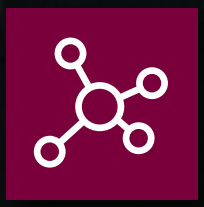
Imaging Materials for a Brighter World

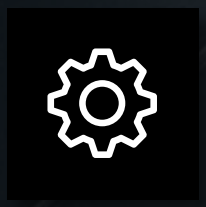
CANADIAN CENTRE FOR ELECTRON MICROSCOPY STRATEGIC PLAN 2023-2029

BREAKTHROUGH MATERIALS RESEARCH



LEADING IN EDUCATION AND TRAINING

PROVIDING SPECIALIZED SERVICES



CCEM Canadian Centre for Electron Microscopy | McMaster University

Imaging Materials for a Brighter World

CANADIAN CENTRE FOR ELECTRON MICROSCOPY **STRATEGIC PLAN: 2023-2029**

This strategic plan outlines the direction the Canadian Centre for Electron Microscopy (CCEM) will take in the next six years to maintain and expand its role as a national enabler of breakthrough materials research, a global leader in electron microscopy and complementary technique education and training, and a provider of accessible specialized microscopy services. We will strengthen our connectivity by leveraging national and international partnerships and networks with leading organizations in materials research. We will enhance our capabilities and capacity in the delivery of our research, training, and services. Using best management practices, our best-in-class instrumentation, and our diverse team of expert scientists, we will contribute to the scale and scope of materials innovations that are important to the prosperity, health and security of Canadians.

About Us

CANADIAN CENTRE FOR ELECTRON MICROSCOPY

The CCEM is located at McMaster University and was opened in 2008. CCEM houses a best-in-class suite of electron and ion microscopes; a team of 15 full-time professional expert staff operate the facility, perform microscopy services, and train users. CCEM has a diverse, national user base of more than 500 users annually. The research published by CCEM users has steadily grown to more than 140 peer reviewed journal articles annually. CCEM serves users from academia, government and industry, from across Canada and internationally. The research projects range from biology to physics, chemistry, geology, and engineering.

Building on its past success and reputation, this six-year strategic plan outlines how CCEM intends to achieve its ambition to be an internationally- recognized, sustainable and accessible research facility for the benefit of Canadian researchers, commercial enterprises and society in general. Our aspiration is to enable CCEM users and partners to achieve tomorrow's material innovations for a brighter world.

Fast Facts

500+

- Over 500 users annually

140

- More than 140 peer-reviewed journal articles annually

900+

- More than 900 webinar attendees

15

- 15 staff members

Nineteen

- 19 major instruments

Drivers, Ambition, Value Proposition

CANADIAN CENTRE FOR ELECTRON MICROSCOPY **STRATEGIC PLAN: 2023-2029**

DRIVERS

- New and improved materials are essential building blocks for a more prosperous, cleaner, and healthier tomorrow. In turn, cutting-edge micro-and nanoscale materials characterization is a critical enabler to unlocking breakthrough materials innovations.
- An increase in the scale and pace of materials innovation in Canada depends on effective international connectivity among researchers and innovators in the materials applications, materials development, and materials characterization domains.
- As the world exits the COVID-19 pandemic and as demands grow for equity and opportunity for all, society is accelerating towards a "new normal", where successful organizations will be those that embrace inclusiveness, collaboration, and innovative delivery of services.
- As a Core Research Platform and a Research Centre for McMaster University, CCEM provides McMaster researchers and their collaborators access to infrastructure, services and expertise needed to advance the University's research mission, provides researchers with opportunities to extend the breadth of their research programs and integrates this research across disciplines and ensures the development and sustainability of equipment and facilities for the future.

