomolecular quantification using large-area surface-enhanced Raman spectroscopy mapping

Surface-enhanced Raman spectroscopy (SERS) based on nanostructured platforms is a promising technique for quantitative and highly sensitive detection of biomolecules in the field of analytical biochemistry. Here, we report a mathematical model to predict experimental SERS signal (or hotspot) intensity distributions of target molecules on receptor-functionalized nanopillar substrates for biomolecular quantification. We demonstrate that by utilizing only a small set of empirically determined parameters, our general theoretical framework agrees with the experimental data particularly well in the picomolar concentration regimes. This developed model may be generally used for biomolecular quantification using Raman mapping on SERS substrates with planar geometries, in which the hotspots are approximated as electromagnetic enhancement fields generated by closely spaced dimers. Lastly, we also show that the detection limit of a specific target molecule, TAMRA-labeled vasopressin, approaches the single molecule level, thus opening up an exciting new chapter in the field of SERS quantification.

General information
Mathematical model for biomolecular quantification using surface-enhanced Raman spectroscopy based signal intensity distributions

This paper presents the development of a novel statistical method for quantifying trace amounts of biomolecules by surface-enhanced Raman spectroscopy (SERS) using a rigorous, single molecule (SM) theory based mathematical derivation. Our quantification framework could be generalized for planar SERS substrates, in which the nanostructured features can be approximated as a closely spaced electromagnetic dimer problem. The potential for SM detection was also shown, which opens up an exciting opportunity in the field of SERS quantification.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Department of Applied Mathematics and Computer Science , Cognitive Systems, Harvard University, Colombia University
Authors: Palla, M. (Ekstern), Bosco, F. (Intern), Yang, J. (Ekstern), Rindzevicius, T. (Intern), Alstrøm, T. S. (Intern), Schmidt, M. S. (Intern), Lin, Q. (Ekstern), Ju, J. (Ekstern), Boisen, A. (Intern)
Pages: 1-4
Publication date: 2015

Host publication information
Title of host publication: Proceedings of IEEE Sensors 2015
Publisher: IEEE
ISBN (Print): 978-1-4799-8202-8
Localized surface plasmon resonances (LSPR) and plasmon couplings in Ag capped Si Nanopillar (Ag NP) structures are studied using 3D FEM simulations and dark-field scattering microscopy. Simulations show that a standalone Ag NP supports two LSPR modes, i.e. the particle mode and the cavity mode. The LSPR peak position of the particle mode can be tuned by changing the size of the Ag cap, and can be hybridized by leaning of pillars. The resonance position of the cavity resonance mode can be tuned primarily via the diameter of the Si pillar, and cannot be tuned via leaning of Ag NPs. The presence of a substrate dramatically changes the intensity of these two LSPR modes by introducing constructive and destructive interference patterns with incident and reflected fields. Experimental scattering spectra can be interpreted using theoretical simulations. The Ag NP substrate displays a broad plasmonic resonance band due to the contribution from both the hybridized particle LSPR and the cavity LSPR modes.
Silver-capped silicon nanopillar platforms for adsorption studies of folic acid using surface enhanced Raman spectroscopy and density functional theory

The study of the interactions of folic acid (FA) with surface enhanced Raman scattering substrates is relevant for understanding its adsorption mechanism for fabricating analytical devices for detection of malignant cells over-expressing folate receptors. This paper presents a study of the adsorption of FA on silver-capped silicon nanopillar substrates employing surface enhanced Raman scattering spectroscopy and density functional theory calculations. The experimentally observed vibrations from free FA and FA bound to the Ag surface display different vibrational spectra indicating chemical interaction of the molecule with the metal surface. Density functional theory calculations show that the Ag–FA interaction is primarily through the nitrogen from the pteridine ring anchoring to the Ag metal surface. To investigate the Ag–FA binding behavior further, the adsorption isotherm of FA on the silver-capped silicon nanopillar surface is estimated. The results show a positive cooperative Ag–FA binding mechanism. That is, adsorbed FA increases the affinity of new incoming FA molecules.
Silver Capped Silicon Nanopillars as Surface Enhanced Raman Spectroscopy Substrates
Towards quantitative SERS detection of hydrogen cyanide at ppb level for human breath analysis

