Dan Shechtman, Nobel laureate.
Photo courtesy of The Ames Laboratory, USDOE.

Iowa State University Materials Science and Engineering Department Professor wins Nobel Prize in Chemistry

AMES, IA - The Nobel Foundation today announced Dan Shechtman of Iowa State University's MSE Department, the U.S. Department of Energy's Ames Laboratory and Israel's Technion has won the 2011 Nobel Prize in Chemistry. The foundation announced that The Royal Swedish Academy of Sciences picked Shechtman "for the discovery of quasicrystals".

That 1982 discovery of crystalline materials whose atoms didn't line up periodically like every crystal studied during 70 years of modern crystallography is regarded as a revolutionary find that changed ideas about matter and its atomic arrangement.

Shechtman, who goes by "Danny," compared winning the Nobel Prize to carrying a country's flag at the Olympics. In this case, he's carrying the banner for an international team of quasicrystal scientists. "I am the spearhead of the science of quasicrystals, but without the thousands of enthusiastic scientists around the globe, quasicrystals would not be what they are today," he said. "Quasicrystals are still an enigma in many ways, waiting to unfold, and I admire the researchers who over the years became friends and who for a quarter of a century have elucidated this science."

Pat Thiel -- an Iowa State Distinguished Professor of Chemistry, a professor in Materials Science and Engineering, and a faculty scientist for the U.S. Department of Energy's Ames Laboratory -- also studies quasicrystals. She said Shechtman's discovery meant scientific definitions had to be changed and textbooks rewritten. "What Danny did was fantastic science," she said. "He instigated a scientific revolution."

That's not what he set out to do during a sabbatical from the Technion and a two-year stint in the United States at what's now known as the National Institute of Standards and Technology. Shechtman was studying rapidly solidified aluminum alloys with a toolbox that included transmission electron microscopy, X-ray diffraction and neutron diffraction. The transmission electron microscopy revealed a structure that science said was impossible: a pattern that when rotated a full circle repeats itself 10 times. In his notebook that day, Shechtman wrote "(10 Fold ???)." Later, he found the pattern was really a five-fold rotation, but that didn't show up in the first experiments.

"For 70 years until 1982, all crystals studied, hundreds of thousands of them, were found to be periodic," he said. "Only certain rotational symmetries are allowed in this periodic array and these are 1,2,3,4,6 and nothing else. This is why, when I saw the ten-fold rotational symmetry, I was so surprised." Shechtman did follow-up experiments to confirm his findings and published his discovery in 1984. His work was widely questioned. "For a long time it was me against the world," he said. "I was a subject of ridicule and lectures about the basics of crystallography. The leader of the opposition to my findings was the two-time Nobel Laureate Linus Pauling, the idol of the American Chemical Society and one of the most famous scientists in the world. For years, till his last day, he fought against quasi-periodicity in crystals. He was wrong, and after a while, I enjoyed every moment of this scientific battle, knowing that he was wrong."

Shechtman is an Iowa State professor of materials science and engineering, a research scientist for the Ames Laboratory and the Philip Tobias Professor of Materials Science at the Technion - Israel Institute of Technology. He is currently at the Technion in Haifa, Israel. The 70-year-old scientist joined Iowa State and the Ames Lab in 2004 and spends about four months a year in the Materials Science and Engineering Department at Iowa State. He will return to Ames in mid-February.

He continues to study magnesium alloys and other materials that are strong but can also be stretched or shaped without breaking. Although the applications of quasicrystals are limited, Shechtman said they are important for changing a long-held scientific paradigm. "People should be interested in scientific advances because the body of knowledge generated by the scientific community improves our lives." he said. "Go back 100 years and see the difference, including life expectancy and life quality."

A more detailed description of quasicrystals is presented in the following excerpt used with permission from Structure-Property Relations in Nonferrous Metals, Russell and Lee, John Wiley and Sons, Inc., pp. 96-97 (2005).

7.4 Quasicrystalline metals

The crystallographer's world was a well-defined orderly place in 1981. Everyone “knew” that crystals were comprised of unit cells that could be stacked side-by-side in any desired number, filling up all available space with exactly repeating copies of the atom positions of the unit cell. To fill space completely with these repeating unit cells, the cells must have two-, three-, four-, or six-fold rotational symmetry. Crystals with five-fold or *n*-fold symmetry (where *n* is an integer greater than 6) cannot fill space completely and are therefore forbidden structures in perfect crystals.

This tidy picture suffered a severe jolt in 1982 when Shechtman generated a diffraction pattern from an Al-Mn alloy similar to the one in Fig. 7.10. The alloy had the symmetry of an icosahedron, possessing six axes of five-fold symmetry, 10 axes of three-fold symmetry, and 15 axes of two-fold symmetry. The finding was so controversial that Shechtman was forced to wait two and a half years to receive peer review approval to publish his findings in a scientific journal. Even after the findings were published, many scientists were reluctant to concede the existence of such crystals, and statements such as the first quotations at the beginning of this chapter exemplify the level of skepticism then extant.