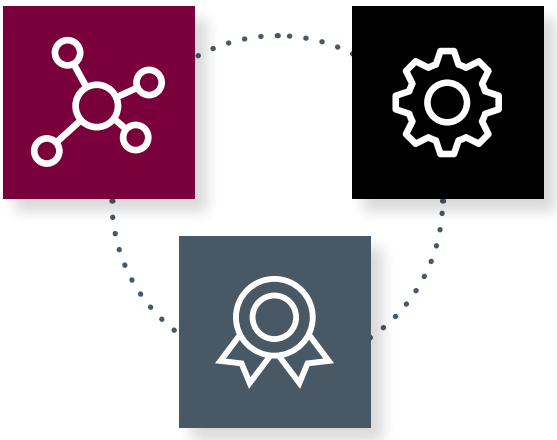
AMBITION

As an internationally recognized Centre of Excellence in electron, ion and x-ray microscopy, we enable tomorrow's materials innovations and innovators.

VALUE PROPOSITION

BREAKTHROUGH MATERIALS RESEARCH

CCEM is an international enabler of breakthrough materials research. CCEM pushes forward the boundaries of materials imaging and characterization to inform and enable materials innovations that are strategically important to Canada and the world.



PROVIDING SPECIALIZED SERVICES

CCEM is a provider of specialized characterization services. CCEM offers wide-ranging, accessible, best-in-class electron, ion and x-ray microscopy solutions for the mission-critical problems of the Canadian and international scientific and technological communities.

LEADING IN EDUCATION AND TRAINING

CCEM is a global leader in microscopy education and training. CCEM provides national leadership in developing the next generation of microscopy experts.

Strategic Goals

1 We will push the cutting-edge of materials characterization that best enables strategically important materials breakthroughs.

1. **Achieve international leadership in microscopy application and technique development.**
   CCEM's network of microscopy leaders, including our Scientific Director, Associate Scientific Directors's, affiliated faculty, embedded researchers, professional staff, and international microscopy researchers will lead and collaborate in research projects, pushing the frontiers of microscopy techniques and applications.

2. **Ever-green our facilities.**
   Enabled by Value Partnerships with leading microscopy instrument vendors, we will pursue opportunities to ever-green our microscopy instrumentation suite and facilities to remain internationally recognized for excellence.

3. **Grow our intellectual capacity.**
   We will expand our network of Associate Scientific Directors and CCEM Affiliated Researchers and will increase research depth with embedded researchers. Through our focus on recruitment and professional development of our CCEM experts, we will be recognized as an international Centre of Excellence (CoE) and high-value partner.

2 We will expand international connectivity to researchers and innovators in materials characterization, development and applications to accelerate the pace and scale of materials innovations.

1. **Build correlative and complementary characterization capabilities.**
   We will create mutually beneficial arrangements with colleague CoEs to make seamless correlative characterization capabilities accessible to Canada's materials researchers and innovators.

2. **Facilitate researcher access to leading microscopy instrumentation.**
   We will collaborate with Canadian university administrations, with colleague international microscopy facilities and with national affiliated researchers to help ensure Canadian microscopy user communities have timely and affordable access to the microscopy instrumentation they need.

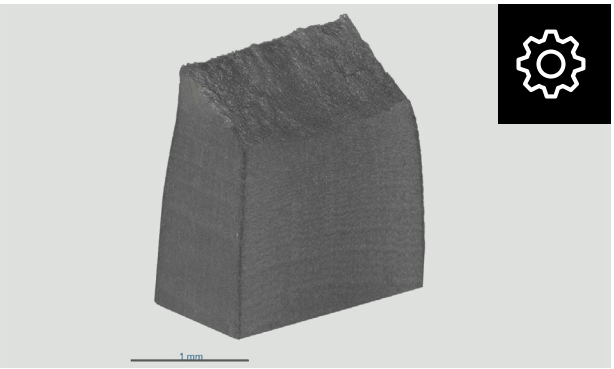
3. **Promote the collaborative pursuit of ideas and projects.**
   We will take a leadership role in the development of grant proposals built on the best ideas emerging across the national and international materials and biological science community and will provide project management services to help ensure project success.

