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Schechtman's Discovery of Quasi-Crystal: Music of Chance/Will & Hope Testimony

Rajendra Sukhadeorao Dongre*

Department of Chemistry, RTM Nagpur University, Campus Nagpur, M.S. India

***Corresponding author:** Rajendra Sukhadeorao Dongre, Department of Chemistry, RTM Nagpur University, Campus Nagpur-440033, M.S. India, Tel: +91-8087723120, E-mail: rsdongre@hotmail.com

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Abstract

An ordered yet non-periodic make-up of pseudo-crystalline pattern continuously fills in entire existing space without invariance of an arrangement under some translation symmetry is called as quasi/quasi-periodic crystal. In 2011 Nobel Prize in Chemistry was awarded to Dan Schechtman for discovery of icosahedral phases which paved the novel pitch for quasi-periodic crystals. Indeed Schechtman discovered it in 1982, mostly altered chemist's perseverance of solid matter and met derision and doubt amid research domain for long span. Finally Schechtman's discovery was accepted in development of significant industrial and commercial materials. Quasi crystals too subsist naturally or made artificially like alloy of Al-Pd-Mn, owing quasi-crystallinity or non-episodal crystallography order with missing repeated structures. Further scientists cognize quasi-crystal at the atomic scale as the regular pattern with exactness, while never gets repeated again like an aperiodic mosaics. Schechtman observed an electron microscopy image of quasi-crystal as peculiar diffraction pattern of points/dots of light quite strange or unreported earlier. As per classical crystallographic restriction theorem crystals can hold mere two-, three-, four-, and six-fold rotational symmetries, while X-ray diffraction pattern of quasi-crystal shows sharp extra peaks five-fold as other symmetry order. Also, such patterns were incredible in usual crystallographic laws or crystal-science. Amorphous crystal own disordered and non-periodicity, but quasi crystal are ordered and non-periodicity, thus both classes differ from well-ordered and well periodic crystalline materials.

Keywords: Shechtman; Quasi/Quasi-Periodic Crystal; Order; Rotational-Translational Symmetry

Introduction

Since modern crystallography natal in 1912, crystalline solid's X-ray diffraction was absolutely known for periodic ordered array, but 70 years later in 1982, science relied on non-fundamental view that atoms are even arranged in non-periodic order-ness for quasi-crystal [1]. Non-periodic pattern in quasi-crystal not repeat over during lattice-growth and such anomaly edicts another dynamic property as is comprised of "tiles" having higher order rotational symmetry [2]. If the rudimentary make-up of quasi-crystal is rotated, it appears dissimilar. Crystallography resolute five viable rotational symmetries in quasi-crystal namely: single symmetry, double, triangular, quadruple and hexagonal. There is no pentagonal symmetry in usual crystals because of no- generacy of periodic order while quasi-crystal indeed displays all of retaining rotational but no translational symmetry [3]. In 1982 Schechtman observed ten microscopic points in the X-ray pattern of Al-Mg alloy quasi-crystal seemed through presence of pentagonal-rotational symmetry owing no-periodicity. This Nobel prize study had discovered novel crystal domain, where solid crystal exists but without order pattern and recognized quite a new fact trickled in, but not known why and what it's indeed. [4]

So raised novel solid owing pentagonal symmetry as incredible material as per crystallography laws. Soon, Schechtman buoyantly established a model to ascertain the occurrence of pentagonal symmetry as one of the rotational symmetries of 3-D icosahedron: object due for 20 matching equilateral triangular faces [5]. This quasi-crystalline make up with pentagonal rotational symmetry and total icosahedral symmetry claimed ultimate changes till known all the views about crystals. Scientific paradigms get replaced and accepted this pentagonal symmetric quasi- periodic crystal and brought revolutions in structure/crystallographic aspects of solid.

The music of chance

Quasi-crystal's discovery and recognition by Schechtman embroils providence, proficiency and purpose besides like many scientific revolutions, truly defines entire finding as a chemistry of such properties [6]. As the music of chance it set a classic model of a test of spirit and hope of coincident. Science, formerly understood to be rudimentary and closed, like what a crystal is, together put new query as how the non-periodicity governs the features of quasi-crystal material. This pentagonal rotational symmetry is found inconsistent with periodicity of crystals [5-7]. This discovery thrusts non-applied materials like alloys owing non-applicable concentrations for making assorted 1-D, 2-D and 3-D quasi/quasi-periodic crystals. Based on atomic ordered quasi- crystals are considered as one of the three basic phases of matter today [8].

