50/50 %

dette er oppg. sett m løsning

Norges teknisk-naturvitenskapelige universitet
Institutt for fysikk

Faglig kontakt under eksamen:
Navn: Ton van Helvoort
Tlf.: 93637

EKSAMEN I FAG TFY4330 Nanotools

Fakultet for naturvitenskap og teknologi
Thursday 28 May 2009
Time: 9.00 – 13.00
English text

Number of pages: **X** (+ X for Bokmål text) Sensur deadline: 19.06.2009
Allowed: Hjelpemidler C (simple calculator).

- There are **5** tasks and **17** questions in total. Attempt to answer all questions, they are independent of each other as far as possible. Some questions have sub-questions.
- Read the question carefully and answer it completely
- Max. score per question is indicated. Total: 200 points = 100%
- This is the English exam text. The bokmål Norwegian comes after the English text. The questions are the same. Answers can be given in English or Norwegian.

TASK 1: Optical microscopy measurements

Titanium nitride (TiN) has some interesting properties like a relatively high hardness and good chemical stability. Therefore it is applied in coatings on all kinds of objects, for example on work tools and medical implants.
Recently Japanees researchers could make TiN with a cubic shape of controlled size (10-50 nm length, $Z_{Ti} = 22$, $Z_N = 7$). The goal is to use these TiN nanoparticles as support material for catalysts. In this text the so called TiN nanodices, are coated with Ag catalytic nanoparticles (diameter < 10 nm, $Z_{Ag} = 49$).

To check if very small (sub-µm) particles are formed, which do not cluster together to larger agglomerates, a sample is taken out of the reactor, diluted and quickly inspected by optical microscopy.

Question 1(a):

[Max. score:10 points]

Name the three standard optical imaging modes? Which one would you choose to study the sub-µm sized ceramic particles in the solvent? Give an argumentation for your choice.

The three main optical techniques are bright field, dark field and phase contrast. This division was stressed in the optical labs and in the lectures. The book, as it has a metallurgy focus, underestimates the importance of phase contrast, which is important in the bio/medical field.
Probably dark field gives the best contrast to observe the smallest details. The difference in refraction index between particle and solvent is large so that would not be a reason to use phase contrast. One could suggest letting the solution with particles dry on a flat surface and get phase contrast from the height difference (as small as 20 nm, see p164).
2 points per technique, 4 points for selected technique including an argumentation (2+2). The aim of this question is to test if the student knows the very basics techniques in optical microscopy.

Question 1(b): [Max. score:15 points]

Assuming the resolution is diffraction limited (Raleigh criteria), how can the resolution of the optical microscopy be improved? Include an explanation in your answer.
In addition, name (no explanation required) an optical microscopy technique that is not diffraction limited.

The students are not expected to reproduce the Raleigh equation, although for answering this question it is very helpful. Handout 2 and the book on several places (for example p12, p132, p171, p187) stress the importance of Rayleigh for understanding the optimum resolution of an imaging system.
The resolution (smaller value is better resoluton) can be improved by using a shorter wave length or increasing the numerical aperture (NA). NA is μsinα, with μ is the refraction index of the medium between lens and object and α is the aperture of the lens (lens opening). μ can be increased from 0.95 for air to 1.3 when having oil between (immersion) lens and object and by using a better quality lens material (more perfect imaging system). NA varies between 0.16 and 1.4 (students are not expected to give these numbers!)
6 points for lower wave length suggestion + explanantion, 6 points for increasing NA + explanation why that works.
No diffraction limited optical microscopy technique: Here two alternatives were introduced in the course: Confocal microscopy and Scanning near-field optical microscopy (SNOM/NSOM) (lecture Optics II, handout 4 (confocal) and Handout 5 (SNOM), book mentions briefly near-field microscopy on p132, confocal microscopy on p152). Only one is asked for! 3 points. Phase contrast can measure small (50 nm) height differences.
The aim of this question is to test if the student knows by what the resolution is limited in a simple lens imaging system. A similar question was used in exercise 7.