Lung infections with *Pseudomonas aeruginosa* (PA) is the most common cause of morbidity and mortality in cystic fibrosis (CF) patients. Due to its ready adaptation to the dehydrated mucosa of CF airways, PA infections tend to become chronic, eventually killing the patient. Hydrogen cyanide (HCN) at ppb level has been reported to be a PA biomarker. For early PA detection in CF children not yet chronically lung infected a non-invasive Surface-Enhanced Raman Spectroscopy (SERS)-based breath nanosensor is being developed. The triple bond between C and N in cyanide, with its characteristic band at ~2133 cm⁻¹, is an excellent case for the SERS-based detection due to the infrequent occurrence of triple bonds in nature. For demonstration of direct HCN detection in the gas phase, a gold-coated silicon nanopillar substrate was exposed to 5 ppm HCN in N₂. Results showed that HCN adsorbed on the SERS substrate can be consistently detected under different experimental conditions and up to 9 days after exposure. For detection of lower cyanide concentrations serial dilution experiments using potassium cyanide (KCN) demonstrated cyanide quantification down to 1 μM in solution (corresponding to 18 ppb). Lower KCN concentrations of 10 and 100 nM (corresponding to 0.18 and 1.8 ppb) produced SERS intensities that were relatively similar to the reference signal. Since HCN concentration in the breath of PA colonized CF children is reported to be ~13.5 ppb, the detection of cyanide is within the required range.

General information

State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Novo Nordisk Foundation Center for Biosustainability, Bacterial Cell Factories, Department of Chemistry, Department of Applied Mathematics and Computer Science, Cognitive Systems, Amphiphilic Polymers in Biological Sensing, Department of Environmental Engineering
Number of pages: 6
Pages: 84-89
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Sensing and Bio-Sensing Research
Volume: 5
ISSN (Print): 2214-1804
Ratings:
Scopus rating (2016): CiteScore 1.49 SJR 0.372 SNIP 0.619
Scopus rating (2015): SJR 0.278 SNIP 0.865 CiteScore 1.31
Original language: English
Surface-enhanced Raman spectroscopy, Hydrogen cyanide, Pseudomonas aeruginosa, Cystic fibrosis, Breath analysis
Electronic versions:
1_s2.0_S2214180415300040_main.pdf
DOIs:
10.1016/j.sbsr.2015.07.002

Bibliographical note
This is an open access article under the CC BY-NC-ND license
Source: FindIt
Source-ID: 2279655559
Publication: Research - peer-review › Journal article – Annual report year: 2015
Wafer-Scale Leaning Silver Nanopillars for Molecular Detection at Ultra-Low Concentrations

Wafer-scale surface-enhanced Raman scattering (SERS) substrates fabricated using maskless lithography are important for scalable production targets. Large-area, leaning silver-capped silicon nanopillar (Ag NP) structures suitable for SERS molecular detection at extremely low analyte concentrations are investigated. Theoretical results show that isolated Ag NPs essentially support two localized surface plasmon (LSP) modes. The most prominent LSP resonance is observed in the near-infrared region (∼800 nm) and can be tuned by changing the diameter of the silicon nanopillars (Si NPs). The corresponding electric field distribution maps indicate that the maximum E-field enhancement is found at the Ag cavity, i.e., the bottom part of the Ag cap. We argue that the plasmon coupling between the resonant Ag cap cavities contributes most to the enhancement of the Raman signal. We experimentally evaluate these findings and show that by exposing Si NPs to an O2-plasma the average Ag NP cluster size, and thus the overall interpillar coupling, can be systematically reduced. We show that deposition of Cr adhesion layers on Si NPs (>3 nm) introduces plasmon coupling loss to the Ag NP LSP cavity mode that significantly reduces the SERS intensity. Results also show that short exposures to the O2-plasma and the use of 1–3 nm Cr adhesion layers are advantageous for reducing the signal background noise from Ag NPs. In addition, the influence of the Ag NP height and Ag metal thickness on SERS intensities is investigated and optimal fabrication process parameters are evaluated. Finally, the SERS spectrum from 100 pM trans-1,2-bis(4-pyridyl) ethylene (BPE) is recorded, showing distinct characteristic Raman vibrational modes. The calculated enhancement factor is of the order of $10^8$, and the SERS signal intensity exhibits a standard deviation of around 14% (660 data points) across a $5 \times 5$ mm$^2$ surface area.
Fabrication and Process Optimization of Wafer-scale Silicon Nanopillar SERS Substates

