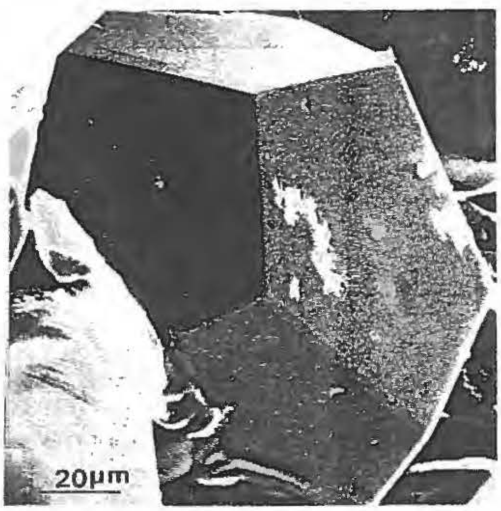
Quasicrystals: A Look at Impossible Symmetry

Suzanne Charnick Literature Seminar October 10, 1991

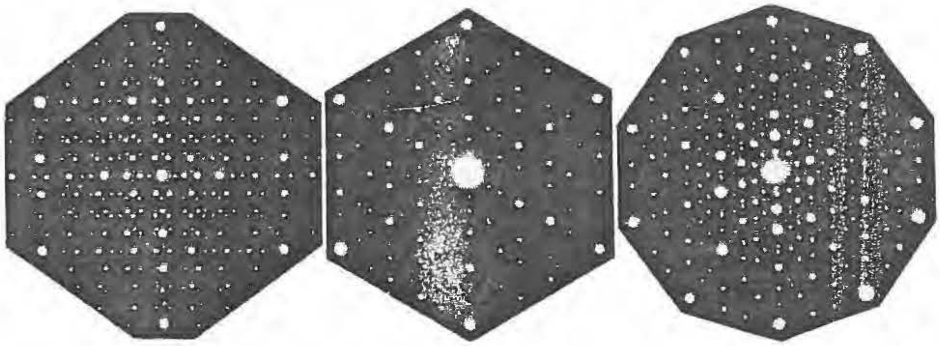
Quasicrystals are solids which do not belong to any of the 230 crystallographic space groups, but which nevertheless possess long range quasiperiodic translational order and long range orientational order. Quasicrystalline materials exhibit symmetries once thought to be impossible to possess. In 1974, Penrose, a mathematician, devised a way to fill a plane with objects of five-fold symmetry, creating patterns or "tilings" that were quasiperiodic and non-repeating [1]. In 1984, Shechtman, Blech, Gratias, and Cahn published the discovery of a rapidly quenched aluminum alloy of approximate composition Al_6Mn which exhibited true icosahedral symmetry and which could be modelled by an extension of Penrose tiling theories to three dimensions [2]. The electron diffraction pattern and dark field imaging experiments verified the five-fold symmetry of this phase.

Since the existence of a quasicrystalline phase contradicted long-standing crystallographic theories, alternative explanations were proposed soon thereafter. Pauling suggested that the icosahedral phase could instead consist of multiply twinned crystals having a large unit cell [3,4]. Many others still maintain, however, that the dark and bright field images, electron micrographs, and electron diffraction patterns of the new materials can only be attributed to their quasicrystalline nature.

The most common quasicrystalline symmetries are icosahedral and decagonal. Decagonal quasicrystals are quasiperiodic in two dimensions and periodic in the third, whereas icosahedral quasicrystals are quasiperiodic in three dimensions. In order to verify that these new materials were indeed quasicrystalline, exhibiting "forbidden" symmetries, electron diffraction, X-ray diffraction, high resolution electron microscopy, and scanning electron microscopy studies have been carried out [4-20]. These provide evidence for the existence of materials which have icosahedral, pentagonal, octagonal, and decagonal symmetries--matching theoretically predicted results as well as computer modeling studies of quasicrystalline solids.



SEM - icosahedral
quasicrystal



Electron diffraction pattern along
2-fold, 3-fold, 5-fold axis

The atomic arrangements in these new solids have not yet been determined. Crystallographic theory must be expanded before the absolute locations of atoms in quasicrystals can be established. This has started with the development of six-dimensional techniques to index X-ray diffraction data.

The factors which affect the stability of quasicrystalline phases are also currently under investigation. There is increasing evidence that quasicrystals are Hume-Rothery phases, with a certain electron per atom ratio determining their formation and stability [21]. It is possible that research in quasicrystalline materials will have impact on the fields of magnetic materials, catalysis, and biochemistry.

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