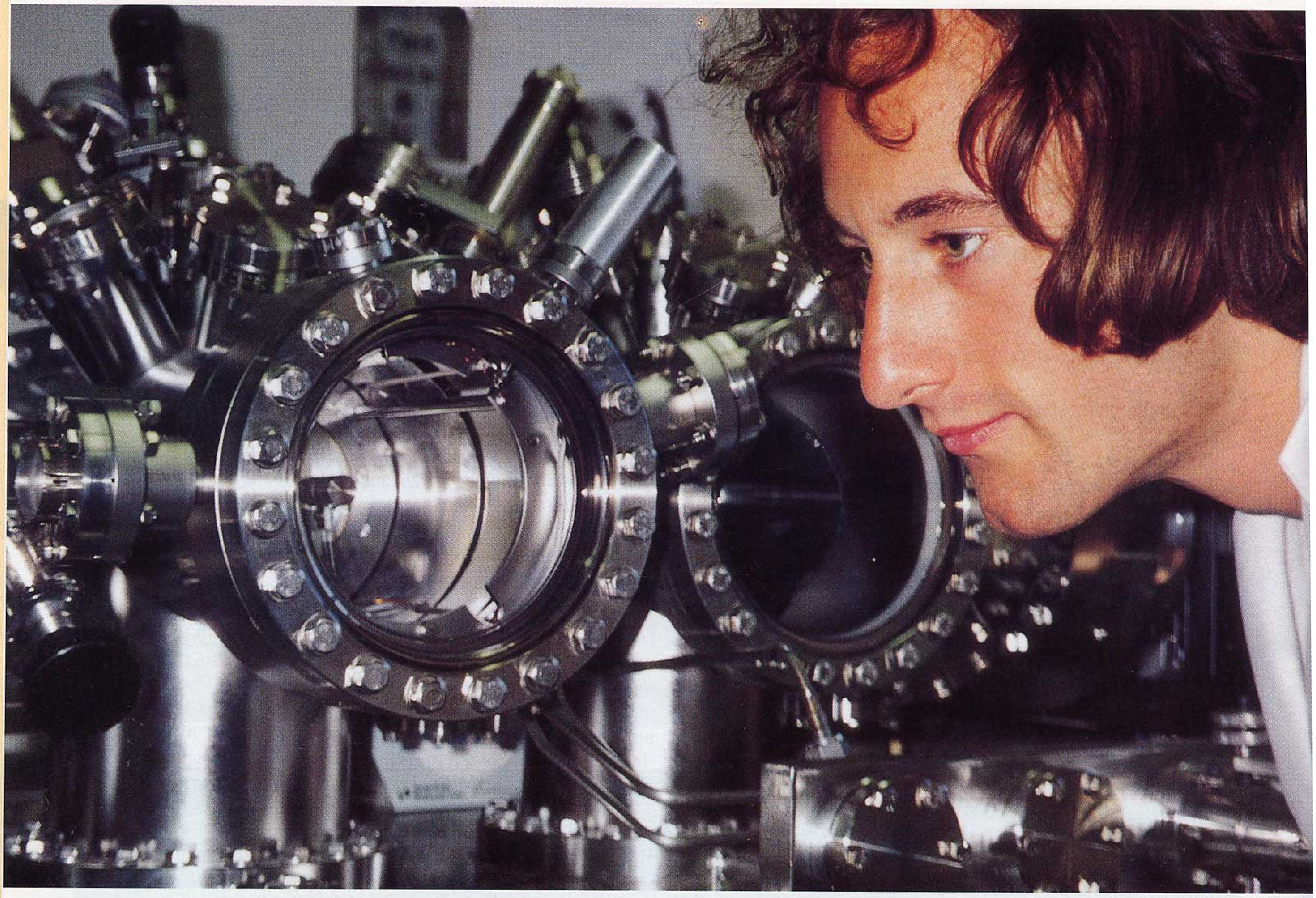

Advanced Materials Research

New Frontiers at UVic's CAMTEC

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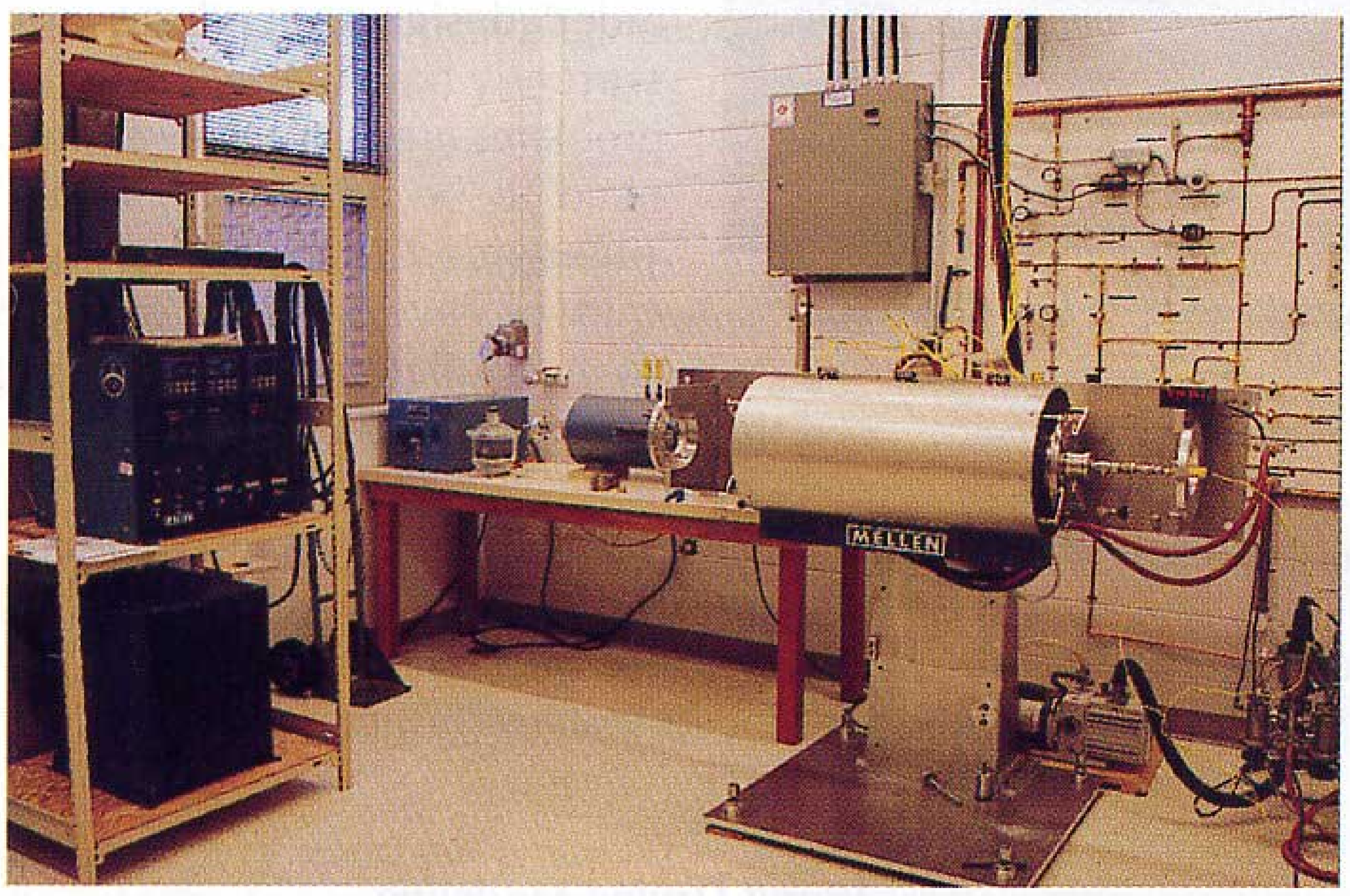
Over the past several decades, the research and development of advanced materials has been a major impetus for technological growth worldwide, with this trend especially evident in countries like Canada, which nurtures a wide range of R&D activities. Since the middle of this century, humankind has witnessed the growth of technology at an incredible pace, with innumerable instances of "futuristic" ideas being brought to fruition through breakthroughs in new materials. To cite one example — photonics — the perception of light signal transmission was only realized through the invention of low cost solid-state lasers and optical fibres.

