Group of Environmental Electron Microscopy

Department of Electron Microscopy

Institute of Scientific Instruments AS CR, v.v.i.

THEMATIC RESEARCH FOCUS

Research area

– Environmental scanning electron microscopy (ESEM)

Excellence

– Design and manufacturing of scintillation single crystal detectors of backscattered and secondary electrons
– Design and manufacturing of ionisation detectors for environmental scanning electron microscopes (ESEM)
– Study of sensitive samples of various nature (electrically non-conductive, wet, biological, living cells and animals)
– Morphological, chemical and structural changes of samples studied in conditions of dynamical in-situ experiments in ESEM

Mission

Excellence in understanding of the influence of electron-liquid and electron-gas interactions on signal detection and imaging in ESEM, development of new detection and experimental techniques for SEM and ESEM.

DEVELOPED TECHNOLOGIES

Content of research

– Theoretical and experimental research of electron-gas interactions in ESEM (Monte Carlo simulations and theoretical models of electron-gas interactions and signal amplification, electron beam scattering in gas environment, electron-gas ionisation and excitation phenomena, charge recombination processes in gas, Monte Carlo simulations of electron-water interactions and study of electron energy losses in thin water layer).
– Gas flow computations in ESEM and detection systems for ESEM (design of optimum geometry of differentially pumped chambers and ESEM equipment as detectors, hydration systems, etc.)

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Live dust mite in water vapor conditions of ESEM

– Scintillation single crystals for the detection of signal electrons in SEM, ESEM (Theoretical and experimental study of electron losses in thin conductive layers on scintillators, design of new scintillation detectors working in high pressure environment, experimental study of combined scintillation and ionisation detectors)

Main capabilities

Basic research

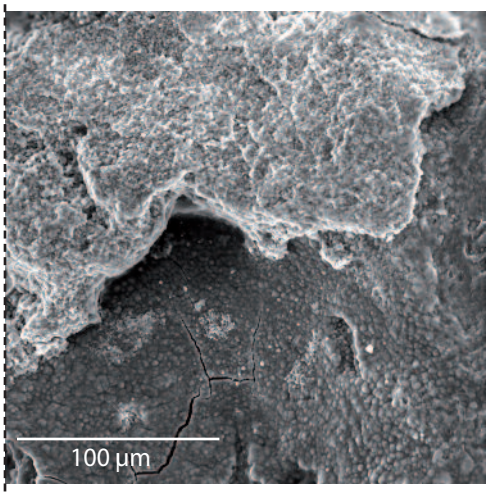
– Understanding of mechanisms of generation and multiplying of signal electrons in an environment of high pressure gas and simulation of these phenomena
– Methods of observation of samples in terms of dynamic in-situ experiments in ESEM
– Imaging methods of special or sensitive biological samples in SEM and ESEM
– Understanding of gas flow phenomena in ESEM and detection systems

Applied research

– New types and features of detectors for SEM and ESEM
– The study of morphology and elemental analysis of electrochemical sensors with sputtered thin diamond-like carbon layers doped with boron using electron beam analytical methods
– Morphological study of solar cell surfaces and of deep holes created, modified or machined by various types of laser technologies, using own patented detector of secondary electrons in ESEM
– Methods for observation of stem cells and other wet biological samples in their native state as well as of live animals in ESEM

Fields of research results application

– Life sciences (medicine, biochemistry, pharmacy, food industry, etc.)
– Materials science (study of some special non-conductive samples)
– Measuring instruments
– Renewable energy
– Plastics, polymers
– Glass, ceramics
– Textile industry
– Chemistry



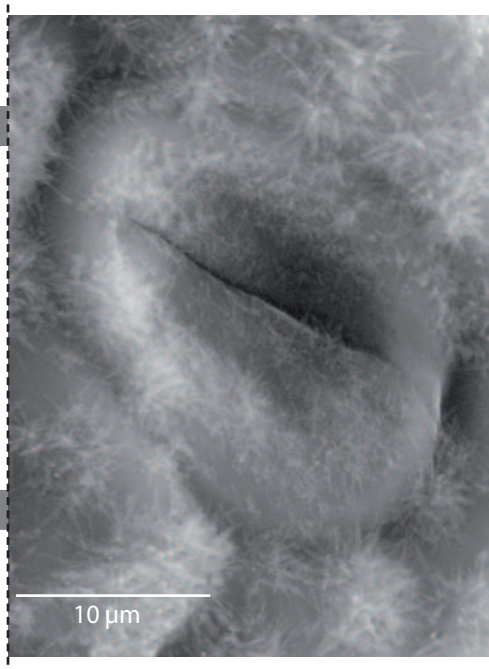
Human tooth with tartar in native state treeted by laser

KEY RESEARCH EQUIPMENT

– Environmental scanning electron microscope AQUASEM I and AQUASEM II
– Uniquely designed hydration system for ESEM
– Ionization secondary electron detector with electrostatic separator (ISEDS)
– Peltier stage for sample cooling in ESEM
– Scintillation BSE detector with integrated ionization detector of SEM for ESEM
– New multichannel pre-amplifier for multi-segmental ionization detector for ESEM
– ISEDS with combined electrostatic and magnetic fields

ACHIEVEMENTS

We are deeply focused on theoretical and experimental research in the field of signal detection, new methods and instrumentation for the study of various types of samples in high pressure conditions of ESEM. We led this topic in Czech Republic. Our tradition was started over twenty years ago when the first ESEM in Czech Republic was designed in cooperation with the Tescan Company. We published over two hundred papers in scientific journals and conference proceedings.