Question 1(c): [Max. score:15 points]

The imaging can be affected by artifacts of the lens system, as for example spherical aberrations, chromatic aberrations or astigmatism. Explain these three phenomena and add some sketches to illustrate your answer.

Due to these three efects a parallel beam is not focussed to 1 single small point by a lens, but smears out. This creates a disc of least confusion. The students are asked to reproduce Fig 3.5 or Fig 4.5 (in both figures (a) is chromatic – various wave length are focussed on various distances from the center of the lens, not one focus point, and (b) spherical aberration – beams that hit the lens at different radius from the center are focussed more (closer to the lens) or less (further away from the lens) by the lens. Astigmatism is that the lens is stronger in one direction than in another direction (see Fig. 4.8), resulting in an extended smeared out not circular spot rather than one focus point. 5 points per explained phenomena. Small point reduction if the whole answer is not 100 % correct.

TASK 2: Scanning electron microscopy (SEM)

The final product of the synthesis, which should contain mainly TiN cubes with Ag nanoparticles, is filtered out and dried. To confirm particle size and distribution here, SEM is used. For this the powder is placed on carbon tape and fixed to an SEM holder. The SEM available has a field emission gun (FEG), an in-lens secondary electron (SE) detector and a backscattered electron (BSE) detector.

Question 2(a): [Max. score:10 points]

With the help of a schematic representation of the interaction volumn, explain if SE or BSE images have a better resolution. Draw a sketch of the intensity SE and BSE signal against their energy. You have the freedom to choose certain high tension for this imaging. List the other signals that are created in the interaction volumn.

This question has several subquestions. First the students are asked to sketch the droplet shape, which was used in nearly half of the lectures and the SEM lab text. The book uses a very course approximation (For example: Fig. 5.4, Fig. 5.19, Fig. 6.1 and Fig 8.1 + body text with these Figures). The SE which are detected come from max 50 nm deep. In this region the beam has not broadened. The BSE come from a volumn down to a few microns. At this depth the beam broadening is substantial and that affects the lateral resolution of the signal recorded. So SE has a better resolution than BSE. A remark, see Fig 5.19, BSE2 (probably at low HT) should suffer less from this deterioating effect. This answer would give a bonus point, as inlens can probe SE1 selectively. If HT up, more SE2, with reduce reslution in SE1.If a low HT is choosen, the BSE volumn is less deep and not so much broader than the probe, but still the SE would give a higher resolution, also partly due to the higher signal.
3 points for the correct description of SE and BSE region. 2 point for conclusion that SE has better spatial resolution.
The SE have a very low energy, the BSE have a high energy, slightly less than the energy of the primary electrons. The students should show a drawing as Fig 5.13. Beside the energy, also the larger number of SE compared to BSE should be shown.
2 points for the correct drawing + argumentation.
The most important other signals that are created in the interaction volume (no explanation required) are Auger electrons, charcateristic X-rays and white radiation.
1 point per correct signal, with a max of 3 points.

Question 2(b): [Max. score:10 points]

Explain which of the SEM imaging techniques having the contrast and resolution required to determine the particle size (< 50 nm) of the TiN nanodices and which could be used to show the Ag nanoparticles (< 10 nm).

Two elements to answer: resolution and contrast. Topographic contrast is most pronounced in SE images and this could be used to see the size of the TiN nanocubes. The resolution for SE images in a standard FEG SEM is in the order of 1-2 nm. 5 points for this answer. Bonus point is given if someone mentions edge contrast for low acceleration voltages.
To image the Ag nanoparticles on the TiN nanocubes could be tricky. In BSE only the heavy Ag particles should light up. However, the BSE resolution is 5-10 nm, so for the smaller Ag particles it might be difficult or even impossible (answer to 2(a) might be relevant for the marking here). SE imaging has the resolution needed, but less contrast. However, judging from Figure 2 there is enough topography contrast possible and there might be a constructive Z contribition at low beam energies and low HT to visualize the Ag nanoparticles clearly (see §5.5.1 and Figure 5.18 (TiCN particles). The aim of this question is to test if the student knows difference between SE and BSE image contrast and resolution. 5 points awarded if answer + argumentation shows this insight. 1 bonus point might be awarded if SE1-SE2 and BSE1-BSE2 are addressed in a relevant way in the answer (Figure 5.19). EDS maps have not the spacial resolution to determine the size of the TiN and Ag nanoparticles. Resolution, contrast, and topology must be named in answer.