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Wu, K. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Number of pages: 1
Publication date: 2014
Event: Poster session presented at 40th International Conference on Micro and Nano Engineering, Lausanne, Switzerland.
Main Research Area: Technical/natural sciences
Electronic versions:
2014.09.MNE.v2.pdf
Source: PublicationPreSubmission
Source-ID: 100597072
Publication: Research - peer-review › Poster – Annual report year: 2014

Improving spectral resolution of SERS using moving Ag nanopillar substrate

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Brøgger, A. L. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Number of pages: 2
Publication date: 2014

Host publication information
Title of host publication: Proceedings of the 24th International Conference On Raman Spectroscopy
Main Research Area: Technical/natural sciences
Conference: 24th International Conference on Raman Spectroscopy, Jena, Germany, 10/08/2014 - 10/08/2014
Electronic versions:
icors2014_ALB_final.pdf
Source: PublicationPreSubmission
Source-ID: 101141591
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2014
Improving spectral resolution of SERS using moving AG nanopillar substrate

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Department of Applied Mathematics and Computer Science, Cognitive Systems
Authors: Brøgger, A. L. (Intern), Schmidt, M. S. (Intern), Rindzevicius, T. (Intern), Alstrøm, T. S. (Intern), Boisen, A. (Intern)
Number of pages: 1
Publication date: 2014
Event: Poster session presented at 24th International Conference on Raman Spectroscopy, Jena, Germany.
Main Research Area: Technical/natural sciences
Electronic versions:
Poster_ICORS.pdf
Source: PublicationPreSubmission
Source-ID: 101141519
Publication: Research - peer-review › Poster – Annual report year: 2014

Low-Power Photothermal Probing of Single Plasmonic Nanostructures with Nanomechanical String Resonators

We demonstrate the direct photothermal probing and mapping of single plasmonic nanostructures via the temperature-induced detuning of nanomechanical string resonators. Single Au nanoslits and nanorods are illuminated with a partially polarized focused laser beam (λ = 633 nm) with irradiances in the range of 0.26–38 μW/μm². Photothermal heating maps with a resolution of ~375 nm are obtained by scanning the laser over the nanostructures. Based on the string sensitivities, absorption efficiencies of 2.3 ± 0.3 and 1.1 ± 0.7 are extracted for a single nanoslit (53 nm × 1 μm) and nanorod (75 nm × 185 nm). Our results show that nanomechanical resonators are a unique and robust analysis tool for the low-power investigation of thermoplasmonic effects in plasmonic hot spots.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Schmid, S. (Intern), Wu, K. (Intern), Larsen, P. E. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Pages: 2318-2321
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Nano Letters
Volume: 14
Issue number: 5
ISSN (Print): 1530-6984
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 13.4
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 14.76
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 14.04
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 14.23
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 13.78
ISI indexed (2012): ISI indexed yes
Plasmonic nanostructures (hotspots) are key components e.g. in plasmon-enhanced spectroscopy, plasmonic solar cells, or as nano heat sources. The characterization of single hotspots is still challenging due to a lack of experimental tools. We present the direct photothermal probing and mapping of single plasmonic nanoslits via the thermally induced detuning of nanomechanical string resonators. A maximum relative frequency detuning of 0.5 % was measured for a single plasmonic nanoslit for a perpendicularly polarized laser with a power of 1350 nW. Finally, we show the photothermal scan over a nanoslit array.