4. **Connect with commercialization support organizations.**
   We will establish business relationships with public and private sector organizations that offer business support services and financing to help start-ups and small- and medium-sized enterprises (SMEs) bring their materials innovations to market.

PROVIDING SPECIALIZED SERVICES

X-ray computed tomography was used to observe particle-induced void formation in a high strength aluminum alloy, and validate a multi-scale model. With this new knowledge, lighter-weight vehicles can be manufactured using aluminum, while maintaining the strength of heavier-weight steel. This allows for greener vehicles of the future.

Publication: A. Sarmah, M. K. Jain, S. Asqardoust, P. Mohammadpour, Multiscale modeling of particle-induced damage in AA7075 aluminum sheet at large plastic strains, International Journal of Plasticity, 103741 (2023).



Strategic Goals

3

We will deploy a re-imagined CCEM business model to drive impact, inclusiveness, and innovation.

1. **Build "Value" Partnerships.**
   We will establish multi-year win-win partnerships with national affiliated faculty, with national and private sector laboratories, with leading instrument vendors and with university administrations so as to both broaden impact and ensure robust financial sustainability.

2. **Transition from data-centric to secure knowledge-centric projects.**
   We will grow our capabilities to translate our partners' datasets into knowledge and solutions through custom-tailored consulting, expanded data acquisition, and processing services, thus improving research context and impact.

3. **Expand our virtual environment.**
   We will expand our ability to engage off-site researchers and clients from across Canada and internationally through virtual access to our facilities and services.

4. **Increase facility access**
   We will increase access to our facilities and services tailored to the specific needs of our partners, collaborators, customers, students, and users.

5. **Lead in health, safety, and equity, diversity and inclusiveness for all.**
   We will promote a culture of openness, transparency, and dialogue and will build an environment that overcomes systemic barriers for all whom we engage.

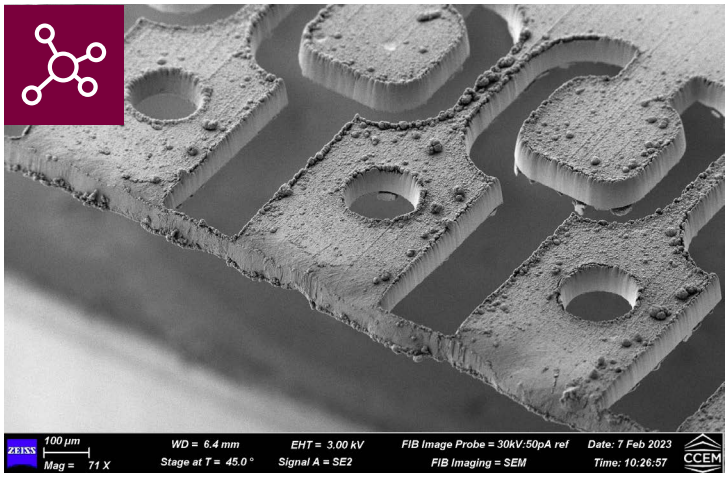
4

We will be Canada's leader in comprehensive, accessible education and training programs for cutting edge microscopy.

1. **Deliver an exceptional student experience.**
   We will place students at the center of our focus, to ensure that they feel welcomed and safe, and that their needs and aspirations are being met.

2. **Grow the CCEM Academy.**
   We will deliver best-in-class online and in-person education and training in partnership with colleagues from national and international microscopy CoEs that can be accredited and integrated into the educational offerings of academic institutions.

3. **Accessible outreach to value partners and the public.**
   Through our outreach program we will deliver tailored workshops and educational content for our value partners, including public education and promotion of science, technology, engineering, and mathematics (STEM) to young students, including under-represented communities.



BREAKTHROUGH MATERIALS RESEARCH

Laser focused ion beam (FIB) and plasma FIB were used to machine micro-tensile testing specimen from hydroelectric power turbine materials. With industrial partners, the testing specimen was used to create realistic models to predict the behavior of steels to engineer turbines with increased strength and lifetime.

