Evolution of intermetallic GaPd$_2$/SiO$_2$ catalyst and optimization for methanol synthesis at ambient pressure

The CO$_2$ hydrogenation to methanol is efficiently catalyzed at ambient pressure by nanodispersed intermetallic GaPd$_2$/SiO$_2$ catalyst with a metal loading of 13 wt.%. Compared to catalysts with 23 wt.% and 7 wt.%, indicating that there is an optimum particle size for the reaction of around 8 nm. The highest catalytic activity is measured on catalysts reduced at 550 °C. To unravel the formation of the active phase, we studied calcined GaPd$_2$/SiO$_2$ catalysts with 23 wt.% and 13 wt.% using a combination of in situ techniques: X-ray diffraction (XRD), X-ray absorption near edge fine structure (XANES) and extended X-ray absorption fine structure (EXAFS). We find that the catalyst with higher metal content reduces to metallic Pd in a mixture of H$_2$/Ar at room temperature, while the catalyst with lower metal content retains a mixture of PdO and Pd up to 140 °C. Both catalysts form the GaPd$_2$ phase above 300 °C, albeit the fraction of crystalline intermediate Pd nanoparticles of the catalyst with higher metal loading reduces at higher temperature. In the final state, the catalyst with higher metal loading contains a fraction of unalloyed metallic Pd, while the catalyst with lower metal loading is phase pure. We discuss the alloying mechanism leading to the catalyst active phase formation selecting three temperatures: 25 °C, 320 °C and 550 °C.

Intrinsic XRF corrections in Timepix3 CdTe spectral detectors

One of the limitations of Hybrid Pixel Detectors (HPD) is the intrinsic X-ray fluorescence emission from the detector semiconductor sensor. These fluorescence photons cause artifacts and false peaks in the photon energy spectrum measured by the HPD. ADVAPIX-Timepix3 is an energy dispersive HPD based on a semiconductor sensor (Si/CdTe/CZT/GaAS) and readout by a Timepix3 ASIC. Timepix3 is capable of measuring simultaneous Time-Over-Threshold (Energy) and Time-of-Arrival as well as sparse readout. This allows unambiguous one-by-one photon detection where each photon measurement is assigned a time stamp. In this work, we use the time and energy information of every single photon to identify intrinsic XRF events in a 57Co radioactive source spectrum as measured by a CdTe based detector. We compute the minimum time (ns) and space (pixels) coincidence window, between the XRF and escape photons, that is required to suppress the XRF effect. These parameters were found to be ±15 ns and 10 pixels (pixel size = 55 μm) for 1 mm CdTe at 3000 V/cm, 24 ± 1°C, and a flux of 1.666 × 10$^3$ photons/s before correction.
Laser ablation of high-aspect-ratio hole arrays in tungsten for X-ray applications

Periodic two-dimensional tungsten X-ray optical gratings were fabricated using a combination of pico-second laser ablation and wet chemical etch. A 200 μm thick cold-rolled sheet of tungsten (99.97%) was used as base material for the fabrication of a 1.5 × 1.5 cm² periodic grating with an array of circular holes of approximately 12:1 aspect ratio. The laser parameters were optimized to obtain through-hole diameters slightly smaller than the desired final dimension. Subsequent wet etching was used to precisely control the diameter of through-holes. The through-hole profile was characterized using scanning electron microscopy (SEM) and showed a slight conical shape with a slope of 1.3%. The two-dimensional tungsten absorption grating was successfully tested in an X-ray phase-contrast imaging setup. The method has proven to have some relevant benefits, such as good reproducibility and fairly easy fabrication due to few manufacturing steps.

Virtual subpixel approach for single-mask phase-contrast imaging using Timepix3

X-ray phase contrast imaging provides a method to distinguish materials with similar density and effective atomic number, which otherwise would be difficult using conventional X-ray absorption contrast. In recent years, multiple methods have been developed to acquire X-ray phase contrast images using incoherent laboratory sources. The single mask edge illumination setup has been demonstrated as a possible candidate for large scale applications due to its relaxed restrictions on longitudinal coherence and mask alignment, and for its ability to do bi-directional phase contrast images in
a single sample exposure. Unfortunately, the single mask edge illumination setup’s refraction sensitivity, and thereby signal to noise, is limited by detector artifacts. Furthermore, it requires multiple exposures to perform dark-field imaging, a method that enables imaging of micro-structures smaller than the image resolution.