Notwithstanding this rapid growth, materials research and development has also matured: the prolific R&D activities that characterized the 1950s and 60s have gradually become more selective and focused over the years. More R&D is now directed towards areas that target either product performance improvements or materials research for specific products. British Columbia in particular faces unique challenges in its transition from resource-based to high-tech industries: many local high-tech companies are small with limited research capabilities, and few large manufacturers can afford a sizable research program.



Nonetheless, opportunities for materials research in BC do exist — and a leader in these initiatives is the University of Victoria's Centre for Advanced Materials and Related Technology (CAMTEC). Committed to interdisciplinary work on advanced materials and technology, CAMTEC coordinates a wide range of theoretical and applied research activities among the Departments of Chemistry, Electrical and Computer Engineering, Mechanical Engineering and Physics. Its participating members work closely with scientists and engineers in the private and public sector to ensure technology transfer to industry and government agencies and the promotion of BC's R&D industry.

CAMTEC Structure and Mandate

Now in its sixth year of operation, CAMTEC carries out fundamental and applied research in advanced materials, trains technical and academic personnel in these areas, and disseminates the knowledge gained from research via technology transfer to private industry as well as through scientific publications, conferences, workshops and seminars.

In the selection of faculty members and strategic development of programs, CAMTEC has focused its efforts on the materials needed for the most rapidly emerging technologies. The driving forces behind current research into advanced materials are: 1) the development and production of high quality materials for high-technology sensor, circuit and optical applications, and 2) the fabrication, treatment and transformation of new or existing materials crucial to industry.

As part of the University of Victoria, CAMTEC also serves as a teaching centre involving graduate students in the latest developments in and applications of materials research. In each of the participating departments, new graduate courses on the science and technology of advanced materials are developed. Moreover, the centre stimulates the development and/or purchase of new equipment and facilities, which also attracts graduate students and visiting scientists.

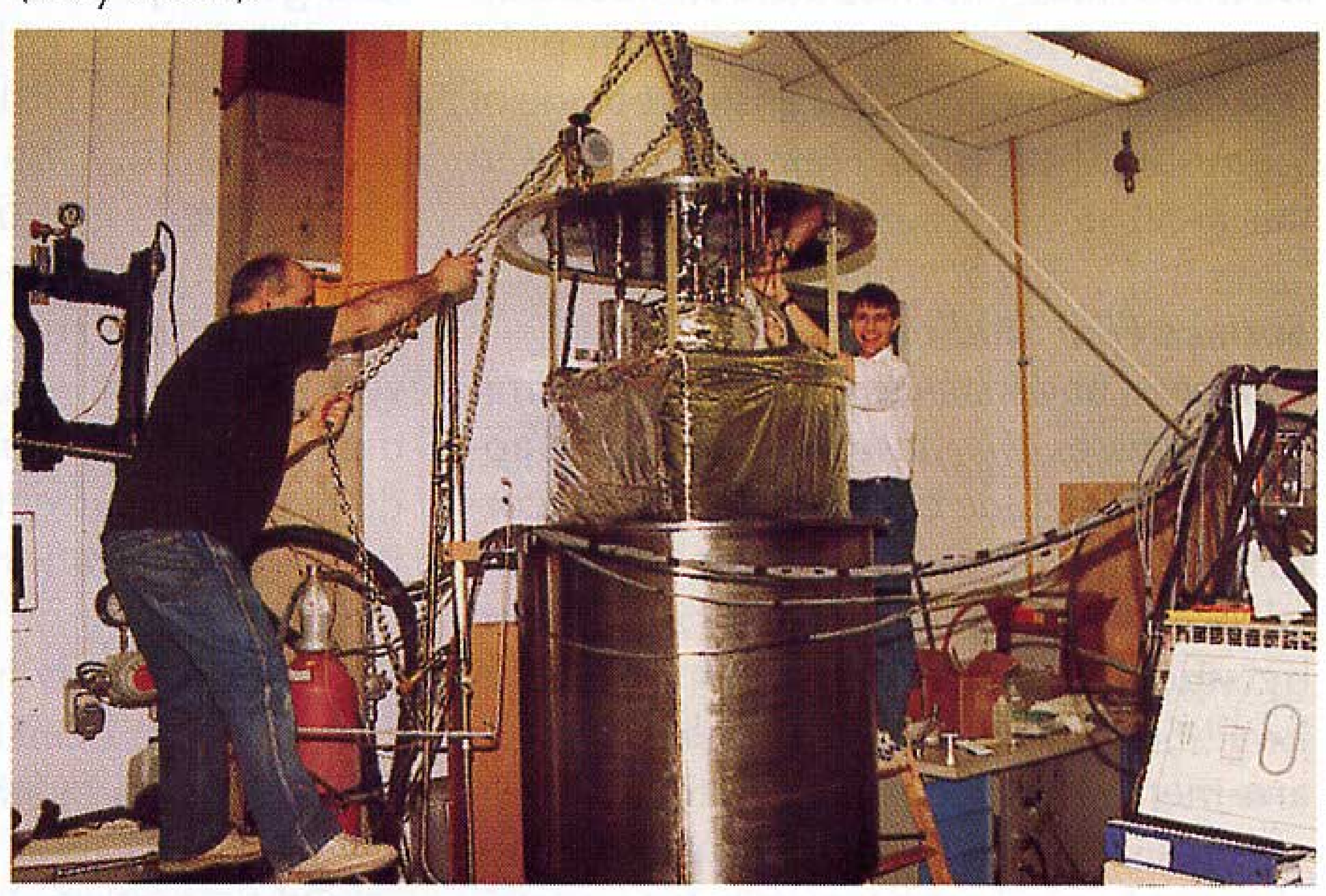
As an interdisciplinary centre, CAMTEC is committed to expanding its measurement capabilities and prototype fabrication facilities as well as making this equipment available to other users.