Guiding Principles

INSPIRATION:
We strive to educate and inspire within the scientific and technological community, as well as the general public. To showcase the enthusiasm of our staff and users, and the exciting research undertaken, CCEM will continue to engage in professional and public outreach and training.

ACCESSIBILITY:
CCEM is committed to providing services to a large interdisciplinary user base across academia, government laboratories and the private sector. We believe that scientific discovery can truly flourish when training and education is readily available, and researchers with different backgrounds and sets of knowledge are given the opportunity to work together.

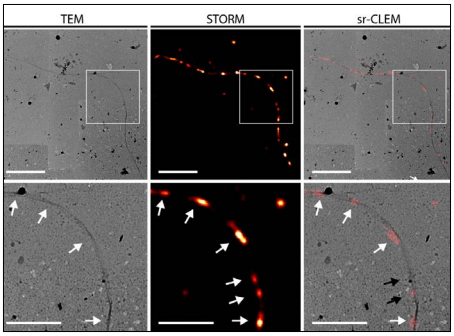
Driving materials innovations and innovators.

ACCOUNTABILITY:
CCEM is committed to accountability by upholding an environment of trust, responsibility, transparency, and return on investment through our internal governance structures, external research communities, funding agencies, and public sponsors. Strong governance and effective management will guide our organizational development.

INCLUSIVE EXCELLENCE:
Science can help create a better world for future generations. We recognize that meaningful inclusion of diverse peoples and perspectives is vital to stimulating the creativity and innovation needed to achieve the quality of research, teaching, service and governance that drives excellence, distinguishing world-class institutions of higher learning.

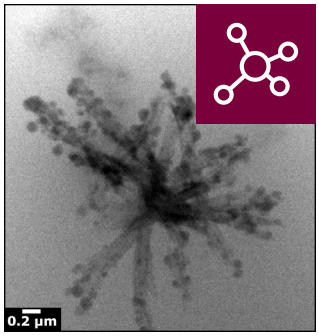
We aim to be the best in performing scientific analysis and producing publishable results. We will apply best practices and quality controls to ensure that research meets the highest international standards.

BREAKTHROUGH MATERIALS RESEARCH



Correlative light and electron microscopy was used to reveal nanodefect sites in cellulose. This allows targets for enzymatic breakdown of cellulose for an increased efficiency in the production of materials needed for renewable biofuels and sustainable nanomaterials.

Publication: Adapted with permission from M. Babi, A. Williams, M. Reid, K. Grandfield, N. D. Bassim, J. M. Moran-Mirabal, Unraveling the Supramolecular Structure and Nanoscale Dislocations of Bacterial Cellulose Ribbons Using Correlative Super- Resolution Light and Electron Microscopy, Biomacromolecules, 258-268. Copyright (2023) American Chemical Society.



Liquid-cell transmission electron microscopy (TEM) was used to study for the first time the evolution of the microstructure of Portland cement at the nanoscale during hydration, and in the presence of nano-silica particles. Improvement in the use or durability of concrete ultimately can reduce the carbon footprint of the planet as concrete is the world's most widely used human-made material, whose manufacturing accounts for 8% of the global greenhouse gas emissions.

Publication: P. Dong, A. Allahverdi, C. M. Andrei, N. D. Bassim, The effects of nano-silica on early-age hydration reactions of nano Portland cement, Cement and Concrete Composites, 104698 (2022).

