OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

Growth of nanoscale deposits on surfaces under the influence of high electric fields or light intensities during operation in organic gas environments

30th of August 2024

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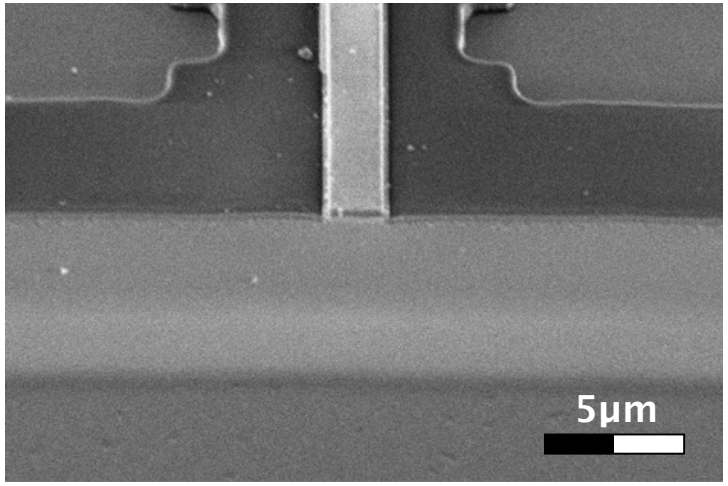
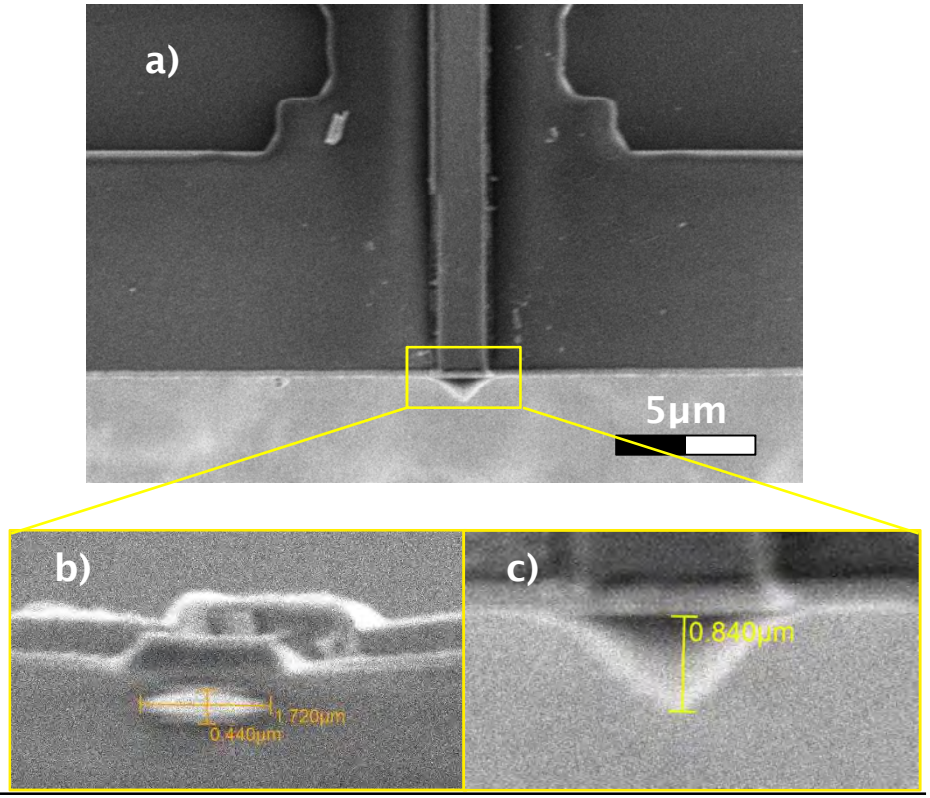
Growth of Depositions at the Active Center of Laser Diodes