Question 2(c): [Max. score:10 points]

How could the image resolution in the SEM be optimised to get the best spatial resolution? Give three parameters or set-ups and include an argumentation for your suggestions.

The resolution is determined by two factors: (i) how small can the scanning probe diameter be realised which still has a useful beam current to give a strong enough signal (signal-to-noise ratio) and (ii) a small interaction volume the electron creates in the specimen.
For (i) the image system characteristics are important as for example a intense source (FEG), stability, good focussing system, short working distance vs aperture size, high acceleration voltage etc.
For (ii) a small interaction volumn (for a given material) the acceleration voltage should be kept low and SE should be used for imaging (small interaction volumn (answer 2(a)), large amount compared to Auger and back scattered electrons).

3 points per answer if both aspects are covered in the answer. 1 point additional if whole answer is correct. Max. score is however 10. Answer should notidentical to 1b, 1c or 2a.

The questions 2(a-c) are related to each other and students score probably very good or very badly on all of them. Together they should show how well a student has understood SEM.

TASK 3: Diffraction

To determine the crystal structure, the sample of TiN nanodice with Ag nanoparticles is characterised by XRD. TiN has the rocksalt (NaCl crystal) structure (lattice parameter a_0 = 4.235 Å) and Ag is face centered cubic (f.c.c., a_0 = 4.086 Å). The obtained XRD pattern is shown in Figure 1. Table 1 gives the reflection positions. The characteristic X-ray used for this diffractogram is Co K_α, with λ = 1.790 Å. For this task assume that the diffraction rules for TiN and Ag are those for f.c.c.-lattice: h,k,l all odd or all even.

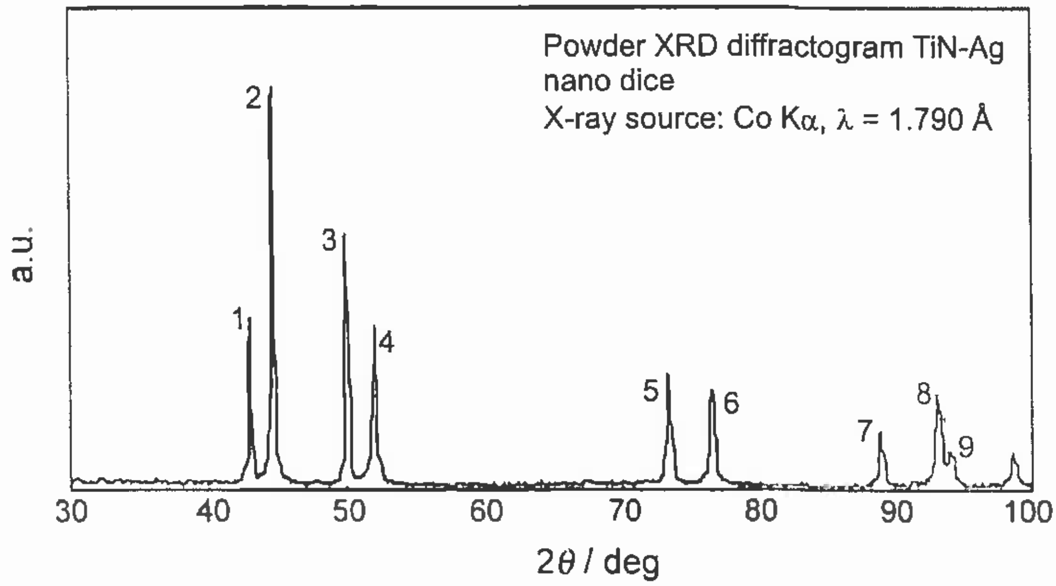

Figure 1: XRD diffractogram of TiN nanodice with Ag particles.