Chemistry of two/three dimensional quasi-crystals found unfit as per certain logical terms of crystallography laws, hitherto, scientific-world was entirely unprepared for the findings of Dan Schechtman as such aperiodicity could truly subsists too in solids/matters. In fact quasi-crystals, discovery emphasized a case of how science should be conducted [9]. As such this new quasi-structure was supposed incredible, also provoked controversy amid crystallographic scientists [10].

Quasi-crystal is quite an attractive aspect of chemical and material science as it broke all the rules of being a crystal at all. Truly Schechtman faced nasty conflicts, also fought against orthodox scientific communities to persuade and to prove what had been seen in X-ray diffraction of quasi-crystals besides about its discovery in 1982 [11]. For a long period, Schechtman was "ridiculed" and "treated wickedly" by peers and recounts.

Nobel laureate Israeli scientists Schechtman, had obtained quasi-crystals of Al-Mg through rapidly cooling of molten squirting mixture of metallic alloy onto a cool surface [4,7]. The product yielded i.e., molten metal "grate" was further analyzed by an electron microscope to see how the electron-wave gets deflected by the quasi-metals/atoms via X-ray diffraction pattern. In electron-microscopy, Schechtman had observed odd forms of new ordered, yet non-periodic quasi-crystal much discrete than ordered-periodic poly-crystal as shown in Figure-1 below.

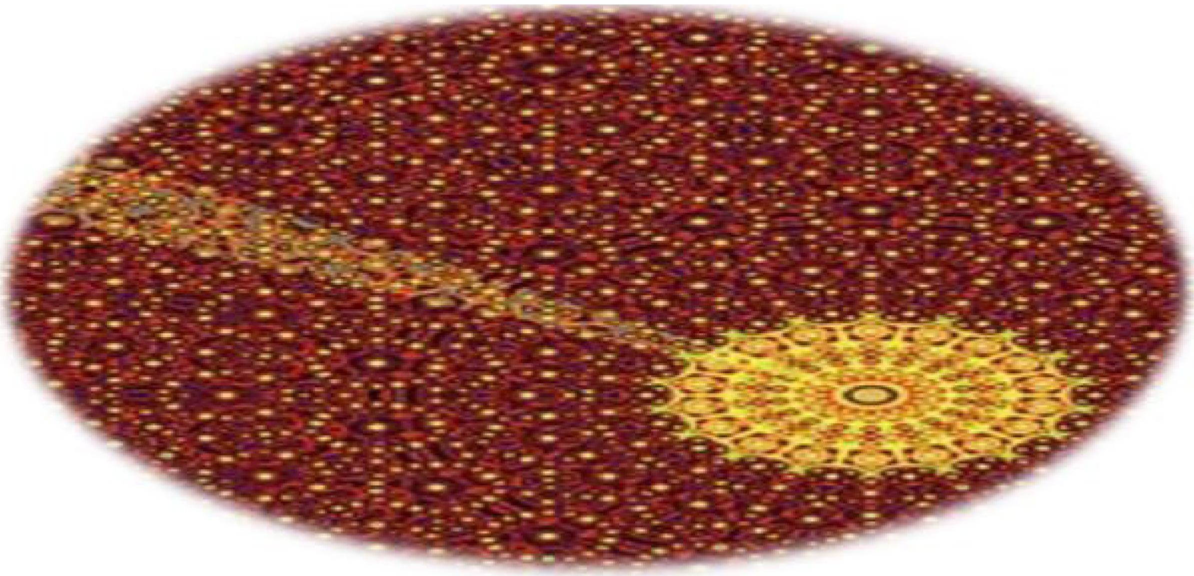

Figure 1: First spied by Schechtman in 1982, the "forbidden symmetry" of quasi-crystals