**General information**
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes
Authors: Schmid, S. (Intern), Wu, K. (Intern), Rindzevicius, T. (Intern), Boisen, A. (Intern)
Pages: 1205-1208
Publication date: 2014
Synthesis and characterization of covalent diphenylalanine nanotube-folic acid conjugates

Herein, we describe the synthesis and characterization of a covalent nanoscale assembly formed between diphenylalanine micro/nanotubes (PNT) and folic acid (FA). The conjugate was obtained via chemical functionalization through coupling of amine groups of PNTs and carboxylic groups of FA. The surface analysis of PNT-FA indicated the presence of FA aggregates on the surface of PNTs. The covalent interaction between FA and self-assembled PNTs was further investigated using fluorescence microscopy, Raman and surface-enhanced Raman scattering (SERS) spectroscopies. The SERS experiments were performed on a large area silver-capped (diameter of 62 nm) silicon nanopillars with an approximate height of 400 nm and a width of 200 nm. The results showed that the PNT-FA synthesis procedure preserves the molecular structure of FA. The PNT-FA conjugate presented in this study is a promising candidate for applications in the detection and diagnosis of cancer or tropical diseases such as leishmaniasis and as a carrier nanosystem delivering drugs to malignant tumors that overexpress folate receptors.
A microfluidic surface enhanced Raman spectroscopic biosensor using aptamer functionalized nanopillars

This paper presents a microchip incorporating an aptamer-functionalized nanopillar substrate, enabling the specific detection of low-abundance biomolecules using surface enhanced Raman spectroscopy (SERS). In a temperature controlled microchamber, aptamers immobilized on the nanostructure surface specifically recognize target molecules. Raman-tagged biomolecules trapped within a cluster of leaning nanopillars report greatly enhanced Raman signals due to the coupling effect of localized surface plasmons. It was demonstrated that integrated intensities of spatially collected Raman responses are linearly proportional to analyte concentrations in the low picomolar regime (10/ 50/ 100/ 200 pM), showing the capability of our device for sensitive and quantitative detection of analyte molecules.
Computational and experimental studies of the interaction between single-walled carbon nanotubes and folic acid
This work involved the preparation of a conjugate between single-walled carbon nanotubes and folic acid that was obtained without covalent chemical functionalization using a simple "one pot" synthesis method. Subsequently, the conjugate was investigated by a computational hybrid method: our own Nlayered Integrated Molecular Orbital and Molecular Mechanics (B3LYP(6–31G(d):UFF)). The results confirmed that the interaction occurred via hydrogen bonding between protons of the glutamic moiety from folic acid and π electrons from the carbon nanotubes. The single-walled carbon nanotube-folic acid conjugate presented herein is believed to lead the way to new potential applications as carbon nanotube-based drug delivery systems.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Nano Bio Integrated Systems, Polymer Microsystems for Medical Diagnostics, Universidad Santo Tomas, Universidad Industrial de Santander
Authors: Castillo, J. J. (Ekstern), Rozo, C. E. (Ekstern), Castillo-León, J. (Intern), Rindzevicius, T. (Intern), Svendsen, W. E. (Intern), Rozlosnik, N. (Intern), Boisen, A. (Intern), O, F. M. (Ekstern)
Pages: 60-64
Publication date: 2013
Main Research Area: Technical/natural sciences

Publication information
Journal: Chemical Physics Letters
Volume: 564
ISSN (Print): 0009-2614
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.71 SJR 0.726 SNIP 0.721
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.733 SNIP 0.747 CiteScore 1.83
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.757 SNIP 0.773 CiteScore 1.83
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.856 SNIP 0.844 CiteScore 2.07
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.101 SNIP 0.916 CiteScore 2.2
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.156 SNIP 1.013 CiteScore 2.38
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.207 SNIP 0.94
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.234 SNIP 0.972
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.296 SNIP 0.937
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.43 SNIP 1.001
Web of Science (2007): Indexed yes
Non-covalent conjugates of single-walled carbon nanotubes and folic acid for interaction with cells overexpressing folate receptors