Table 1: $2\theta_{hkl}$ values of diffractogram shown in Figure 1.

Peak	1	2	3	4	5	6	7	8	9
$2\theta_{hkl}$ (°)	42.94	44.59	50.01	51.96	73.42	76.58	89.00	93.18	94.13

Question 3(a): [Max. score: 5 points]

Write down Braggs' law and explain the symbols used.

$$n\lambda = 2d_{hkl}\sin\theta_{hkl}$$

n is an integer (order), λ is the wave length (in nm), d_{hkl} is the lattice spacing of type hkl planes and θ_{hkl} is the diffraction angle Bragg incident angle on planes of type hkl. [p57, p59, handout 3 p120].

1 point for the correct formula, 1 point for each symbol explained correctly and the final point if all what is written is correct. Angle out is $2\theta_{hkl}$ relative to transmitted beam. The very same question was used in last year's exam. Aim is to get the formula for question 3(b). Discription of angle is difficult without a drawing and d is for certain hkl.

Question 3(b): [Max. score:15 points]

Which of the peaks in Fig. 1 represent TiN-(111), TiN-(311) and Ag-(220)?
Show the calculation used to derive your answer. You can use your answer of question 2(a) and:

$$\frac{1}{d^2} = \frac{h^2 + k^2 + l^2}{a_0^{\ 2}} \qquad (1)$$

The aim of this question is to test if the student understands simple crystal systems, what a diffractogram is and can extract information from diffractogram. Using (1) the students should find: $d_{TiN\text{-}(111)} = 2.445$ Å, $d_{TiN\text{-}(311)} = 1.277$ Å and $d_{Ag\text{-}(220)} = 1.445$ Å.

Table 1A: $2\theta_{hkl}$ values of diffractogram shown in Figure 1, d calculated with answer 3(b).

Peak	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
$2\theta_{hkl}$ [°]	*42.94*	*44.59*	*50.01*	*51.96*	*73.42*	*76.58*	*89.00*	*93.18*	*94.13*
d [Å]	*2.445*	*2.359*	*2.118*	*2.043*	*1.497*	*1.445*	*1.277*	*1.232*	*1.222*
Index	*TiN-(111)*	*Ag-(111)*	*TiN-(200)*	*Ag-(200)*	*TiN-(220)*	*Ag-(220)*	*TiN-(311)*	*Ag-(311)*	*TiN-(222)*

Hence, TiN-(111) is peak 1, TiN-(311) is peak 7 and Ag-(220) is peak 6.

If all coorect answers (which peak) and calculation is show with enough decimals and units. If not: 2 points for each correct calculated d-spacing (0.5 deduction if units are not included). 2 points for each of 3 d-spacings calculated from diffractogram (including calculations and units). 1 point for concluding which peak is which. Presentation should be structured and student shows no weakness on this topic and calculated all peaks correctly.

Question 3(c): [Max. score:10 points]

In addition to the peak position, there are other features in the diffractogram which hold information about the studied specimen. Give two features present in a diffractogram and which sample characteristics these features shed light on?

6 points for (relative peak) intensity (for example for studying texture, composition or phase determination using standard JCPDS/ICDD cards) and 4 points for peak shape (for studying crystal size or microstrain). In the course (lectures and XRD/TEM lab) it was stressed that a diffractogram contains more information than just $2\theta_{hkl}$. *The book addresses this partly (p 65, §2.4 and workout example), the handout about diffraction in more detail. Aim is again to test insight in diffraction.*
1 point for amorphous background. 1 point for peak shift due to homogenious strain, despite that it is peak position (not asked for).