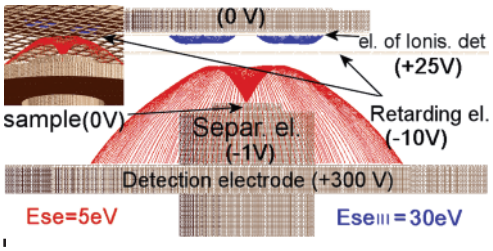


Stomata on somatic embryo of cotyledon in native state

European patent

- **The world's first high efficiency secondary electron detector for ESEM allows the energy separation of detected electrons and simultaneous work with the original BSE-YAG detector and ionisation detector. Suitable for working pressures from units to thousands of Pa.**

– Neděla, V.; Jirák, J.; Ionisation detector of an environmental scanning electron microscope. Institute of Scientific Instruments, Academy of Sciences of the Czech Republic, EP2195822 (A2), (2010)

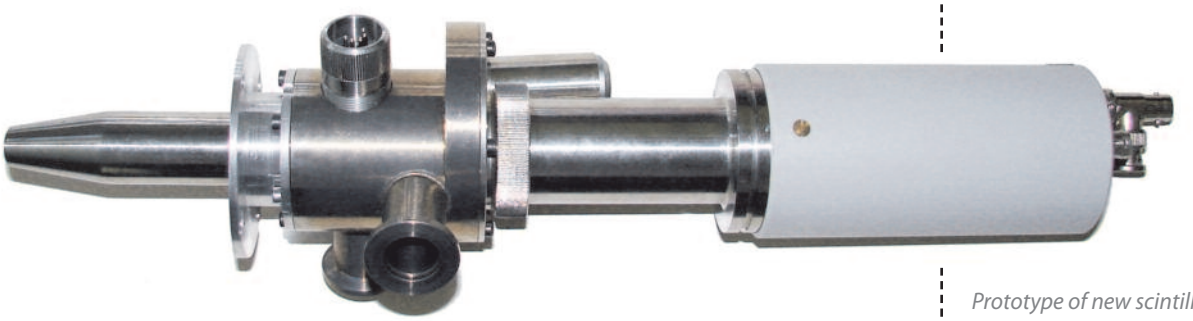


Ionization secondary electron detector with electrostatic separator

Scientific results of team members are regularly published in high profile scientific journals

- **The world's first high efficiency secondary electron detector suitable for SEM or ESEM. Detector based on a scintillator-photomultiplier working principle can be used for the study of samples in the pressure range from a thousandth to a thousand Pa.**

– Jirák, J.; Neděla, V.; Černoch, P.; Čudek, P.; Runštuk, J.; *Scintillation SE detector for variable pressure scanning electron microscopes.* Journal of Microscopy, 239, 3, (2010), p. 233–238



Prototype of new scintillation SE detector for SEM and ESEM

- **Various types of sample hydration methods for long time observation in ESEM were tested. A new method for additional sample hydration from agar substrate was described.**

– Neděla, V.; *Methods for Additive Hydration Allowing Observation of Fully Hydrated State of Wet Samples in Environmental SEM.* Microscopy research and technique, Vol.70, p. 95–100

- **The evaluation of morphological changes of biological sample surface during the dynamical insitu experiment in the specimen chamber of ESEM.**

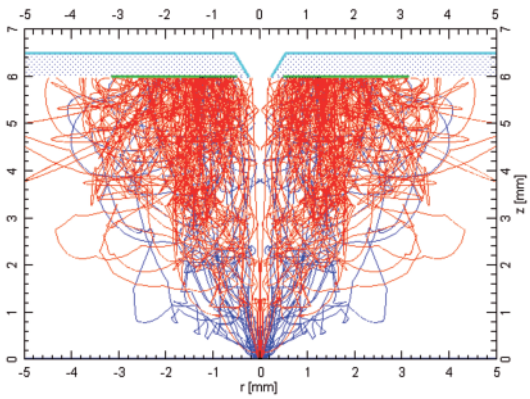
– Neděla, V.; *Controlled dehydration of a biological sample using an alternative form of environmental SEM.* Journal of Microscopy, 237(1), (2010), p. 7–11