We here present a method to form a noncovalent conjugate of single-walled carbon nanotubes and folic acid aimed to interact with cells over-expressing folate receptors. The bonding was obtained without covalent chemical functionalization using a simple, rapid “one pot” synthesis method. The zeta potential for the single-walled carbon nanotube–folic acid solution was $-32.4$ mV at pH 7.0 and the result indicates that the folic acid coating inhibited aggregation of the carbon nanotubes. Properties of the single-walled carbon nanotube–folic acid conjugate were analyzed using ultraviolet-visible, fluorescence and Raman spectroscopies. While the folic acid fluorescence signature was significantly quenched by the presence of single-walled carbon nanotubes, the Raman spectra of the conjugate displayed a decreased distribution of sp3 sites. Both results were attributed to the noncovalent functionalization of the single-walled carbon nanotubes with folic acid. A more detailed investigation of the single-walled carbon nanotube–folic acid conjugates utilizing scanning electron microscopy, atomic force microscopy and energy-dispersive X-ray spectroscopy confirmed the presence of the well-defined folic acid coating on the individual single-walled carbon nanotubes. The single-walled carbon nanotube–folic acid conjugates were incubated with THP-1 cells and the internalization was evaluated by Giemsa staining with light microscopy, and cytotoxicity was evaluated using the MTT reduction assay. The cytotoxicity studies presented a low toxicity of the conjugates in the THP-1 cells. The low toxicity and the cellular uptake of single-walled carbon nanotube–folic acid by cancer cells suggest their potential use in carbon nanotube-based drug delivery systems and in the diagnosis of cancer or tropical diseases such as leishmaniasis.

General information

State: Published
Organisations: Department of Micro- and Nanotechnology, Nano Bio Integrated Systems, Polymer Microsystems for Medical Diagnostics, Nanoprobes, Universidad Industrial de Santander
Authors: Castillo, J. J. (Ekstern), Rindzevicius, T. (Intern), Novoa, L. V. (Ekstern), Svendsen, W. E. (Intern), Rozlosnik, N. (Intern), Boisen, A. (Intern), Escobar, P. (Ekstern), Martinez, F. (Ekstern), Castillo-Léon, J. (Intern)
Pages: 1475–1481
Publication date: 2013
Main Research Area: Technical/natural sciences

Publication Information
Journal: Journal of Materials Chemistry B
Volume: 1
Issue number: 10
ISSN (Print): 2050-750X
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Surface-Enhanced Raman Spectroscopy Based Quantitative Bioassay on Aptamer-Functionalized Nanopillars Using Large-Area Raman Mapping

Surface-enhanced Raman spectroscopy (SERS) has been used in a variety of biological applications due to its high sensitivity and specificity. Here, we report a SERS-based biosensing approach for quantitative detection of biomolecules. A SERS substrate bearing gold-decorated silicon nanopillars is functionalized with aptamers for sensitive and specific detection of target molecules. In this study, TAMRA-labeled vasopressin molecules in the picomolar regime (1 pM to 1 nM) are specifically captured by aptamers on the nanostructured SERS substrate and monitored by using an automated SERS signal mapping technique. From the experimental results, we show concentration-dependent SERS responses in the picomolar range by integrating SERS signal intensities over a scanning area. It is also noted that our signal mapping approach significantly improves statistical reproducibility and accounts for spot-to-spot variation in conventional SERS quantification. Furthermore, we have developed an analytical model capable of predicting experimental intensity distributions on the substrates for reliable quantification of biomolecules. Lastly, we have calculated the minimum needed area of Raman mapping for efficient and reliable analysis of each measurement. Combining our SERS mapping analysis with an aptamer-functionalized nanopillar substrate is found to be extremely efficient for detection of low-abundance biomolecules.
Dense high aspect ratio pillar arrays for carbon MEMS electrodes

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Nanoprobes, Bioanalytics, Technical University of Denmark, Capres A/S, Ecole Polytechnique, University of California, Irvine, University of Canterbury, Lund University
Authors: Amato, L. (Intern), Hansen, R. J. (Ekstern), Heiskanen, A. (Intern), Gammelgard, L. (Ekstern), Rindzevicius, T. (Intern), Martinez-Duarte, R. (Ekstern), Singh Bisht, G. (Ekstern), Downard, A. (Ekstern), Baronian, K. (Ekstern), Tenje, M. (Ekstern), Madou, M. (Ekstern), Boisen, A. (Intern), Emnéus, J. (Intern), Keller, S. S. (Intern)
Number of pages: 1
Publication date: 2012