Question 3(d): [Max. score:15 points]

What would be the effect of using Cu $K_{\alpha 1}$ with $\lambda = 0.15406$ nm instead of Co K_{α} as radiation source when this diffractometer (2θ range 10-100°) is used? Discuss only effect on peak positions and calculate all new positions.

This was tought to be a challenging question to distinguish the A-students. The same question was also included in the XRD lab questions which were not compulsory and not discussed as well as in class exercise 7 (absorption only). Would be nice if stated "probe more of reciprocal space".
The peaks will shift to lower 2θ *values. A shorter wave length would lead to more of the reciprocal space is probed/increase diameter limiting sphere (Handout 3, book p 63). The resolution depending on the measured angle will not be improved. For the given* 2θ *range the peaks TiN-(400) will appear at 93.31, Ag-(222) at 81.55 and Ag-(400) at 97.84. TiN-(331) and Ag-(331) reflections lie outside the range.*

All new 2θ *positions(°):*

	TiN	*Ag*
111	36.71	38.10
200	42.65	44.28
220	61.90	64.43
113	74.17	77.36
222	78.08	81.55
400	93.31	97.84
[illegible]	104.84	110.45

3 points for stating peak shift. Calculated just for 3 peaks of 3b): 6 points, calculate all 9 labelled: 8 points. 4 points for calculated additional peaks (including correct indices) which appear in the range. Bonus 1 point for stating which reflections fall outside the given range.

TASK 4: Transmission Electron Microscopy (TEM)

The TiN cubes with Ag nanoparticles are dispersed on a Cu grid with a thin amorphous C foil for a TEM study.

Question 4(a): [Max. score:10 points]

Sketch the selected area electron diffraction (SAED) pattern you would expect to observe from this specimen. Explain the features you include in the sketch.

In the selected area the amorphous carbon would give 2 broad rings and the powder with nanoparticles would give sharp rings as the powder contains many random oriented TiN and Ag crystals. Argument can be that only 1 TiN dice (spot pattern) in aperture and many Ag particles (ring pattern). Many draw TiN as rings and Ag as spots, maybe because in the labs they studied carbon nanotubes with just a few metal seed particles, so there never full rings. However here there are many metal particles (see Fig. 2).
The relative spacings and intensities (in first approximation) of these rings are similar to the XRD diffractogram of Figure 1. See p97, p109 (worked out example), TEM lab text, TEM questionnaire and all students included in their case study report. Cu is not thin enough to give electron diffraction.

2 points for broad rings from amorphous carbon foil, 4 points for sharp rings caused by Ag and TiN, 2 points for diameter of rings like in XRD diffractogram and 1 point for intensity like in XRD diffractogram. 1 points for 000 (or beam blocker). Rings (perhaps spots) should be indexed. All rings should be included.

Question 4(b): [Max. score:10 points]

A bright field (BF) TEM is shown in Figure 2(a) and a high angle annular dark field (HAADF) scanning TEM (STEM) in Figure 2(b).
What are the two main contrast forms present in BF TEM images like Figure 2(a)? How is a BF image formed? Make a simple sketch to support your answer.

For BF-TEM mass-thickness contrast and, diffraction contrast are present, but not phase-contrast. Atomic number or Z-contrast is the answer is the contrast in HAADF-STEM. The Ag nanoparticles are bright dots on the TiN cubes in figure 2(b).
In BF-TEM an objective aperture is introduced in the back focal plain of the objective lens and all Bragg scattered beams (caused by specimen) are blocked and only the non-diffracted beam is used to form the final image on the screen/film/CCD [p203-p207, Figure 4.16, TEM lab exercise].

3 points per given contrast mechanism (no explanation asked for) and 4 points for explaining how a BF image is formed (sketch should be included).