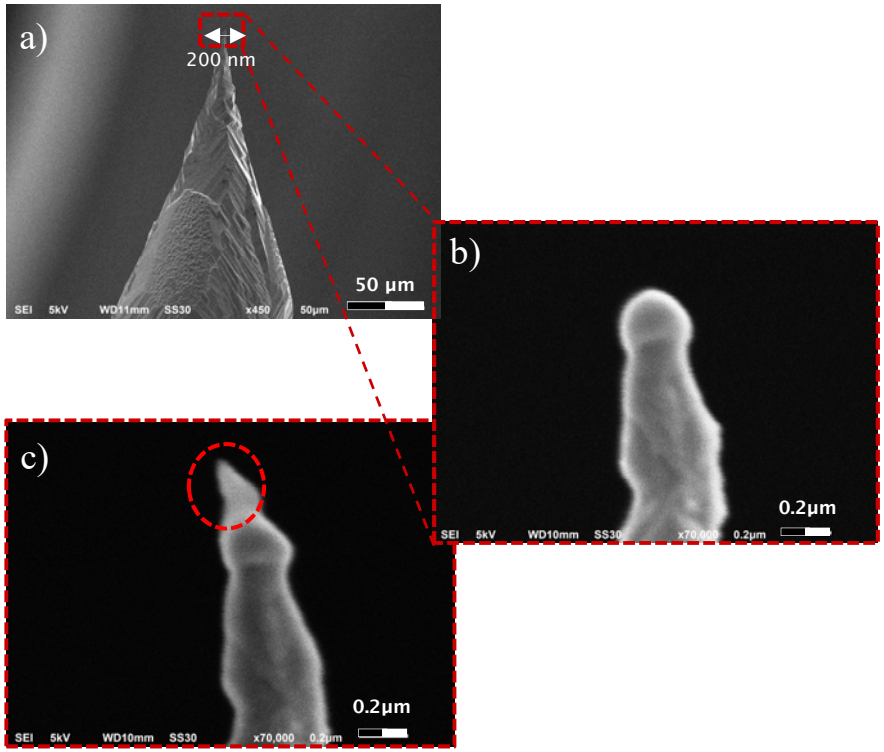
- Laser diode before deposition (30˚ angle front perspective)

- Laser diode after deposition (30˚ (a, c, top perspective, b front perspective)