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**Simulation tools for scattering corrections in spectrally resolved X-ray Computed Tomography using McXtrace**
Spectral computed tomography is an emerging imaging method that involves using recently developed energy discriminating photon-counting detectors (PCDs). This technique enables measurements at isolated high-energy ranges, in which the dominating undergoing interaction between the x-ray and the sample is the incoherent scattering. The scattered radiation causes a loss of contrast in the results, and its correction has proven to be a complex problem, due to its dependence on energy, material composition, and geometry. Monte Carlo simulations can utilize a physical model to estimate the scattering contribution to the signal, at the cost of high computational time. We present a fast Monte Carlo simulation tool, based on McXtrace, to predict the energy resolved radiation being scattered and absorbed by objects of complex shapes. We validate the tool through measurements using a CdTe single PCD (Multix ME-100) and use it for scattering correction in a simulation of a spectral CT. We found the correction to account for up to 7% relative amplification in the reconstructed linear attenuation. It is a useful tool for x-ray CT to obtain a more accurate material discrimination, especially in the high-energy range, where the incoherent scattering interactions become prevailing (>50 keV).

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Spectral correction algorithm for multispectral CdTe x-ray detectors

Compared to the dual-energy scintillator detectors widely used today, energy-resolved photon-counting x-ray detectors show the potential to improve material identification in various radiography and tomography applications used for industrial and security purposes. However, detector effects, such as charge sharing and photon pileup, distort the measured spectra in pixelated, photon-counting detectors operating under high flux. These effects result in a significant performance degradation of the detectors when used for material identification where accurate spectral measurements are required. We have developed a semianalytical, postdata acquisition, computational algorithm that corrects the measured attenuation curve for severe spectral distortions caused by the detector. The calibration of the algorithm is based on simple attenuation measurements of commercially available materials using standard laboratory sources, enabling the algorithm to be used in any x-ray setup. The algorithm is developed for correcting spectral data acquired with the MultiX ME100 CdTe x-ray detector but could be adapted with small adjustments to other photon-counting, energy-resolved detectors with CdTe sensors. The validation of the algorithm has been done using experimental data acquired with both a standard laboratory source and synchrotron radiation. The experiments show that the algorithm is fast, reliable at x-ray flux up to 5 Mph/s/mm(2) and greatly improves the accuracy of the measured spectrally resolved linear attenuation, making the algorithm useful for both security and industrial applications where photon-counting detectors are used. (C) 2018 Society of Photo-Optical Instrumentation Engineers (SPIE)
Subpixel resolution in CdTe Timepix3 pixel detectors

Timepix3 (256 × 256 pixels with a pitch of 55 μm) is a hybrid-pixel-detector readout chip that implements a data-driven architecture and is capable of simultaneous time-of-arrival (ToA) and energy (ToT: time-over-threshold) measurements. The ToA information allows the unambiguous identification of pixel clusters belonging to the same X-ray interaction, which allows for full one-by-one detection of photons. The weighted mean of the pixel clusters can be used to measure the subpixel position of an X-ray interaction. An experiment was performed at the European Synchrotron Radiation Facility in Grenoble, France, using a 5 μm × 5 μm pencil beam to scan a CdTe-ADVAPIX-Timepix3 pixel (55 μm × 55 μm) at 8 × 8 matrix positions with a step size of 5 μm. The head-on scan was carried out at four monochromatic energies: 24, 35, 70 and 120 keV. The subpixel position of every single photon in the beam was constructed using the weighted average of the charge spread of single interactions. Then the subpixel position of the total beam was found by calculating the mean position of all photons. This was carried out for all points in the 8 × 8 matrix of beam positions within a single pixel. The optimum conditions for the subpixel measurements are presented with regards to the cluster sizes and beam subpixel position, and the improvement of this technique is evaluated (using the charge sharing of each individual photon to achieve subpixel resolution) versus alternative techniques which compare the intensity ratio between pixels. The best result is achieved at 120 keV, where a beam step of 4.4 μm ± 0.86 μm was measured.