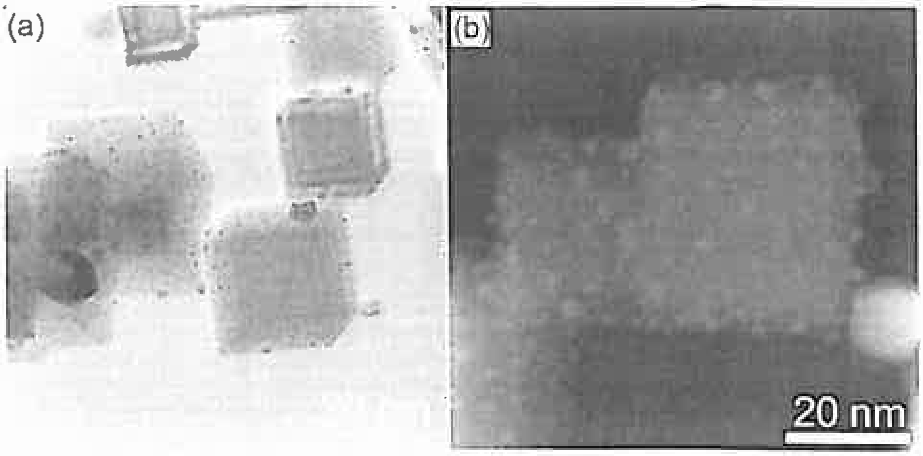

Figure 2: (a) BF-TEM and (b) HAADF STEM image of TiN nanodice with Ag nanoparticles.

Question 4(c): [Max. score:10 points]

To visualize the crystal lattice, high resolution TEM can be used. Name two microscope settings by which the resolution can be improved. Include an argumentation in the answer. What is the difference between the terms *point resolution* and *information limit* for a TEM?

There are several correct answers possible (See §4.3.3): a higher acceleration voltage would result in a smaller wave length and hence a better resolution (p 91, p 185-188), as lattice imaging TEM is phase contrast, a more coherent source would be helpful, a more stable environment would be benificial, the spatial frequencies allowed to form the image (large objective aperture), the parallelness of the beam, the defocus used to compensate for the spherical aberrations in the imaging system. What should be included in a quality answer is the contrast transfer function (CTF, p 210). Then it is relatively easy to explain the difference between point resolution and information limit: the first is the first zero point (defocus value) in the CTF, the smallest detail that can be interpreted directly (also called point-to-point resolution) and the second is the point at which the CTF tailed down to zero at whicht the smallest bit of spatial information that is transferred by the imaging system (p 210). As one of the main arguments to choose a TEM for a study, instead of other microscopy techniques, is the good resolution, the students should know how resolution in TEM is defined and where its limit lies. This question could have partly the same answer as question 2(d) or 1b, but phase image (smaller wave length more important than more intensity) and CFT are crucial elements of a good answer.

Two times 3 points per correct microscope setting (1 for what, 1 for changing in what direction and 1 for explanation why), 1 point for explaining CFT correctly and 3 points for correctly explaining the difference between point resolution and information limit.

Question 4(d): [Max. score:15 points]

In the TEM the composition of the nanoparticles can be characterised by energy dispersive spectroscopy (EDS). Some EDS maps are shown in Figure 3. Why do the images in Figure 3 have a relatively poor resolution compared to the (S)TEM images in Figure 2? Suggest and explain the principle of an alternative analytical technique in an electron microscope to determine the composition of these nanoparticles.