Current Activities

CAMTEC has identified the following critical areas of R&D in advanced materials that are needed in BC:

- Electronic materials for crystal growth, devices, integrated circuits and sensors.
- Mechanical devices for refrigeration, sensing, power and fuel.
- Biological materials for medical and clinical diagnostic/therapeutic applications.
- Materials applications in the paper and pulp industry.
- Materials research in the minerals and chemical industry.

International collaboration is maintained on an individual project basis and CAMTEC members encourage joint projects with foreign universities and research institutions. A larger forum for discussion and research exchange is provided through international conferences. CAMTEC members have been instrumental in attracting to Victoria two major events on advanced materials research: the Eighth International Conference on Mechanical Behaviour of Materials (May 16-21, 1999) and the 17th URSI International Symposium on Electromagnetic Theory (May 2001).



***Facing page:* A graduate student takes a closer look at the ultrahigh vacuum surface analysis system used to deposit thin films and study their properties. *Above, left:* gradient freezing furnace and controller used to grow crystal semiconductors; *right:* mounting the superconducting magnet assembly into the regenerator housing unit used for hydrogen liquefaction.**

Specific Projects
CAMTEC's research and development projects in advanced materials include the following:

Crystal Semiconductor Growth
High quality semiconductor single crystals made of silicon and other compounds play a crucial role in the development of electronic and optoelectronic devices. CAMTEC is conducting research on solution growth techniques with the potential to develop high quality compound and alloy semiconductors whose availability would open new horizons in the optoelectronics industry.

