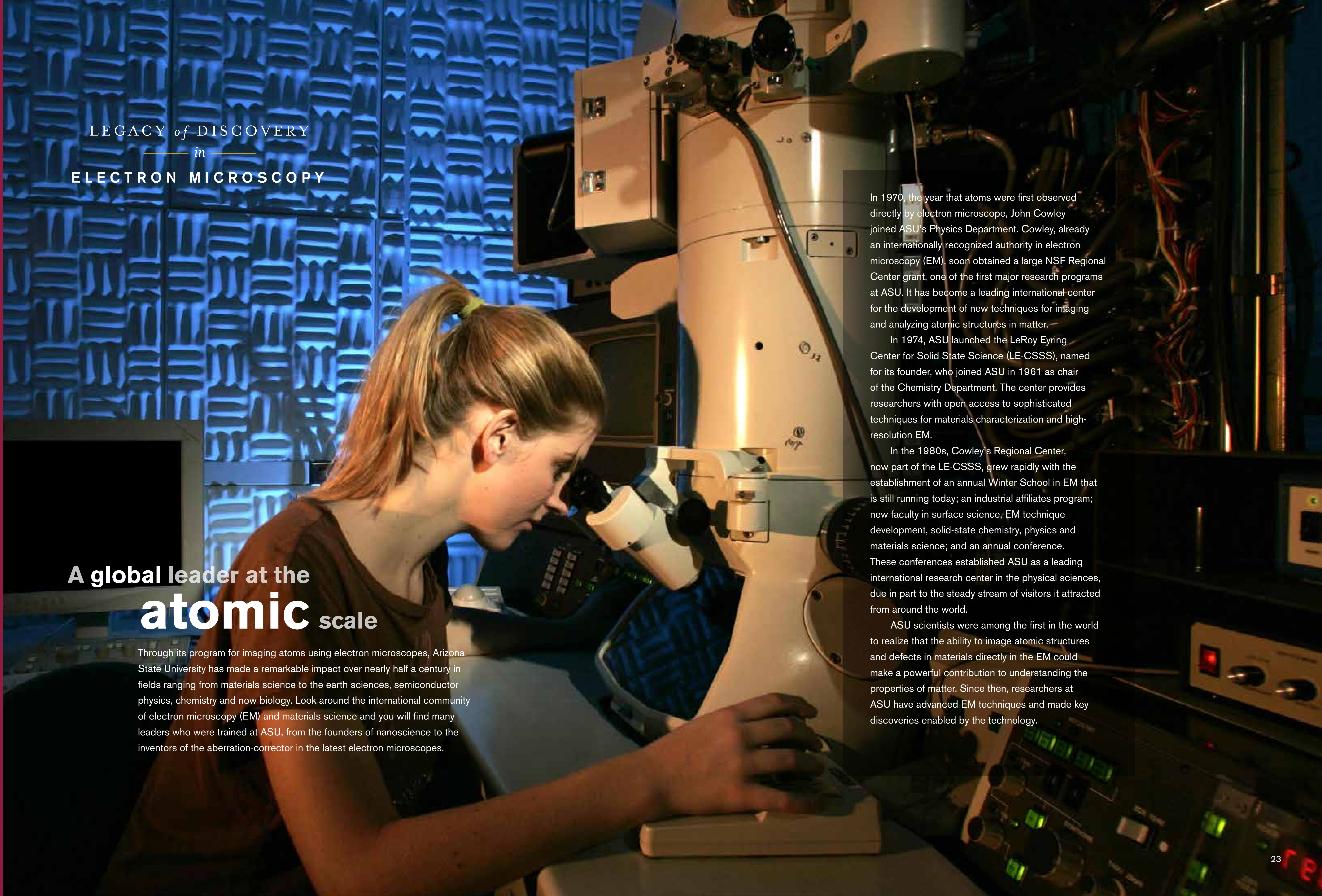

LEGACY *of* DISCOVERY *in* ELECTRON MICROSCOPY

A global leader at the **atomic** scale

Through its program for imaging atoms using electron microscopes, Arizona State University has made a remarkable impact over nearly half a century in fields ranging from materials science to the earth sciences, semiconductor physics, chemistry and now biology. Look around the international community of electron microscopy (EM) and materials science and you will find many leaders who were trained at ASU, from the founders of nanoscience to the inventors of the aberration-corrector in the latest electron microscopes.

In 1970, the year that atoms were first observed directly by electron microscope, John Cowley joined ASU's Physics Department. Cowley, already an internationally recognized authority in electron microscopy (EM), soon obtained a large NSF Regional Center grant, one of the first major research programs at ASU. It has become a leading international center for the development of new techniques for imaging and analyzing atomic structures in matter.

In 1974, ASU launched the LeRoy Eyring Center for Solid State Science (LE-CSSS), named for its founder, who joined ASU in 1961 as chair of the Chemistry Department. The center provides researchers with open access to sophisticated techniques for materials characterization and high-resolution EM.