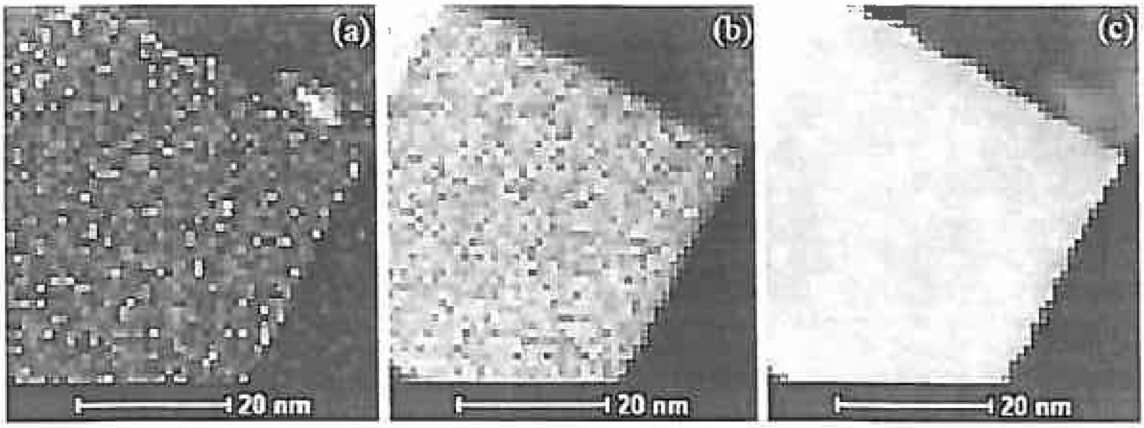

Figure 3: STEM EDS maps of TiN nanodice with Ag recorded in TEM (a) Ag-L, (b) Ti-K and (c) N-K.

The resolution for EDS maps (in TEM or SEM) is relatively poor for several reasons. The characteristic X-rays are created in a volumn which is large compared to the probe diameter, although for the thin TEM sample it is less a problem than for SEM specimens. By fluorescence the recorded signal can originate from a completely different area (Fig 6.12). In BF TEM and STEM scattered electrons build-up the image.
The main issue is that the image is based on counting statistics. To get a trustworthy result in each pixel, a higher number of counts per pixel per element edge should be recorded. Larger number of pixels would lead to impractical very long counting times. Specimen drift, specimen damage of build-up of contamination becomes a limiting factor. §5.3.1 goes into detail on this. For (S)TEM EDS the specimen is thin , hence a small volumn creates the characteristic X-rays rsulting in a lower counting rate than in SEM-EDS (in addition the detector is further away and has a smaller area than in SEM). p 354 discusses the low signal in thin specimens. A TEM or STEM image as in Figure 2 is recorded in one process step (not adding scan after scan) and more pixels can be used.
The student could suggest different alternative techniques for EDS to measure the composition. For in TEM and the relative low Z for Ti and N, electron energy loss spectroscopy (EELS, §6.2) would be the first choice. Explanation of EELS should be correct and to the point.
AES (2 points max for naming) in TEM could be possible, but is not very practical and common. Same is true for WDS (1 point max). In addition, WDS would give a better element (energy) resolution compared to EDS, but not improving the spatial resolution of the analytical technique (here compositional image quality).

If the student chooses a technique outside an electron microscope and explains it correctly, some point will be given. Including correct terms like sensitivity, detection limit, elemental and spatial resolution relative to EDS in the answer is awarded.

Max 7 points for part one of the question (comparing EDS signal regarding spatial resolution, including SEM vs. TEM. Suggested devision: EDS cause max 2, originating for larger volume, but not same interaction voliume as I 2 for SEM as sample is thin, max3, describing STEM: max 2, counting statistics: max 2). 3 points for suggesting EELS or EFTEM, 4 points for describing it correctly. 1 point if the whole answer is correct and shows understanding of the topic.

This question tests the knowledge of analytical electron microscopy (AEM). This is the only question in this exam that directly tests the student's insight into AEM. As this question requires a longer answer and AEM is an important and relative large course topic, the total max score of this question is 15 instead of 10 points.
PS: The book gives several times examples with TiN as material when discussing SEM and AEM.

TASK 5: Surface characterisation

The synthesised TiN-Ag powder is used to coat the inside of a small chemical reactor. The catalytic behaviour of this coating is studied. Before and after testing at elevated temperatures the synthesised material is characterised by X-ray photo spectroscopy (XPS). The presence of O peaks together with the change in the Ti-2P peak position, suggests that part of the TiN nanodices are oxidised under testing.