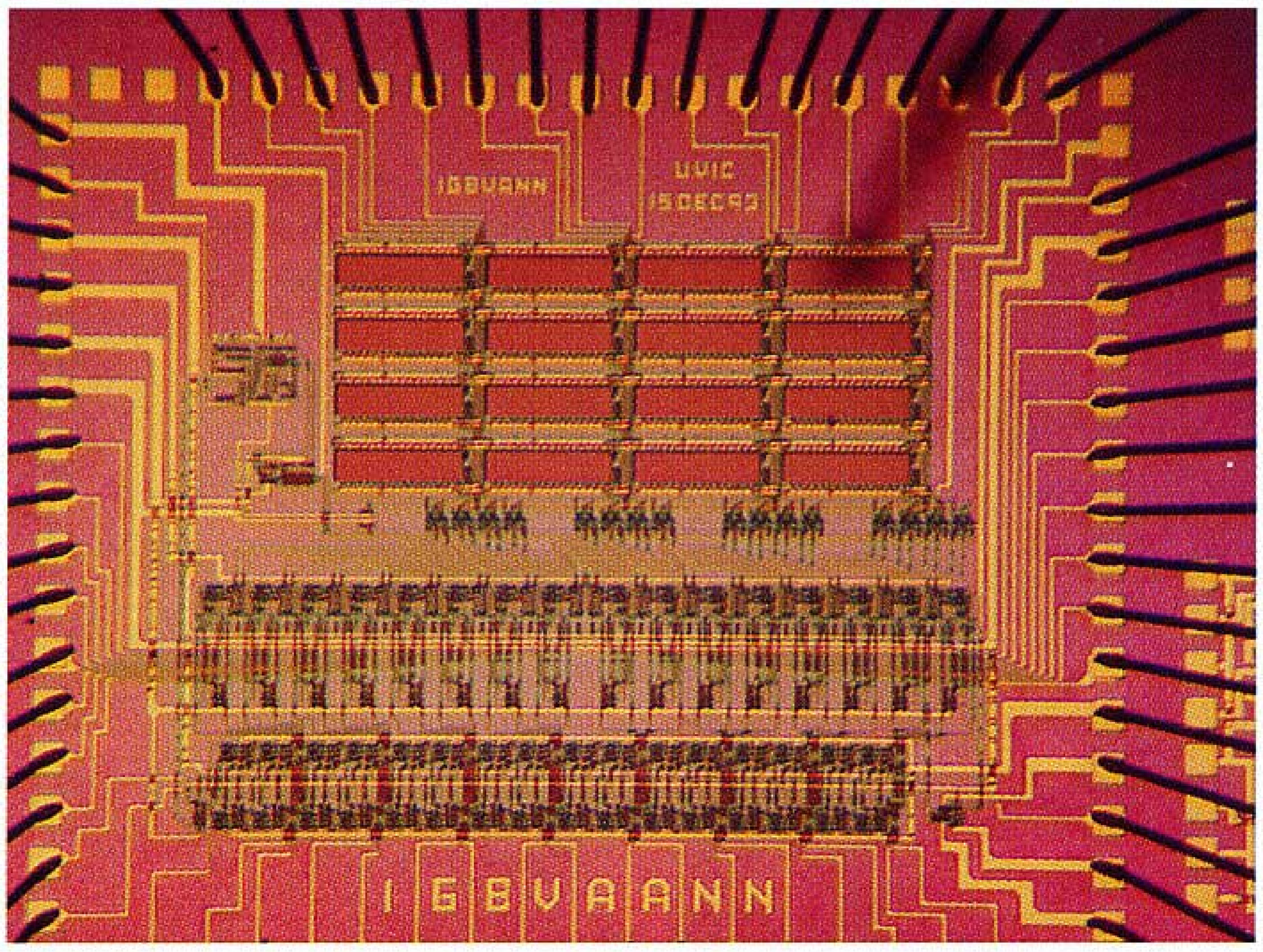
The program has received major financial support from the Canadian Space Agency through its Microgravity Science Program, the Japan Science Technology Fund (JSTF) and Crystar Research Inc of Victoria, and has been carried out in close collaboration with the Research Institute of Electronics (RIE) at Shizuoka University, Japan, with additional financial support from the Natural Science and Engineering Research Council (NSERC) and RIE. This work has also led to other research programs on piezoelectric ceramics that have attracted support from the federal Network Centres of Excellence, the BC government, JSTF and private companies.

CAMTEC's crystal growth research has contributed significantly to technology transfer and the training of highly qualified people in Canada, and has led to the development of state-of-the-art materials research laboratories, spinoff research programs and significant research publications. Today, UVic is considered one of the world's best known research centres in this area.