Strategic Focus

ASPIRATION:

We strive to build and strengthen our connectivity to national and international players in the intersecting domains of materials characterization, material development and materials applications in order to:

- Enhance our capabilities and capacity in the delivery of our microscopy research, training, and services
- Enhance our contributions to the scale and scope of materials innovations that are important to the prosperity, health, and security of Canadians

CAPABILITIES FOCUS:

We strive to be best-in-class in all we do, while recognizing that there are bounds on the capabilities in which we can excel. Our focused capabilities for excellence and impact can be grouped into three major themes from the technique/workflow/ instrumentation perspective:

- **Materials characterization:** microscopy (electron, ion, atom probe); chemical characterization in 2-D and 3-D (electron energy loss spectroscopy, atom probe tomography, 3-D focused ion beam sectioning w/spectroscopy); structure (electron backscatter diffraction, 4-D scanning transmission electron microscopy); dynamic: in-situ microscopy (liquid, cryo-heating, correlated electrons), correlative (linkages across length and time scales); computational microscopy (acquisition and post- processing)
- **Materials development:** functional, structural, metals, semiconductors, nanomaterials, 2-D materials, polymers, and biological samples
- **Materials applications:** advanced manufacturing, infrastructure, structural materials, semiconductors, nuclear materials, quantum computing, biomedical and life sciences, defence, and clean energy

CONNECTIVITY FOCUS:

To achieve our aspiration, we will pursue value-added partnerships with the following academic, public and private sector organizations that are recognized CoEs in their specific domains:

- **Materials characterization:** International CoEs, national CoEs in microscopy and correlative techniques; Microscope designers/ manufacturers, SMEs
- **Materials development:** International CoEs, International Universities and Funding Agencies
- **Materials applications:** International CoEs, national superclusters, agencies that support materials commercialization

LEADING IN EDUCATION AND TRAINING

CCEM is committed to equitable and accessible education and training from industry/academic professionals to youth as young as six. Here two elementary school students exhibit their SEM artwork made achievable by CCEM's NextGen Microscopy program in collaboration with McMaster's Art Museum.

Research Focus

Prioritization of our capabilities and our partnerships over the course of the Plan's 6-year span will enable CCEM to deliver value through research that advances both the science of microscopy and materials science. Three priority research themes have been identified:

- Enabling Multiscale correlative microscopy
- Ultrahigh Resolution Spectroscopy
- In situ Microscopy

As shown in the table below, within these priority areas, CCEM acts as a research enabler that can create interdependence between researchers who focus on advancing microscopy instrumentation/technique and researchers who focus on advancing materials applications. Through value partners with stakeholders, CCEM delivers advances in microscopy instrumentation and technique research that enable advances in materials-specific applications, with the goal of generating impactful research advances in both fields. Materials of importance to the CCEM map onto national and international priorities, and include semiconductors, energy materials for a sustainable future, advanced manufacturing, and health/biology-related research

PRIORITY RESEARCH THEME: ENABLING MULTISCALE CORRELATIVE MICROSCOPY	
Advancing the Science of Microscopy	**Advancing Materials Science**
Develop novel workflows and tools to go from Macro (xCT instrumentation) to meso (laser-FIB, plasma FIB, Laser-Scanning Confocal) to micro (FIB/TEM) to nano/pico (APT, TEM) across multiple imaging modalities (photons, ions, electrons).	Create digital twins of advanced alloys for power generation to enable advanced manufacturing and energy applications

PRIORITY RESEARCH THEME: ULTRAHIGH RESOLUTION SPECTROSCOPY	
Advancing the Science of Microscopy	**Advancing Materials Science**
Develop latest ground-breaking electron energy loss spectroscopy (EELS) and energy-dispersive spectroscopy (EDS) measurements using the aberration-corrected monochromated transmission electron microscopes, including momentum-resolved EELS and aloof-mode EELS.	Examine vibrational and electronic modes in materials or quantum computing applications to advance fundamental and applied semiconductor materials research.

PRIORITY RESEARCH THEME: IN SITU MICROSCOPY	
Advancing the Science of Microscopy	**Advancing Materials Science**
Develop workflows with heating, cryo, gas-cell and liquid cell systems, across multiple length-scales including in SEM and TEM.	Investigate real-time catalytic behaviour of nanoparticles for converting carbon dioxide into fuel in energy materials. Study real-time bio mineralization of hydroxyapatite to understand the fundamentals of bone growth related to orthopedic applications in bio/health science applications.