In the ensuing decades, many more such crystals with forbidden symmetries have been discovered, and the term *quasicrystal* is used to identify the entire family of such materials. Although quasicrystals cannot be defined by a stacking of unit cells that fill space completely, the debate about their existence ended long ago. Their crystal structure is most easily described by unit cells that interpenetrate one another (Fig. 7.11). The typical quasicrystal is a binary or higher-order alloy, often containing 60 to 70 at% Al. Quasicrystals are typically hard, brittle materials with unusually low conductivities and coefficients of friction. They are used sparingly in current engineering design, finding applications in cookware, surgical tools, and electric razors. Their unusual combination of high electrical resistivity (400 to 600 $\mu\Omega\cdot$cm), high hardness, and low coefficient of friction makes them potentially useful as wear-resistant coatings for parts subjected to sliding contact, thermal barrier coatings, and reinforcing phases in metal matrix composites. Some quasicrystals can dissolve large amounts of H, making them potentially useful in H fuel storage systems. They can be applied as coatings by thermal spray, and bulk parts can be fabricated by P/M.

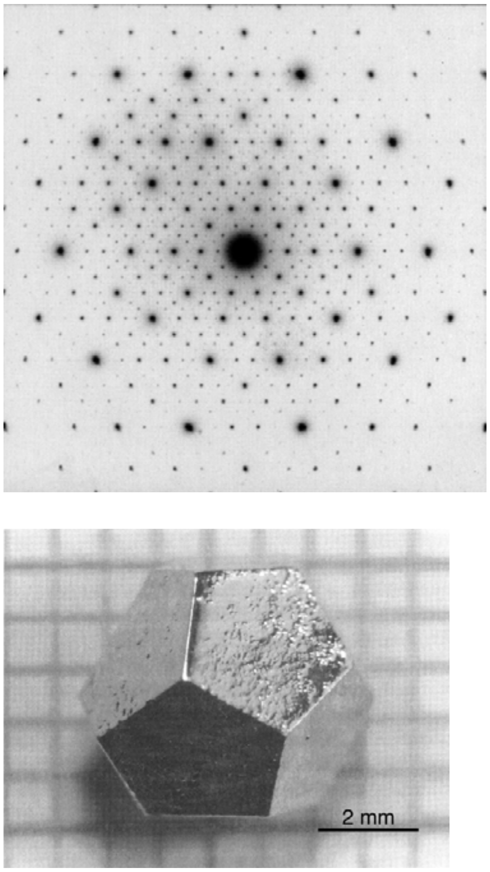

Fig. 7.10 (*a*) Electron diffraction pattern taken from as-cast, quasicrystalline $Al_{65}Ni_{30}Ru_5$ alloy along its 10-fold axis. Note the five-fold and 10-fold rotational symmetry. Such symmetry is forbidden by conventional crystallographic models of repeating unit cells stacked side by side to fill all space within the crystal. (*b*) Five-fold symmetry is also prominent in this optical photograph of an icosahedral $Ho_9Mg_{34}Zn_{57}$ crystal. [(*a*) From Sun and Hiraga, 2002; and (*b*) from Canfield and Fisher, 2001; with permission of Elsevier.]

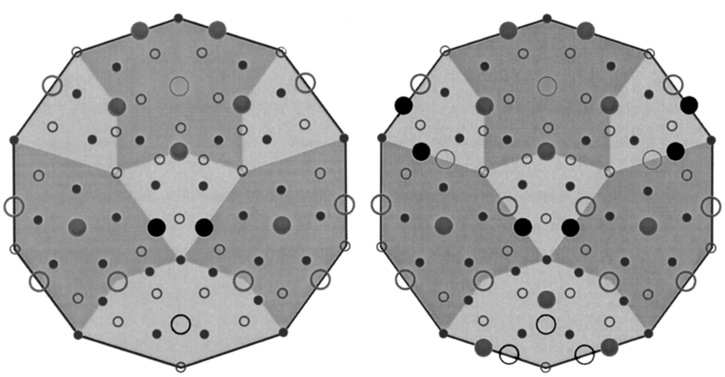

Fig. 7.11 Model of the decagonal quasi-unit cell of $Al_{72}Ni_{20}Co_8$. Large circles represent Ni (gray) and Co (black) atoms; small circles represent Al atoms. Circle sizes do not correlate with actual atom sizes. The structure has two distinct layers along the periodic c-axis, which is perpendicular to the page. Solid circles represent the atoms on the c = 0 level, and open circles represent the atoms on the *c* = 1/2 level. The image on the right is the same decagonal quasi-unit cell showing

additional atoms present from the “overlap” of neighboring quasi-unit cells. (From Steinhardt, 1996, p. 613-614; with permission.)