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A METHOD OF SECURITY SCANNING OF CARRY-ON ITEMS, AND A CARRY-ON ITEMS SECURITY SCANNING SYSTEM

A security scanning system (1) comprises a first stage module (3) having at least one X-ray source (6) and at least three first detectors (7) that are line-shaped and arranged in mutually different orientations and have at least dual energy resolution. A group of carry-on items (4) on a carrier are scanned simultaneously in the first stage module solely by transmission contrast radiography generating projections of two-dimensional image data. A processing device (9) reconstructs a 3D representation of the carry-on items and analyzes the 3D representation to determine whether further scanning is required.

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A Monte Carlo simulation of scattering reduction in spectral x-ray computed tomography

In X-ray computed tomography (CT), scattered radiation plays an important role in the accurate reconstruction of the inspected object, leading to a loss of contrast between the different materials in the reconstruction volume and cupping artifacts in the images. We present a Monte Carlo simulation tool for spectral X-ray CT to predict the scattered radiation generated by complex samples. An experimental setup is presented to isolate the energy distribution of scattered radiation. Spectral CT is a novel technique implementing photon-counting detectors able to discriminate the energy of incoming photons, enabling spectral analysis of X-ray images. This technique is useful to extract efficiently more information on energy dependent quantities (e.g. mass attenuations coefficients) and study matter interactions (e.g. X-ray scattering, photoelectric absorption, etc...). Having a good knowledge of the spectral distribution of the scattered X-rays is fundamental to establish methods attempting to correct for it. The simulations are validated by real measurements using a CdTe spectral resolving detector (Multix ME-100). We observed the effect of the scattered radiation on the image reconstruction, becoming relevant in the energy range where the Compton events are dominant (i.e. above 50keV).

Detector response artefacts in spectral reconstruction

Energy resolved detectors are gaining traction as a tool to achieve better material contrast. K-edge imaging and tomography is an example of a method with high potential that has evolved on the capabilities of photon counting energy dispersive detectors. Border security is also beginning to see instruments taking advantage of energy resolved detectors. The progress of the field is halted by the limitations of the detectors. The limitations include nonlinear response for both x-ray intensity and x-ray spectrum. In this work we investigate how the physical interactions in the energy dispersive detectors affect the quality of the reconstruction and how corrections restore the quality. We have modeled detector responses for the primary detrimental effects occurring in the detector; escape peaks, charge sharing/loss and pileup. The effect of the change in the measured spectra is evaluated based on the artefacts occurring in the reconstructed images. We also evaluate the effect of a correction algorithm for reducing these artefacts on experimental data acquired with a setup using Multix ME-100 V-2 line detector modules. The artefacts were seen to introduce 20% deviation in the reconstructed attenuation coefficient for the uncorrected detector. We performed tomography experiments on samples with various materials interesting for security applications and found the SSIM to increase >; 5% below 60keV. Our work shows that effective corrections schemes are necessary for the accurate material classification in security application promised by the advent of high flux detectors for spectral tomography.
Spectral correction algorithm for multispectral CdTe x-ray detectors

Compared to the dual energy scintillator detectors widely used today, pixelated multispectral X-ray detectors show the potential to improve material identification in various radiography and tomography applications used for industrial and security purposes. However, detector effects, such as charge sharing and photon pileup, distort the measured spectra in high flux pixelated multispectral detectors. These effects significantly reduce the detectors’ capabilities to be used for material identification, which requires accurate spectral measurements. We have developed a semi analytical
computational algorithm for multispectral CdTe X-ray detectors which corrects the measured spectra for severe spectral distortions caused by the detector. The algorithm is developed for the MultiX ME100 CdTe X-ray detector, but could potentially be adapted for any pixelated multispectral CdTe detector. The calibration of the algorithm is based on simple attenuation measurements of commercially available materials using standard laboratory sources, making the algorithm applicable in any X-ray setup. The validation of the algorithm has been done using experimental data acquired with both standard lab equipment and synchrotron radiation. The experiments show that the algorithm is fast, reliable even at X-ray flux up to 5 Mphs/mm², and greatly improves the accuracy of the measured X-ray spectra, making the algorithm very useful for both security and industrial applications where multispectral detectors are used. **General information** Publication status: Published Organisations: Department of Physics, Neutrons and X-rays for Materials Physics, University of Copenhagen, European XFEL Contributors: Christensen, E. D., Kehres, J., Gu, Y., Feidenhans'l, R., Olsen, U. L. Number of pages: 15 Publication date: 2017