Measuring Success

Over the course of the next six years, we will systematically measure our progress towards the goals set out in our Strategic Plan and will adjust to meet expectations. We will compare progress to expectations through four lenses.

PLAN IMPLEMENTATION:

Are we on track in implementing the Plan's objectives? If not, are we taking appropriate action to get back on track?

OUTCOMES AND IMPACT:

As we progress with the Plan's implementation, are we seeing improvements in our national and international outcomes and impacts to which the Plan aspires? If not, are we taking appropriate action to adjust our Plan to achieve the aspiration? Are we seeing improvements in our national and international impacts, as captured in our key performance indicators to which the Plan aspires?

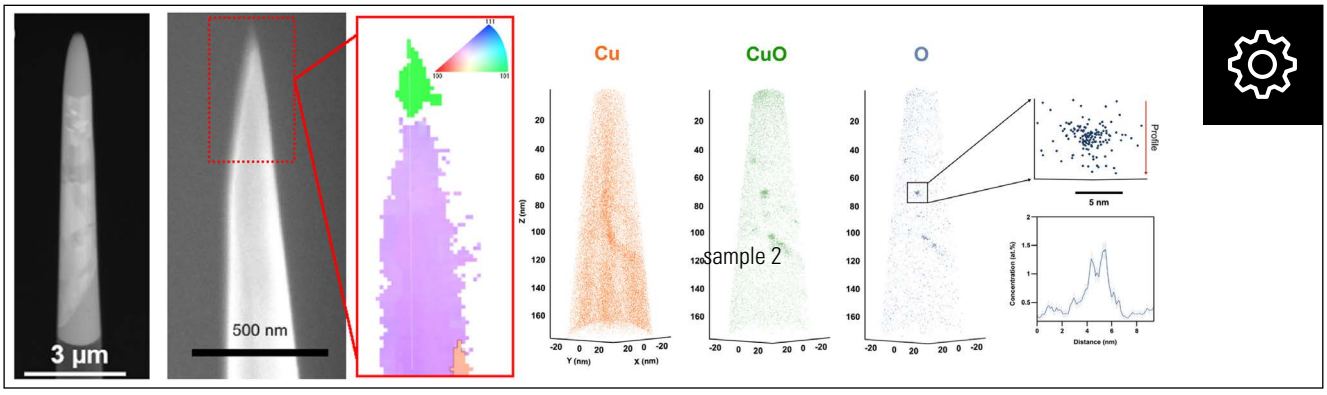
STAKEHOLDER EXPECTATIONS:

Are we meeting and exceeding the expectations of our stakeholders, including our partners, customers, funders, including Value Partners, staff and students? If not, are we taking appropriate action to address our shortfalls?

INDEPENDENT EXPERT REVIEW:

At approximately the half-way point in the Plan's lifetime, we will invite a panel of independent subject matter experts to review CCEM and progress towards the goals set out in our Strategic Plan.

PROVIDING SPECIALIZED SERVICES



Atom probe tomography (APT) in combination with focused ion beam (FIB) and transmission Kikuchi diffraction (TKD) was used to study potential materials for used fuel containers of Canadian nuclear waste. Without the combined techniques and nanoscale 3D characterization capabilities at CCEM, specific degradation mechanisms have remained unknown to the science community. Understanding these mechanisms bring Canadians and the world closer net-zero carbon emissions, using nuclear energy and the safe disposal of its waste.

Publication: Adapted with permissions from S. J. Persaud, W. J. Binns, M. Guo, D. Williams, Q. Dong, G. A. Arcuri, K. Daub, R. C. Newman, M. R. Daymond, P. G. Keech, Applying state-of-the-art microscopy techniques to understand the degradation of copper for nuclear waste canisters, Materials and Corrosion, 1 – 13. Copyright (2023) Wiley-VCH GmbH.

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