Study Material for QuasiCrystal

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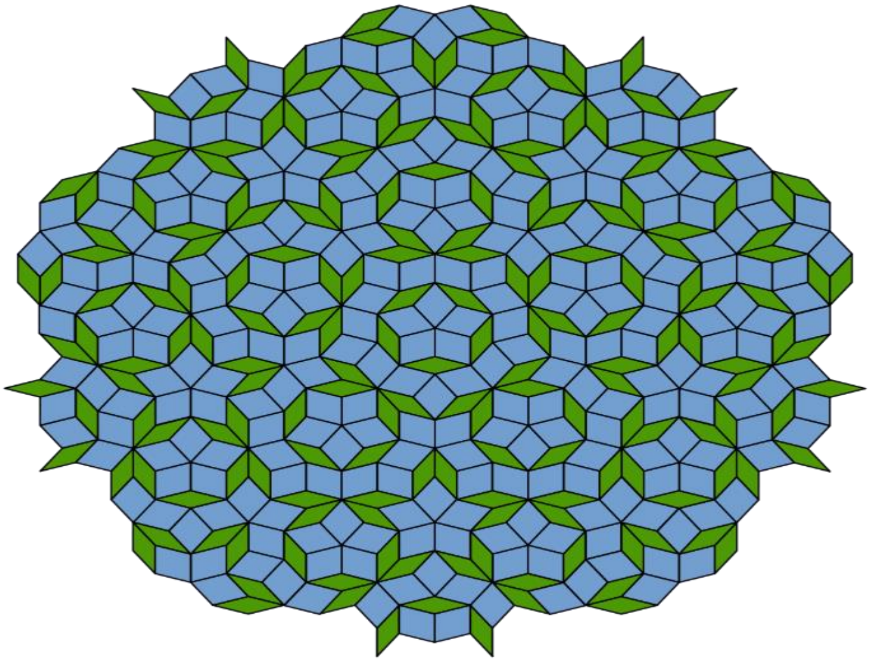
QuasiCrystal

A Q**uasicrystal**, like other crystals, contain an ordered structure, but the patterns are very fine and do not recur at precisely regular intervals.

Dan Shechtman was awarded the Nobel Prize in Chemistry in 2011 for his work on quasicrystals. His discovery of quasicrystals revealed **principle for packing of atoms and molecules.** Earlier in 2009, it was found that thin-film quasicrystals can be formed by self-assembly of uniformly shaped, nano-sized molecular units at an air-liquid interface. It was later demonstrated that those units can be not only inorganic, but also organic. In 2018, chemists from Brown University announced the successful creation of a self-constructing lattice structure based on a strangely shaped quantum dot.

Structure

Quasicrystals appear to be formed from two different structures assembled in a nonrepeating array, the three-dimensional equivalent of a tile floor made from two shapes of tile and having an orientational order but no repetition.



In other words, Quasicrystal lacks translational symmetry (that a particular translation does not change the object). in crystal structure. While crystals, according to the classical crystallographic restriction theorem, can possess only two-, three-, four-, and six-fold rotational symmetries, the Bragg diffraction pattern of quasicrystals shows sharp peaks with other symmetry orders for instance, five-fold.

When it was discovered, these structures surprised the scientific community, but now it appears that quasicrystals rank among the most common structures in alloys of **aluminium with metals like iron, cobalt, or nickel etc** [(Al-Li-Cu), (Al-Mn-Si), (Al-Ni-Co), (Al-Pd-Mn), (Al-Cu-Fe), (Al-Cu-V) etc.), but numerous other compositions are also known [(Cd-Yb), (Ti-Zr-Ni), (Zn-Mg-Ho), (Zn-Mg-Sc), (In-Ag-Yb),(Pd-U-Si) etc.).

Two types of quasicrystals are known.

- The first type, **polygonal** (dihedral) quasicrystals, have an axis of 8, 10, or 12-fold local symmetry (octagonal, decagonal, or dodecagonal quasicrystals, respectively). They are periodic along this axis and quasi-periodic in planes normal to it.
- The second type, **icosahedral** quasicrystals, are aperiodic in all directions.