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Threat detection of liquid explosives and precursors from their x-ray scattering pattern using energy dispersive detector technology

Energy dispersive X-ray diffraction (EDXRD) can be applied for identification of liquid threats in luggage scanning in security applications. To define the instrumental design, the framework for data reduction and analysis and test the performance of the threat detection in various scenarios, a flexible laboratory EDXRD test setup was build. A data set of overall 570 EDXRD spectra has been acquired for training and testing of threat identification algorithms. The EDXRD data was acquired with limited count statistics and at multiple detector angles and merged after correction and normalization. Initial testing of the threat detection algorithms with this data set indicate the feasibility of detection levels of > 95 % true positive with < 6 % false positive alarms. **General information** Publication status: Published Organisations: Department of Physics, Neutrons and X-rays for Materials Physics, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics Contributors: Kehres, J., Olsen, U. L., Lyksborg, M. Number of pages: 9 Publication date: 2017

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Novel micro-reactor flow cell for investigation of model catalysts using in situ grazing-incidence X-ray scattering

The design, fabrication and performance of a novel and highly sensitive micro-reactor device for performing in situ grazing-incidence X-ray scattering experiments of model catalyst systems is presented. The design of the reaction chamber, etched in silicon on insulator (SiO), permits grazing-incidence small-angle X-ray scattering (GISAXS) in transmission through 10 µm-thick entrance and exit windows by using micro-focused beams. An additional thinning of the Pyrex glass reactor lid allows simultaneous acquisition of the grazing-incidence wide-angle X-ray scattering (GIWAXS). In situ experiments at synchrotron facilities are performed utilizing the micro-reactor and a designed transportable gas feed and analysis system. The feasibility of simultaneous in situ GISAXS/GIWAXS experiments in the novel micro-reactor flow cell was confirmed with CO oxidation over mass-selected Ru nanoparticles.

Reduction of a Ni/Spinel Catalyst for Methane Reforming

A nickel/spinel (Ni/MgAl2O4) catalyst, w(Ni) = 22 wt%, was investigated in situ during reduction with wide angle X-ray scattering (WAXS) in a laboratory setup and with anomalous small angle X-ray scattering (ASAXS) at a synchrotron source. Complementary high resolution transmission electron microscopy (HRTEM) was performed on the fresh catalyst sample. The Ni particles in the fresh catalyst sample were observed to exhibit a Ni/NiO core/shell structure. A decrease of the Ni lattice parameter is observed during the reduction in a temperature interval from 413 – 453 K, which can be related to the reduction of the NiO shell, whereby stress due to the lattice mismatch of Ni and NiO is relieved.
Morphology Changes of Co Catalyst Nanoparticles at the Onset of Fischer-Tropsch Synthesis

Cobalt nanoparticles play an important role as catalysts for the Fischer-Tropsch synthesis, which is an attractive route for production of synthetic fuels. It is of particular interest to understand the varying conversion rate during the first hours after introducing synthesis gas (H-2 and CO) to the system. To this end, several in situ characterization studies have previously been done on both idealized model systems and commercially relevant catalyst nanoparticles, using bulk techniques, such as X-ray powder diffraction and X-ray absorption spectroscopy. Since catalysis takes place at the surface of the cobalt particles, it is important to develop methods to gain surface-specific structural information under realistic processing conditions. We addressed this challenge using small-angle X-ray scattering (SAXS), a technique exploiting the penetrating nature of X-rays to provide information about particle morphology during in situ experiments. Simultaneous wide-angle X-ray scattering was used for monitoring the reduction from oxide to catalytically active metal cobalt, and anomalous SAXS was used for distinguishing the cobalt particles from the other phases present. After introducing the synthesis gas, we found that the slope of the scattered intensity in the Porod region increased significantly, while the scattering invariant remained essentially constant, indicating a change in the shape or surface structure of the particles. Shape- and surface change models are discussed in light of the experimental results, leading to an improved understanding of catalytic nanoparticles.
**Introducing a standard method for experimental determination of the solvent response in laser pump, x-ray probe time-resolved wide-angle x-ray scattering experiments on systems in solution**