Surface Film Studies
A deeper understanding of electrochemical processes — whose many practical applications include batteries, fuel cells, corrosion prevention, surface coatings and fabrication of new materials — is obtained by studying reactions at the molecular level. Surfaces of interest for this purpose are metals and semiconductors. Single crystals are usually used to control the chemical reactions as precisely as possible and to learn the effect of surface structure on reactivity. Molecules, or thin films, are deposited by electrochemical methods in which the surface is exposed to a solution and a current is passed through it.

Two complementary approaches are used to understand the nature of the reactions. The first approach uses electrochemical kinetic methods, which give information about the rates of the adsorption or reaction processes taking place as well as the numbers of molecules reacting. The second approach uses an array of modern ultrahigh vacuum surface science methods to identify the molecules and how they are bonded to the surface.

A special feature of UVic's apparatus is that, after electrochemical deposition in solution at atmospheric pressure, the surface may be quickly transferred to the ultrahigh vacuum part of the apparatus for analysis. Projects of this nature range from fundamental work, such as determining the details of adsorption, to more practical projects, such as creating new materials with interesting properties.



High speed network IC chip designed and tested by CAMTEC.

Charge-Coupled Devices
CAMTEC has collaborated with researchers at TRIUMF (Tri-University Meson Facility) on the development of high speed gallium arsenide (GaAs) charge-coupled devices (CCDs) for use in transient digitizers designed to capture very short durations of analog signals and digitize them at a reduced speed. These devices are currently being used at the Brookhaven National Laboratory in the United States in a large particle physics experiment involving the decay of kaons. This work has been funded by NSERC and MICRONET, a federal Network Centre of Excellence.

Other projects have been initiated to assist in the chip-level integration of CCD transient digitizers; in particular, high speed GaAs analog and digital chips operating at one billion clock cycles per second have been designed. Preliminary work has also been initiated to explore the photonic application of these CCDs as detectors in nuclear medicine imagery. There is significant potential in the application of such CCDs in high speed, position sensitive optoelectronics, such as in the case of a visual processor.

Microwave Design Software
Microwave design engineers rely heavily on accurate computer-aided analysis and design tools to reduce the cost intensive, trial-and-error development of microwave and millimeter-wave circuits for the telecommunications industry. The development of constantly evolving integrated circuit technologies and the rapid growth of the telecommunications industry — with the trend to ever-smaller systems and fabrication by material growth processes — continues to create a heavy demand for microwave/millimeter-wave design software all over the world.

Although many computer-aided design procedures are currently available, several problems are still unsolved and need to be addressed. Computer-aided design routines must be developed and utilized to their full potential; only then can time frames for component development be significantly shortened and, consequently, cost effectiveness considerably increased. CAMTEC's research program in this area has been supported by the BC Advanced Systems Institute (ASI), NSERC and JSTF.

Wood Drying Modeling
In collaboration with the Department of Wood Science at the University of British Columbia, CAMTEC is pursuing an industrially oriented research project on the development of a software modeling tool for the radio frequency (RF) drying of wood in a vacuum kiln. The project is supported by MacMillan Bloedel Research, Salton Fabrication and Glade Technologies as industrial partners, with industry funding matched by ASI and NSERC. This research has led to the development of a time-domain model that includes the following physical phenomena involved in the drying of wood:

- electromagnetic field distribution in the wood and surrounding kiln;
- energy deposition, which increases the mobility of moisture in the lumber;
- heat transfer; and
- mass transfer which, in turn, changes the dielectric properties of the wood.

Experimental validation of the model will be undertaken using UBC's vacuum/RF kiln. The expertise and know-how generated from this research is presently supporting new technology developments at MB Research in Burnaby through UVic's spinoff company, Faustus Scientific Corporation, which intends to enable BC companies to carry out their own modeling inhouse. UVic and Faustus are the only providers of RF wood modeling and simulation support in BC.