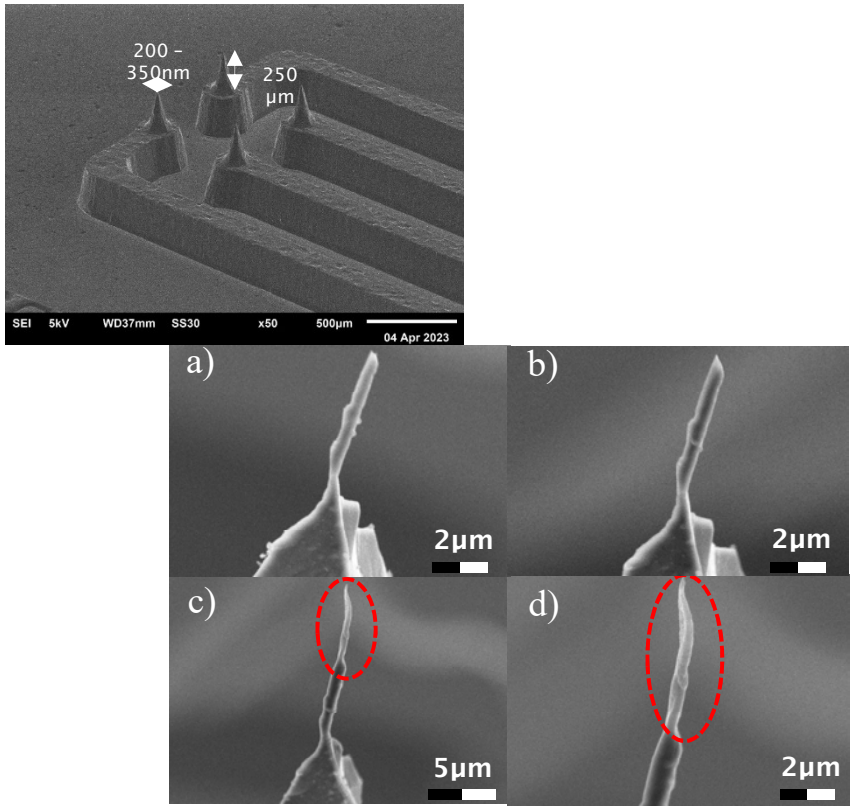


Growth of Deposition on Top of Field Emitting Devices

- Tungsten-Field-Emitter

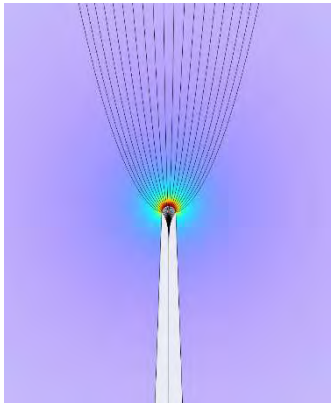


- Silicon-Field-Emitter

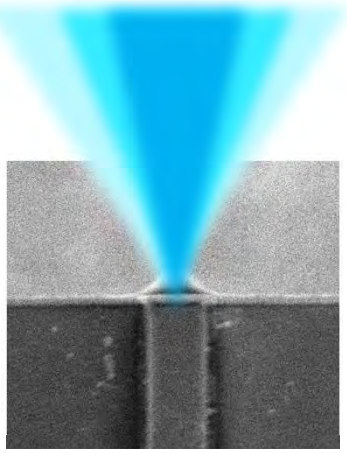


What do both have in common?

- Deposition on site of the highest field
- Reaction only in the presence of organic substances
- in both cases formation of tapered deposits



Simulation of Electric field intensity in vicinity of the field emitter



Visualisation of Laser beam Propagation

Questions, which arise:

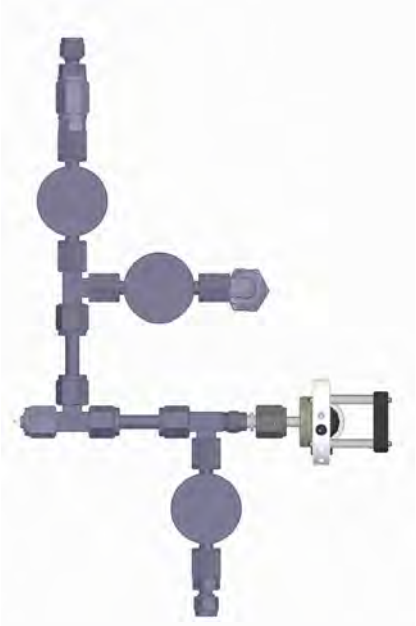
- Do different organic compounds show the same behaviour in both experiments?
- Which elements are deposited in both kinds of experiments?
- How is the structural composition of the deposition (molecular bonds, etc)?
- Do the material compositions indicate mechanistic parity between light and electron induced deposition

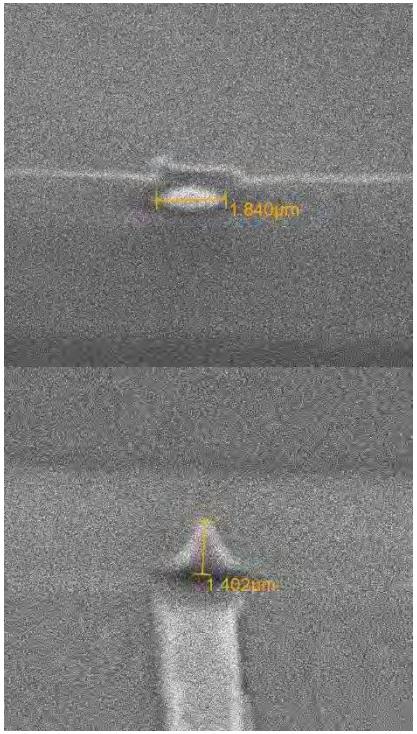
Main Challenge: How to analyse the very small depositions on our devices?