In time-resolved laser pump, X-ray probe wide-angle X-ray scattering experiments on systems in solution the structural response of the system is accompanied by a solvent response. The solvent response is caused by reorganization of the bulk solvent following the laser pump event, and in order to extract the structural information of the solute, the solvent response has to be treated. Methodologies capable of doing so include both theoretical modelling and experimental determination of the solvent response. In the work presented here, we have investigated how to obtain a reproducible solvent response—the solvent term—experimentally when applying laser pump, X-ray probe time-resolved wide-angle X-ray scattering. The solvent term describes difference scattering arising from the structural response of the solvent to changes in the hydrodynamic parameters: pressure, temperature and density. We present results based on NIR and dye mediated solvent heating, and demonstrate that the solvent response is independent of the heating method. The NIR heating is shown to be rendered unusable by higher order effects under certain experimental conditions, while the dye mediated solvent heating is demonstrated to exhibit first order behaviour with respect to the amount of energy deposited in the solution. We introduce a standardized method for recording solvent responses in laser pump, X-ray probe time-resolved X-ray wide-angle scattering experiments by using dye mediated solvent heating. Furthermore, we have generated a library of solvent terms, which can be used to describe the solvent term in any TRWAXS experiment, and made it available online.
Methanation on mass-selected Ru nanoparticles on a planar SiO$_2$ model support: The importance of under-coordinated sites

Mass-selected Ru nanoparticles were deposited onto planar SiO$_2$ support and their capability for the methanation reaction investigated. The catalytic activity for the methanation reaction at 100mbar under hydrogen rich conditions (1:99 CO/H$_2$ ratio) was measured as a function of particle size. We found that the Turnover Frequency increased with nanoparticle diameter in the range 4–10nm. As the TOF decreases over reaction repetition, we investigated the possible reasons and ruled out carbon deposition as a cause for activity loss. As no particle sintering was observed, we invoked surface restructuring as a possible cause.

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Dynamical Properties of a Ru/MgAl$_2$O$_4$ Catalyst during Reduction and Dry Methane Reforming

Combined in situ small- and wide-angle X-ray scattering (SAXS/WAXS) studies were performed in a new laboratory setup to investigate the dynamical properties of a ruthenium/spinel (Ru/MgAl$_2$O$_4$) catalyst, w(Ru) = 4 wt %, during the reduction and subsequent dry methane reforming. The Ru particles in the fresh catalyst sample were found to be partially oxidized. High-resolution transmission electron microscopy (HRTEM) indicated a coexistence of pure Ru and RuO$_2$ nanoparticles. Reduction in hydrogen occurred at a temperature between 373 and 393 K. The mean particle diameter as refined from SAXS of the size regime attributed to scattering from Ru/RuO$_2$-particles decreases slightly by about 0.2 nm during the reduction. Dry methane reforming experiments were performed in a temperature interval from 723 to 1023 K by applying a gas mixture of carbon dioxide and methane in molar ratio of 3:1. The catalyst did not show any deactivation during the experiment of overall 32 h, indicated by stable turnover frequencies for methane. The mean Ru-particle diameter remained constant during the dry methane reforming experiments, revealing a high sintering stability of the Ru/MgAl$_2$O$_4$ catalyst.

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**Dynamical properties of nano-structured catalysts for methane conversion: an in situ scattering study**

The reactivity of catalyst particles can be radically enhanced by decreasing their size down to the nanometer range. The nanostructure of a catalyst can have an enormous and positive influence on the reaction rate, for example strong structure sensitivity was observed for methane reforming and ammonia synthesis, and it is therefore crucial that catalysts preserve their nanostructures under operational conditions. Fundamental understanding of the relation between the catalytic activity and the morphology of the nanoparticle, their crystallinity and crystallite size, is required to improve the catalysts and assess the optimum conditions of operation. A powerful and suitable technique to resolve these relations is simultaneous small and wide angle X-ray scattering coupled with mass spectroscopy measurements, performed in situ at conditions comparable to large scale processes. A new heater setup for an in situ cell, accommodated in a laboratory SAXS/WAXS camera, has been developed and a sample gas system has been designed and installed. A mass spectrometer has been implemented to monitor the chemical reactions during the in situ experiments. The heater permits experiments in a temperature range from 298 - 1073 K. The heater performance was tested and it was shown that no temperature calibration is needed. The applicability of the new setup, to study nanostructured materials, was successfully demonstrated using anatase TiO2 nanorods. Heating experiments on the nanorods were performed in a temperature range from 298 - 1023 K. Correlated crystallite and particle growth due to sintering were observed after the decomposition of the surfactant. Furthermore transformations from rod to spherical particle shape were observed. In situ reduction experiments of a Ni/MgAl2O4 catalyst were performed. The Ni/NiO particles in a fresh catalyst sample showed a Ni/NiO core shell structure. The Ni lattice parameter decreased during the reduction due to the release of stress between the Ni core and the NiO shell. Ni particles sintered during heating in hydrogen after the reduction of the NiO shell. Dry reforming experiments were performed over a Ru/MgAl2O4. The catalyst showed a high sintering stability and no catalyst deactivation was observed. The results presented in this thesis emphasize the advantage of the simultaneous SAXS/WAXS laboratory setup to study nanostructured materials and catalysts in situ.