In the 1980s, Cowley's Regional Center, now part of the LE-CSSS, grew rapidly with the establishment of an annual Winter School in EM that is still running today; an industrial affiliates program; new faculty in surface science, EM technique development, solid-state chemistry, physics and materials science; and an annual conference. These conferences established ASU as a leading international research center in the physical sciences, due in part to the steady stream of visitors it attracted from around the world.

ASU scientists were among the first in the world to realize that the ability to image atomic structures and defects in materials directly in the EM could make a powerful contribution to understanding the properties of matter. Since then, researchers at ASU have advanced EM techniques and made key discoveries enabled by the technology.

A scanning electron micrograph of a flower's anther—part of the stamen—filled with spherical pollen grains, created for a collaborative project between ASU's School of Life Sciences and School of Art.

credit: Kyle Horace, undergraduate, under direction of Robert Roberson, SOLS

Crystal mystery solved 1977

ASU researchers solve the long-standing mystery of what causes "non-stoichiometry" in oxide crystals such as minerals. This means that the number of one type of atom in a crystal is not an exact multiple of another type. Using EM, Cowley and post-doctoral researcher Sumio Iijima show details of the "mistakes" in the ordered pattern of atoms that make this possible—findings with later applications in the chemical industry.

Crystallography breakthrough 1978

ASU chemist Peter Buseck, along with Iijima and another post-doc Michael O'Keefe, develops a new technique for high-resolution imaging of crystal structures using transmission electron microscopes. In July 2014, the journal Nature hails their paper as a milestone in the science of crystallography.

Carbon nanotubes discovered 1991

Iijima discovers carbon nanotubes using a high-resolution transmission electron microscopy technique he developed at ASU. A founding member of the LE-CSSS, Iijima has been a major contributor to the rise of nanoscience throughout the world.

Aberration correction 1997

Physicist Ondrej Krivanek, an early member of the LE-CSSS, is co-inventor of the aberration-correction device, which has revolutionized the field of EM by improving resolution to less than one-tenth of one nanometer. In the same year, Krivanek founds Nion. This highly successful venture is the only U.S. company that manufactures transmission electron microscopes.

Orbital observation 1999

John Spence, another early member of the LE-CSSS, his student J.M. Zuo, M. Kim and O'Keefe develop a method for imaging the chemical bonds between atoms in cuprite (Cu_2O) crystals, resulting in a famous picture on the cover of Nature. The images resolve a controversy about the types of bonds in superconducting copper oxides and provide the first direct observation of electron orbitals.

Improving climate models 2008

ASU engineers Peter Crozier and James Anderson use a novel EM technique to determine the optical properties of brown carbon nanoparticles in the atmosphere. The particles, particularly those produced by fossil fuel combustion, are among the least understood components in global climate change. The ASU team's contributions could lead to more accurate climate modeling.

Special facility for sensitive equipment 2012

ASU dedicates the new Southwestern Center for Aberration Corrected Electron Microscopy, constructed to house new aberration-corrected EM instruments. Because this equipment is extremely sensitive, the windowless building is designed to eliminate vibrations, noise, electrical fields, temperature changes, air currents and pressure pulses—even from people working inside. The center is used by the ASU community, other universities and industry.

Structurally bizarre diamonds 2013

ASU scientists use EM to debunk the existence of a new form of diamond called lonsdaleite, which is associated with meteorite and asteroid impacts. Péter Németh, a former ASU visiting professor, and ASU research professor Laurence Garvie show that what has been called lonsdaleite is in fact a structurally disordered form of ordinary diamond.

Carbon under pressure 2013

Buseck and his colleague Jun Wu demonstrate another novel EM technique, studying samples under high pressures and temperatures. Their findings show that inner-Earth materials subjected to high heat and pressure develop faults that concentrate carbon along them. The new method could help solve the mystery of where large amounts of carbon reside in the Earth's interior.

Simplifying the nano-diamond alphabet 2015

Németh, Garvie and Buseck make another diamond discovery. In recent years, scientists have identified various kinds of nanodiamond structures and named them by letters, such as h-diamond, n-diamond, etc. Using ASU's ultra-high-resolution EMs, the team finds that all of these structures are ordinary cubic diamonds (c-diamonds) with intimately "twinned" crystals that create unpredicted structural complexity.

Antibacterial clays 2016

A former ASU doctoral student, Keith Morrison, and ASU clay-mineral scientist Lynda Williams use a variety of instruments at the LE-CSSS to help identify two metallic elements in certain blue and green clays that can kill infectious bacteria.

New tech to image biomolecules 2016

ASU acquires a state-of-the-art cryo-electron microscope for imaging biological molecules at the atomic scale for solving molecular structures. Such structural biology is involved in processes as varied as human vision, drug development, virus infection and the host of molecular machines on which life depends.