Question 5(a): [Max. score:15 points]

Explain how XPS works. What quantity is recorded during the experiment and what material characteristic is obtained from XPS? Suggest an alternative technique that could have been used to determine the same characteristic.

This question tests the knowledge on electron photo spectroscopy. An X-ray of known energy excites an atom in the specimen. This excited electron escapes from the specimen and its kinetic energy is precisely measured. This characterstic energy is a measure for the binding energy (most be named in answer) of the electron in the specimen. The energy resolution is so good that not only the element, the sub shell but also the chemical environment can be deduced (see for example Figure 8.5). As the low "characteristic" energy of the photo electron is measured, it must come from the surface area. Photo electrons created deeper in the material can not escape elastically from the specimen into the vacuum to be detected. Plotted is counted electrons ("intensity in a.u.) vs. binding energy. Formulation should be exact: in XPS no SE (or BSE) are created.
Alternative techniques (no explanation asked): Auger electron spectroscopy (AES), FTIR or Raman.

7 points for explaining how XPS work, 3 points for describing what is measured. 5 points for the correct alternative technique. No bonus points for remark that Auger peaks could be present in XPS spectra or that the de-exciting atom could send out characteristic X-rays.

Question 5(b): [Max. score:10 points]

With the help of a focussed ion beam (FIB), with a Ga-source and no electron source (as in a Dual.-beam), a small plane view specimen is taken out of the reactor wall for studying the surface by atomic force microscopy (AFM).
List 4 effects that might occur when the accelerated Ga^{2+} ions interact with the specimen?

Here the very basics behind FIB (or other ion microscopy or analytical techniques) is tested. See §5.8.2. The interaction can lead to:
- Atoms or ions are sputtered away from the specimen. This is used for cutting in a FIB.

- SE are created when the Ga ion is slowed down in the material. This is used for imaging in a FIB.
- Ga ions could be implanted into the specimen. Often an unwanted effect.
- A crystalline specimen could be damaged: becoming amorphous in or just under the specimen surface or defects could be formed as for example vacancies and interstitals.
- Ga ions could be backscattered. Not one of the main applications in a FIB
- Like in an SEM (Question 2(a)) Auger electrons, characteristic X-rays and white radiation could be formed. To date they are not exploited in a FIB and not mentioned in the book.
Backscattered electrons are not created in a single-beam FIB! Answers should not be to similar, as for example ion milling and sputtering.
2.5 point per correct answer (no explanation asked for).

Question 5(c): [Max. score:15 points]

What are the three operation modes available on an AFM? Which of the three modes would you apply here to study whether the morphology of the nanoparticles on the surface of the coating has changed in addition to the chemical change as measured by XPS?
In your answer include an argumentation and the requirements for the AFM tip for the choosen task and operational mode.

The three modes are contact, intermediate or tapping mode and non-contact mode. Probably the surface is still relatively rough and possibly contaminated, and hence non-contact would not be the first choice (used for flat surfaces, high resolution or very soft surfaces).
If tip wear or scratching the surface is not considered to be a problem, contact mode is a good choice. Surface absorbance is less of a problem; larger surface roughness could be a problem. For this mode the tip should be wear resistant (book lists, p405, some alternatives as diamond (coated), W, WC, Si_3N_4 tips). No large steps on surface should be present.
Tapping mode is fast, has a good resolution and is used for all types of surfaces also when height differences are relatively big. It should work well here. Tip is silicon and the cantilver is less stiff than in contact mode. For both techniques the resolution improves when the tip is sharp and has a smaller diameter (probe-sample deconvolution, well adressed in AFM lab and students comment on it in case study reports).

Each mode: 3 points, chosen mode with argumentation: 6 points. Substraction if modes are mixed up. No bonus for irrelevant additional info, minor substraction for errors in non-relevant additional info.

This question is very similar to a question in last year's exam on which the score was high. It is a kind of relative simple bonus question for those who got to this last question of the exam. This is the only question related to the topic SPM.