How to analyse the Reaction Products?

Limitations Gas Phase Analysis

Experimental Setup





Calculation of Chemical Throughput of an Experiment

- Chamber Volume: 15mL
- Estimated substances: Carbon certain amount of Oxygen
- Volume of Deposition (Approximated Pyramid): $V = 0.45\mu m^3$

→ Reaction Product versus ambient Particles $\sim 1.0 \cdot 10^{-4}$ppb

→ No Method fits those requirements

How to analyse the Depositions

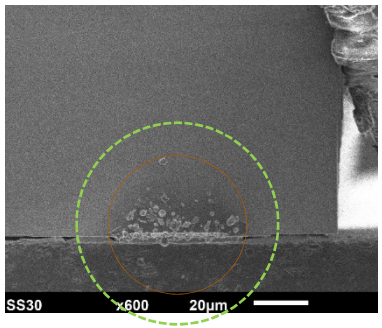
X-ray photoelectron spectroscopy (XPS)

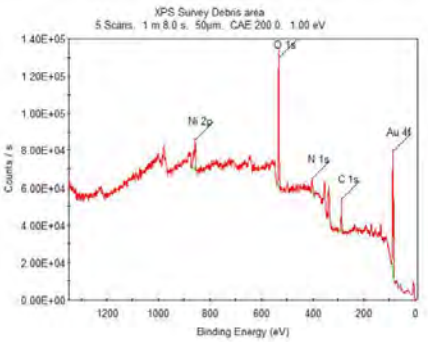
Theoretical Background on XPS

- The surface of a material is excited by x-rays to emit electrons
- Measured electron reveals element and binding conditions
- Applied for inorganic compounds, metal alloys or polymers

Execution:

- Analysis Area to large
- No proper adjustment on focus
- No appropriate data



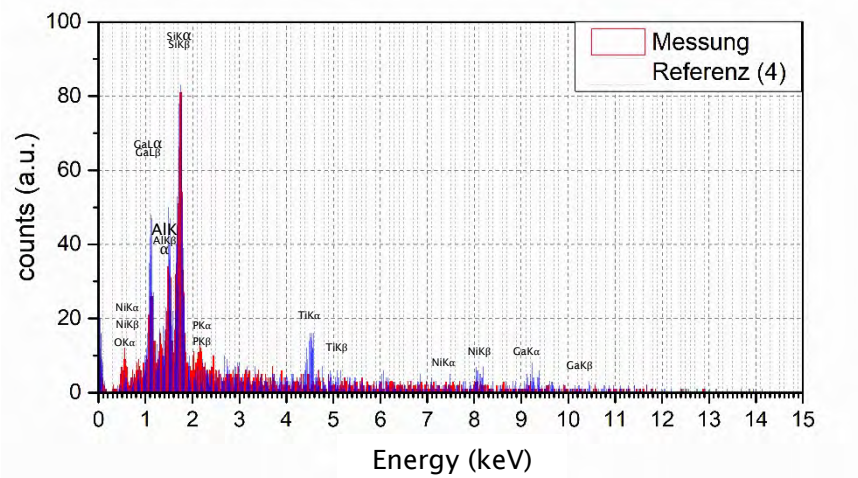


Energy-dispersive X-ray spectroscopy (EDX)

Theoretical Background

- Incident x-Ray beam excites and ejects an electron from an inner atom shell
- The inner shell-electron is replaced by one from an outer shell
- The energy difference is compensated by emission of characteristic x-rays
- EDX therefore reveals the type of atoms in a material

Execution:



- Rather bulk than surface analysis (too high background signals)
- No significant differences between sample and reference