- **New results of Monte Carlo simulations of electron-gas interactions and signal amplification for selected energies of signal electrons in high pressure conditions of ESEM were introduced.**

– Neděla, V.; Konvalina, I.; Lencová, B.; Zlámal, J.; *Comparison of calculated, simulated and measured signal amplification in variable pressure SEM.* Nucl. Instrum. Meth A, 645 (1), (2011), p. 79–83

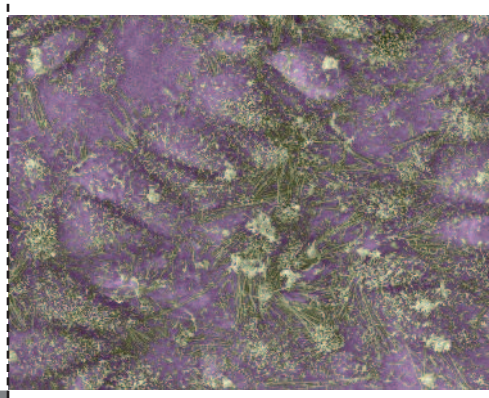
- **New method for observation of native plant sample in ESEM was introduced. The world's first images of early conifer embryonic tissues in their native state were shown using ESEM.**

– Neděla, V.; Hrib, J.; Vooková, B.; *Imaging of early conifer embryonic tissues with the environmental scanning electron microscope.* Biologia Plantarum, 56 (3), (2012), p. 595–598



Monte Carlo simulation of electron trajectories in water vapor environment (50 Pa) inside the specimen chamber of ESEM

- **The morphological study of undifferentiated human embryonic stem cells in different state of preparation was realized using ESEM and SEM.**
  - Neděla, V.; Tihlaříková, E.; Hampl, A.; Sedláčková, M.; *SEM and ESEM Observation of Stem Cells.* G.I.T. Imaging and Microscopy, 4, (2012), p. 32–34
- **New system of pressure-limiting apertures for scintillation secondary electron detector was introduced.**
  - Maxa, J.; Neděla, V.; Jirák, J.; *Analysis of gas flow in the new system of apertures in the secondary electron scintillation detector for ESEM.* Microscopy and Microanalysis, 18, Suppl 2, (2012), p. 1264–1265



A false colored SEM image of the undifferentiated human embryonic stem cells surface

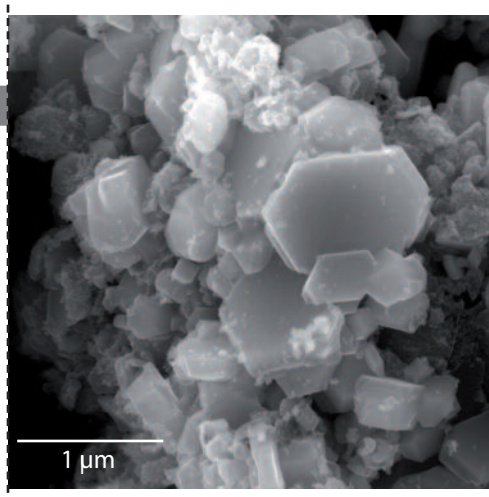
MAIN COLLABORATING PARTNERS

Collaboration with academic partners

- University of Cambridge (Cambridge, GB)
- ESEM Research Laboratory (Sydney, AU)
- University at Albany (New York, USA)
- Masaryk University (Brno, CZ)
- Brno University of Technology (Brno, CZ)

Collaboration with companies

- Delong Instruments (Brno, CZ)
- BVT Technologies, a.s. (Brno, CZ)
- Solartec s.r.o. (Rožnov pod Radhoštěm, CZ)
- Hitachi (Tokyo, JP)
- JEOL(Tokyo, JP)
- Crytur s.r.o (Turnov, CZ)



Portlandite crystals in $Ca(OH)_2$, observed in wet state

EXPECTATIONS

Offers

- Licensing of the patented detection systems for electron microscopes
- Testing of functional properties of detection systems for SEM and ESEM
- Partnership in international projects
- Morphological study of different cell cultures and impact of growing parameters on their structure, preparation methods for study in SEM and ESEM
- Morphological study of wet biological or pharmaceutical samples
- Study of microstructure and functional properties of building materials, plastics, rubbers, wood and paper
- Microstructure of wet materials and liquids
- Materials properties and their changes in dynamical experiments (battery mass, samples in acids, heated and cooled materials, food chemical reactions, etc.)
- Study of specific properties of sensitive or chemically active samples

Requirements

We look for cooperation with academic partners as well as companies in the fields of instrumentation for SEM and ESEM, microtechnologies, nanotechnologies, building materials, pharmacy, food science, plant science, chemistry, medicine, etc.

- Partners for FP7 research project in the field of instrumentation of electron microscopes, materials science, biology, pharmacy, food science, etc.
- Collaboration with industrial partners in common projects dedicated to applied science
- New complementary technologies