Host publication information
Title of host publication: Proceedings of the 38th International Conference on Micro and Nano Engineering
Main Research Area: Technical/natural sciences
3D microelectrodes, Pyrolysed micropillars, Carbon MEMS electrodes
Electronic versions:
Dense high aspect ratio pillar arrays for carbon MEMS electrodes.pdf
Source: dtu
Source-ID: u::10312
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2013

Projects:

Development of Highly sensitive raman spectroscopy system for monitoring of multicomponent drug mixtures in the PPM Concentration range

Department of Micro- and Nanotechnology
Period: 01/11/2017 → 31/10/2020
Number of participants: 4
Phd Student:
Slipets, Roman (Intern)
Supervisor:
Ilchenko, Oleksii (Intern)
Rindzevicius, Tomas (Intern)
Main Supervisor:
Boisen, Anja (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Optical Sensor Disc
Department of Micro- and Nanotechnology
Period: 01/10/2017 → 30/09/2020
Number of participants: 4
Phd Student:
Serioli, Laura (Intern)
Supervisor:
Rindzevicius, Tomas (Intern)
Zor, Kinga (Intern)
Main Supervisor:
Boisen, Anja (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Sensors on disc
Department of Micro- and Nanotechnology
Period: 01/05/2017 → 30/04/2020
Number of participants: 4
Phd Student:
Rajendran, Sriram Thoppe (Intern)
Supervisor:
Rindzevicius, Tomas (Intern)
Zor, Kinga (Intern)
Main Supervisor:
Boisen, Anja (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Fonde
Project: PhD

Nanomechanical Sensors
Department of Micro- and Nanotechnology
Period: 01/10/2016 → 30/09/2019
Number of participants: 4
Phd Student:
Padmanabhan Rangacharya, Varadarajan (Intern)
Supervisor:
Larsen, Peter Emil (Intern)
Rindzevicius, Tomas (Intern)
Main Supervisor:
Boisen, Anja (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

**Development of Surface-Enhanced Raman Scattering Sensors**
Department of Micro- and Nanotechnology
Period: 01/09/2016 → 31/08/2019
Number of participants: 4
Phd Student:
Viehrig, Marlitt (Intern)
Supervisor:
Rindzevicius, Tomas (Intern)
Schmidt, Michael Stenbæk (Intern)
Main Supervisor:
Boisen, Anja (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Fonde
Project: PhD

**SERS based Sensing and Centrifugal Microfluidics**
Department of Micro- and Nanotechnology
Period: 15/01/2015 → 14/01/2018
Number of participants: 5
Phd Student:
Durucan, Onur (Intern)
Supervisor:
Matteucci, Marco (Intern)
Rindzevicius, Tomas (Intern)
Schmidt, Michael Stenbæk (Intern)
Main Supervisor:
Boisen, Anja (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

**Disc System for Cellular Studios**
Department of Micro- and Nanotechnology
Period: 01/12/2014 → 21/12/2017
Number of participants: 4
Phd Student:
Morelli, Lidia (Intern)
Supervisor:
Rindzevicius, Tomas (Intern)
Zor, Kinga (Intern)
Main Supervisor:
Boisen, Anja (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD
Surface Plasmon based sensors using nanopillar arrays

Department of Micro- and Nanotechnology
Period: 15/08/2013 → 08/02/2017
Number of participants: 7
Phd Student:
Thilsted, Anil Haraksingh (Intern)
Supervisor:
Rindzevicius, Tomas (Intern)
Schmidt, Michael Stenbæk (Intern)
Main Supervisor:
Boisen, Anja (Intern)
Examiner:
Hübner, Jörg (Intern)
Ariese, Freek (Ekstern)
Pedersen, Jens Engholm (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering

Relations
Publications:
Transparent Substrates for Plasmonic Sensing by Lithography-Free Fabrication
Project: PhD

SERS as tool for monitoring lung infections

Department of Micro- and Nanotechnology
Period: 01/11/2012 → 08/02/2017
Number of participants: 7
Phd Student:
Lauridsen, Rikke Kragh (Intern)
Supervisor:
Molin, Søren (Intern)
Rindzevicius, Tomas (Intern)
Main Supervisor:
Boisen, Anja (Intern)
Examiner:
Bohr, Jakob (Intern)
Gilchrist, Francis J. (Ekstern)
Turner, Anthony P. F. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering

Relations
Publications:
SERS detection of pneumonia in breath of children with cystic fibrosis
Project: PhD

Activities:

A nanofiltration technique for analyte extraction from complex matrix and surface enhanced Raman spectroscopy based sensing
Period: 20 Sep 2017
Onur Durucan (Guest lecturer)
Our novel proof-of-concept centrifugal microfluidics sensing platform (Fig. 1), allows to perform fast and facile purification (nanofiltration) of the complex sample by incorporating inertial (centrifugal) and capillary forces. Furthermore, integrated in the platform, highly uniform Au capped Si nanopillar (NP) substrates for surface enhanced Raman spectroscopy (SERS) are capable to detect analyte molecules in trace amounts [1]. However, in most of the cases SERS based sensing applications are accompanied with complicated sample manipulation and external purification steps. This can be addressed to various experimental difficulties of SERS based measurements when handling real-life complex samples. Therefore, we believe that combination with the nanofiltration technique would sufficiently increase sensitivity and applicability of SERS based sensors. In addition to that, the nanofiltration of the sample and SERS based sensing of analyte is carried out on the same chip (Au NP surface) which provides robustness to the platform.

Degree of recognition: International

Related event

43rd International conference on Micro and Nano Engineering
18/09/2017 → 22/09/2017
Braga, Portugal
Activity: Talks and presentations › Conference presentations

Structural aspects of hydrates – insight into phase transformations using nanomechanical sensors
Period: 28 Jun 2017 → 30 Jun 2017
Peter Ouma Okeyo (Guest lecturer)
Peter Emil Larsen (Guest lecturer)
Oleksii Ilchenko (Guest lecturer)
Tomas Rindzevicius (Guest lecturer)
Roman Slipets (Guest lecturer)
Anja Boisen (Guest lecturer)
Thomas Rades (Guest lecturer)
Jukka Rantanen (Guest lecturer)

Department of Micro- and Nanotechnology
Nanoprobes

Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Degree of recognition: International

Related event

11th annual meeting of the Pharmaceutical Solid State Research Cluster
28/06/2017 → 30/06/2017
Graz, Austria
Activity: Talks and presentations › Conference presentations

Integration of Nanopillar SERS Substrates in a Microfluidic Platform for Analyte Separation and Quantitative Sensing
Period: 11 Jun 2017 → 17 Jun 2017
Onur Durucan (Guest lecturer)
Lidia Morelli (Guest lecturer)
Kaiyu Wu (Guest lecturer)
Marlitt Viehrig (Guest lecturer)
Oleksii Ilchenko (Guest lecturer)
Related event

9th International Conference on Advanced Vibrational Spectroscopy
11/06/2017 → 17/06/2017
Victoria, Canada
Activity: Talks and presentations › Conference presentations

SERS combiner for high-speed and high-sensitive quantitative analysis
Period: 11 Jun 2017 → 17 Jun 2017
Oleksii Ilchenko (Guest lecturer)
Tomas Rindzevicius (Guest lecturer)
Onur Durucan (Guest lecturer)
Michael Stenbaek Schmidt (Guest lecturer)
Roman Slipets (Other)
Lidia Morelli (Guest lecturer)
Anja Boisen (Guest lecturer)
Department of Micro- and Nanotechnology
Nanoprobes
Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics

Related event

9th International Conference on Advanced Vibrational Spectroscopy
11/06/2017 → 17/06/2017
Victoria, Canada
Activity: Talks and presentations › Conference presentations

SERS combiner for high-speed and high-sensitive quantitative analysis
Period: 11 Jun 2017 → 17 Jun 2017
Oleksii Ilchenko (Guest lecturer)
Tomas Rindzevicius (Guest lecturer)
Michael Stenbaek Schmidt (Guest lecturer)
Roman Slipets (Guest lecturer)
Onur Durucan (Guest lecturer)
Lidia Morelli (Guest lecturer)
Anja Boisen (Guest lecturer)
Department of Micro- and Nanotechnology
Nanoprobes
Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Related event

9th International Conference on Advanced Vibrational Spectroscopy
11/06/2017 → 17/06/2017
Victoria, Canada
Activity: Talks and presentations › Conference presentations