Future plans include further developing and testing a dynamic model of coupled electromagnetic/thermal/moisture behaviour of wood exposed to electromagnetic fields, which will be used to predict and design procedures and systems for the RF drying of softwood lumber and other biopolymers such as hay. The same model could, with some modification, be applied to other coupled systems such as biological and medical procedures involving RF energy as well as other industrial processes for the heating and drying of materials. CAMTEC will also explore possibilities for collaboration with researchers in mechanical engineering with expertise in thermal and mass transfer phenomena in materials.

Powder Compaction/Sintering

The manufacture of components and products through the compaction of a variety of metal and plastic powders and subsequent sintering (partial welding without melting) is used extensively in the aircraft and automobile industries. It has a number of distinct advantages including the absence of machining, attainment of good accuracy and the ability to use materials with special properties.

The powder contains a small amount of wax to bind the particles at the time of compaction. During sintering, at relatively high temperatures, the wax melts and the powder particles bond and form a solid body. Compaction is often carried out in presses after the powder is poured in a die; in some cases, usually for larger items, the powder is placed in a rubber container and pressurized hydrostatically. The degree of compaction varies according to the type of powder used; it is generally desirable that most of the gas in the voids is driven out. The aim is to design the process of compaction and sintering so that the final product is as close to design specifications as possible.

CAMTEC's research objective was to determine density distribution in the powder during compaction, since a uniform density distribution can be expected to minimize distortions in the sintered product. A series of computational models were developed for the one-sided and double-sided compaction of cylindrical compacts; the results were found to be in good qualitative agreement with anticipated density distributions. In order to obtain quantitative comparisons the CAMTEC research team, in collaboration with its industrial partner, developed a test procedure and instrumented a production press to obtain experimental results.

Magnetic Liquefier for Hydrogen

The transition to hydrogen as a vehicular fuel is highly dependent on the development of a refueling infrastructure that can provide an energy equivalent quantity of hydrogen at prices comparable to, or less than, gasoline or diesel. An important element in the development of such a network of refueling stations is an efficient and inexpensive hydrogen liquefier. Magnetic refrigeration for hydrogen liquefaction is potentially more efficient and less expensive than conventional gas cycle technology.

The objective of this research project is to develop suitable materials for use in optimized magnetic liquefiers for hydrogen. Primarily amorphous materials were investigated as they possess many unique properties attractive for the intended application. However, in order to use any of these materials in a regenerative cycle they must be integrated into a high performance regenerator. Regenerator design, manufacturing and testing techniques for evaluating the performance of several geometries were also studied in a project funded by Natural Resources Canada. Collaboration with other related materials research projects is also underway.

Future projects will examine magnetic refrigerants other than amorphous, including a class of new materials revealed through recent developments from another research group. The design and characterization of highly efficient regenerator geometries using these materials and, ultimately, the preliminary design of a magnetic liquefier for hydrogen will be CAMTEC's main targets in the future.

Conclusion

CAMTEC's programs have served to foster closer links with BC companies engaged in materials-oriented R&D as well as companies that use advanced materials and technology. In collaboration with its industrial, research and academic partners, and supported by funding from a variety of sources within and outside BC, CAMTEC will continue its commitment to interdisciplinary research projects and advancements in materials applications in important areas of engineering and science for the ultimate benefit of society.

CAMTEC Equipment and Facilities

- ultrahigh vacuum surface analysis system (including auger electron spectroscopy, low energy electron diffraction and thermal desorption mass spectrometry) used to deposit and study thin films
- NMR spectrometer
- polishing and crystal alignment equipment
- X-ray diffractometers
- spin meter for the fabrication of amorphous materials
- scanning electron microscope
- double monochromator for photoluminescence and laser light scattering in crystals
- argon arc and annealing furnace
- Nikon microscope for photomicroscopy
- RF sputtering machine
- advanced photoelasticity unit
- materials testing system for mechanical properties
- equipment for liquid phase epitaxial (LPE) and electroepitaxial (LPEE) growth of semiconductors
- microwave facility with equipment for frequencies up to 110 GHz including spectrum analyzers, vector and scalar network analyzers, MMIC probing station, optical fibre equipment and anechoic chamber
- integrated circuit test equipment including probing station, parameter analyzer and digital tester
- device characterization equipment such as CV and CT
- state-of-the-art computer workstations and electronic test equipment

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