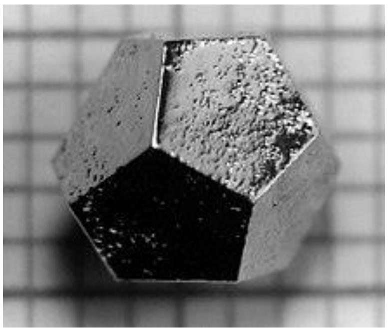


Fig:Ho-Mg-Zn dodecahedral quasicrystal formed as a pentagonal dodecahedron, the dual of the icosahedron. This quasicrystal has faces that are true regular pentagons

Quasicrystals classified on the basis of different **thermal stability**:

- Stable quasicrystals grown by slow cooling or casting with subsequent annealing.
- Metastable quasicrystals prepared by melt spinning.
- Metastable quasicrystals formed by the crystallization of the amorphous phase.

Except for the Al–Li–Cu system, all the stable quasicrystals are almost free of defects and disorder, as evidenced by X-ray and electron diffraction revealing peak widths as sharp as those of perfect crystals such as Si.

The stabilization mechanism is different for the stable and metastable quasicrystals. In spite of that, there is a common feature observed in most quasicrystal-forming liquid alloys or their undercooled liquids is a local icosahedral order. The **icosahedral order** is in equilibrium in the *liquid state* for the stable quasicrystals, whereas the icosahedral order prevails in the ***undercooled liquid state*** for the metastable quasicrystals.

A nanoscale icosahedral phase was formed in Zr-, Cu- and Hf-based bulk metallic glasses alloyed with noble metals.

Properties

Quasicrystal is known for their **high strength and light weight** and is useful in potential applications in aerospace and other industries. Most quasicrystals have ceramic-like properties including high thermal and electrical resistance, hardness and brittleness, resistance to corrosion, and non-stick properties. Many metallic quasicrystalline substances are **impractical for most applications** due to their thermal instability; the **Al-Cu-Fe** ternary system and the **Al-Cu-Fe-Cr** and **Al-Co-Fe-Cr** quaternary systems, **thermally stable up to 700 °C**, are notable exceptions.

Applications

Quasicrystalline substances have potential applications in several forms.

1. Quasicrystals (QCs) are metallic materials, but with similar properties to those of ceramic materials, such as low thermal and electrical conductivities, and high hardness. In particular, QCs that have low surface energy are commercially used as coatings to replace Polytetra-fluoroethylene **(PTFE)**, also known as Teflon, on frying pans, as they do not scratch easily.

2. QCs exhibits excellent **anti-wetting** and **anti-icing** properties and therefore appear as good candidates to be employed as **ice-phobic** coatings (anti-icing on aeroplane wings). Al-based QCs have been applied by High Velocity Oxyfuel (HVOF) thermal spray on typically used **aeronautic materials**, such as Ti and Al alloys, as well as steels. The coatings have been characterized and evaluated, including the measurement of hardness, roughness, wetting properties, ice accretion behaviour in an icing wind tunnel (IWT), and ice adhesion by a double lap shear test. The Quasicrystals coating was compared with PTFE and two polyurethane (PU)-based commercial paints, one of them known to have anti-icing properties, and the results indicate an ice accretion reduction relative to these two materials, and ice adhesion lower than **PU paint (AA6061-T6).**

3. The Nobel citation said that quasicrystals, while brittle, could reinforce steel "like armour". When Don Shechtman was asked about potential applications of quasicrystals he said that a precipitation-hardened stainless steel is produced that is strengthened by small quasicrystalline particles. It does not corrode and is extremely strong, suitable for **razor blades and surgery instruments.**

4. The small quasicrystalline particles impede the motion of dislocation in the material.
5. Bone repair and artificial limb manufacturing applications where biocompatibility, low friction and corrosion resistance are required.

6. LEDs manufacturing Industry, Diesel Engines, low friction plastic gears in transmission.

7. Solar absorbers for power conversion.

8. Broad-wavelength reflectors.

Key Words:

1. Dodecahedran: It is pentagonal dodecahedron or Polyhedron with 12 flat faces, no. of edges:30, no. of vertices:20
2. Icosahedron: Polyhedron with 20 faces. No. of edges: 30, No. of vertices: 12
3. Icosidodecahedron or Dual Polyehedron: Thirty-faced polyhedron, is a convex polyhedron with 30 rhombic faces.