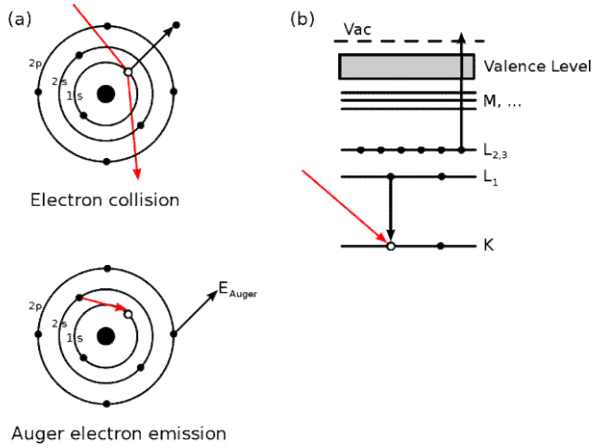
Auger Electron Spectroscopy (AES)

Theoretical Background

- Electrons or X-Rays hitting an atom cause an inner shell electron to leave the atom
- A outer shell electron replaces it
- The transition energy is coupled to a further outer shell electron, which is also emitted carrying a charateristic amount of energy
- The elements of atoms approxymatly of the 10 atomic layers of a solid state surface can be analysed

Execution

- Could not be executed lacking AES with the necessary resolution

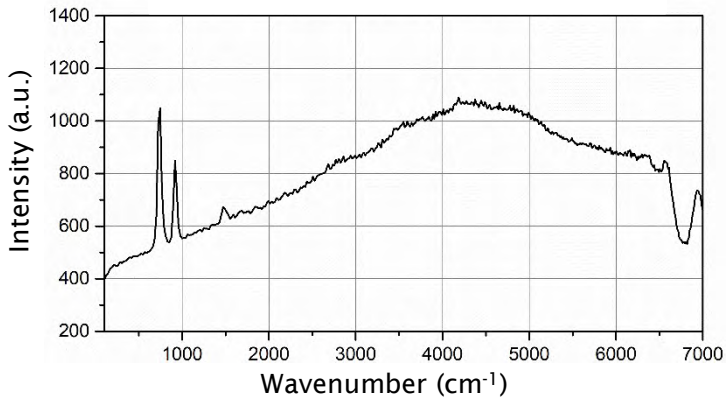


Raman Spectroscopy

Theoretical Background

- Incident laser light is scattered by certain molecules due to dipole polarizations
- The frequency shift in the incident laser signal can be detected and correlated to certain types of molecules

Execution



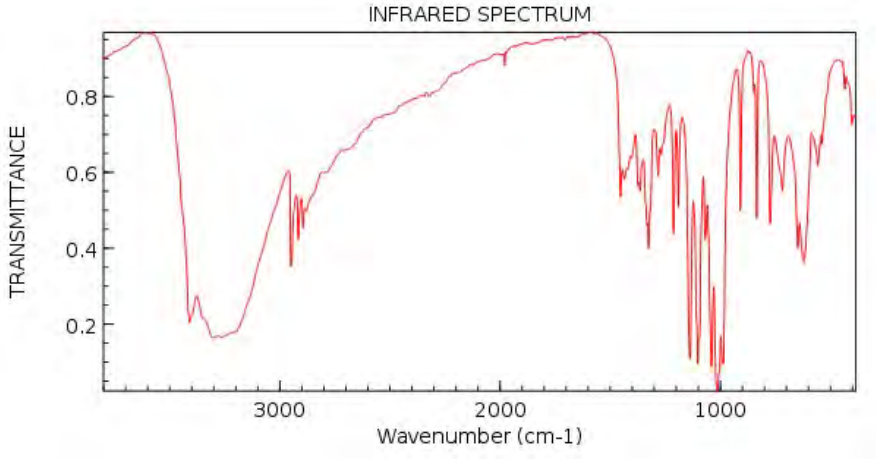
- Fluorescence effects superimposed Raman Peaks
- Background crystal structures also affected the measurements