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Combined in situ small and wide angle X-ray scattering studies of TiO2 nano-particle annealing

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Combined in situ small and wide angle X-ray scattering studies of TiO2 nano-particle annealing to 1023 K

Combined in situ small- and wide-angle X-ray scattering (SAXS/WAXS) studies were performed in a recently developed laboratory setup to investigate the dynamical properties of dry oleic acid-capped titanium dioxide nanorods during annealing in an inert gas stream in a temperature interval of 298-1023 K. Aggregates formed by the titanium dioxide particles exhibit a continuous growth as a function of temperature. The particle size determined with SAXS and the crystallite size refined from WAXS show a correlated growth at temperatures above 673 K, where the decomposition of the surfactant is expected. At temperatures above 823 K, the particle and crystallite sizes increase rapidly. An increasing discrepancy between particle and crystallite size indicates growth of a shell structure on the single-crystalline core of the particles. This was confirmed by high-resolution transmission electron microscopy studies of the sample. Transmission electron microscopy shows a transformation from a rod to a spherical particle shape; the WAXS data indicate that the shape change occurs in a temperature interval of 773-923 K. The highly crystalline titanium dioxide particles remain in the metastable anatase phase during the entire annealing process. The transition to the thermodynamically stable rutile phase was not observed at any temperature, in agreement with existing experimental observations.

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Hydrogen rotational and translational diffusion in calcium borohydride from quasielastic neutron scattering and DFT
Hydrogen dynamics in crystalline calcium borohydride can be initiated by long-range diffusion or localized motion such as rotations, librations, and vibrations. Herein, the rotational and translational diffusion were studied by quasielastic neutron scattering (QENS) by using two instruments with different time scales in combination with density functional theory (DFT) calculations. Two thermally activated reorientational motions were observed, around the 2-fold (C2) and 3-fold (C3) axes of the BH4− units, at temperature from 95 to 280K. The experimental energy barriers (EaC2 = 0.14 eV and EaC3 = 0.10 eV) and mean residence times are comparable with those obtained from DFT calculations. Long-range diffusion events, with an energy barrier of EaD = 0.12 eV and an effective jump length of 2.5 Å were observed at 224 and 260 K. Three vacancy-mediated diffusion events, H jumps between two neighboring BH4−, and diffusion of BH4− and BH3 groups were calculated and finally discarded because of their very high formation energies and diffusion barriers. Three interstitial diffusion processes (H, H2, and H2O) were also calculated. The H interstitial was found to be highly unstable, whereas the H2 interstitial has a low energy of formation (0.40 eV) and diffusion barrier (0.09 eV) with a jump length (2.1 Å) that corresponds well with the experimental values. H2O interstitial has an energy of formation of −0.05 eV, and two different diffusion pathways were found. The first gives a H jump distance of 2.45 Å with a diffusion barrier of 0.68 eV, the second one, more favorable, exhibits a H jump distance of 1.08 Å with a barrier of 0.40 eV. The correlation between the QENS and DFT calculations indicates that, most probably, it is the diffusion of interstitial H2 that was observed. The origin of the interstitial H2 might come from the synthesis of the compound or a side reaction with trapped synthesis residue leading to the partial oxidation of the compound and hydrogen release.

Grazing incidence small and wide angle scattering studies on TiO2 nanorods and nanotubes for photocatalysis
Grazing incidence small and wide angle scattering studies on TiO2 nanorods and nanotubes for photocatalysis
Small and wide angle in situ scattering with a rotating anode X-ray source

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