Infrared Spectroscopy

Theoretical Background

- Infrared light is absorbed by molecules
- The frequency of the absorbed light can be correlated to specific molecule vibration which are based on certain molecular bondings or functional groups
- Reveals partially elements but, specifically Bondings and functional groups

Execution

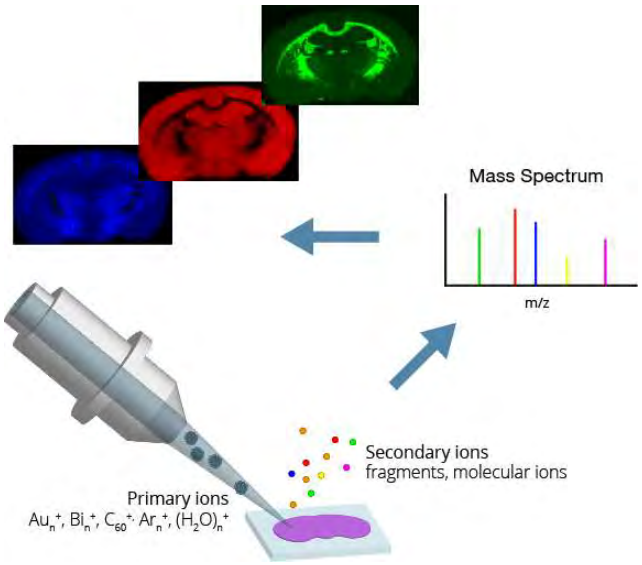


- Lack of devices with appropriate analysis area

Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS)

Theoretical Background:

- The sample surface is bombarded using a primary Ion Source
- Secondary ions are generated and smashed out of the sample background
- These secondary ions can be analysed in the time-of-flight mass spectrometer



Execution:

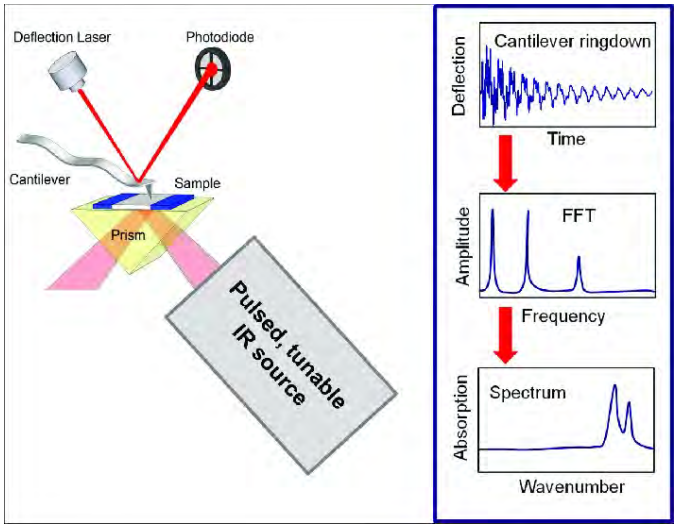
- Spatial obstruction of the measurement by the sample package

How to analyse the Depositions

Atomic Force Microscopy Infrared Spectroscopy

Theoretical Background

- An IR-Laser beam is focused right at the position of the AFM-Cantilever
- Photothermal expansion of the sample due to absorption of laser energy alters the oscillation of the cantilever
- By altering the laser wavelength a local IR-Spectrum can be received detecting altered oscillation of the cantilever



Possible Limitations:

- Limited to few elements and their bonding behaviour

Conclusion

- Structural and elemental analysis are indispensable for modelling the mechanisms
- Most analysis methods do not fit the requirements we are looking for
- Especially the size of the deposition is a limiting factor

→ Since it is very difficult to enlarge the depositions or to decouple them from the device background, we are still looking for new methods to obtain information

→ I am therefore looking forward to stimulating discussions your expertise


Thank you for your attention