Once discovered, this research was dejected by most global scientists, so Schechtman cried and said in Hebrew *"Eyn chaya kazo"* means *"there can be no such creature/matter"* [4,12]. As this finding was in contradiction to the grain/crystal chemistry, Schechtman recounted in an interview with Technion that "The head of lab came to smiling sheepishly and put a book on desk and said: 'Danny, why don't read this and see that it's impossible what you are saying,' Later Schechtman was mortified to lab-groups and advised to leave the research-laboratory, so while returning to motherland, he had published this result and exclaimed "Then all hell-broke loose." Many worldwide experts were skeptical with Schechtman's research, and to his dying day, Linus Pauling, American Chemical Society's (ACS) head said that Shechtman was "talking nonsense"[13-15]. While, Bassam Shakhashiri, president of ACS's spoke to BBC and said: "This is how we make progress in science," [if] someone comes up with a discovery that we are skeptical about, we [have to] take time to verify the observations and discuss the conclusions amid ourselves: this is a really great example of the triumph of science". He further said it's an opportunity for all, who are curious about nature, must be vigilant and careful besides should engage in respectful debate about the interpretation of such results [12]. It's 'Quite a beautiful' justified homage to Shechtman by Bassam Shakhashiri, president of ACS's on the behalf of so called logical or must say illogical global researchers of that era. Typical irregular shapes, akin to Schechtman's experimental quasi-crystal image were also found in Spain's Alhambra Palace primitive Islamic mosaic-tiles lined on walls and floors as regular with designed rules, yet too no repetitions. Following the Shechtman's discovery, till date other kinds of quasi-periodic crystals are prepared artificially and also observed naturally e.g., Russian river containing minerals [16].

Thrust to material and science: Subsequent unique discovery by Dan Schechtman, numerous quasi-crystals are prepared testified and applied to offer myriad benefits in advanced S&T[17]. Quasi-crystals are established regularly in aluminum alloys such as Al-Li-Cu, Al-Mn-Si, Al-Ni- Co, Al-Pd-Mn, Al-Cu-Fe, Al-Cu-V, etc[18]. Likewise many composites are recognized with quasi-crystals growth like Cd-Yb, Ti-Zr-Ni, Zn-Mg-Ho, Zn-Mg-Sc, In-Ag-Yb, Pd-U-Si, etc [19]. Maximum quasi-crystals display ceramic-like features such as huge thermal/electrical resistance, rigidity and fragility, anti-corrosion, and non-stickiness [20]. Several metal based quasi-crystals are useless by virtue of thermal flux for wide range applicability. While ternary and quaternary alloys appear as prominent exceptions including Al-Cu-Fe, Al-Cu-Fe-Cr and Al-Co-Fe-Cr systems found thermally much stable even up to 700 °C [17, 21,22].

Characteristics of Quasi-crystals: The characteristics of quasi-crystals are mentioned below: There exists two types of quasi-crystal, first as polygonal (dihedral) family holding axial periodic along with planer quasi-periodic patterns like 8-fold/octagonal, 10-fold/decagonal and 12-fold/dodecagonal in local symmetries, while second as icosahedral family owing aperiodic pattern in all directions. These quasi-crystals offer three sets of distinct heat/thermal stability as: [18-22]

- Stable quasi-crystal as pre-casted via slow cooling/casting with consequent hardening,

- Meta-stable quasi-crystals as molded by melt-spinning processing, and
- Meta-stable quasi-crystals as shaped through crystallizing the amorphous phases. Excluding Al–Li–Cu alloys, all the stable quasi-crystals are virtually free of crystal-defects and disorder. X-ray and electron-diffraction arrays of quasi-crystals have shown the peak-widths as sharp as perfect crystal like Silicon, besides diffraction patterns reveal 2-fold, 3-fold, and 5-fold local rotational symmetries, and reflections are arranged quasi-periodically in 3-D [22-24].

The basis of the stabilization is distinct for the stable and metastable quasi-crystals, yet, through local icosahedral order there exists common feature in maximum cases like liquid/molten-alloys or under-cool liquids [26]. By the way icosahedral order is balanced in the liquid/molten phase for stable quasi-crystal, however gets prominent in the under-cool liquid/molten state for metastable quasi-crystal. Likewise nano-icosahedral order is also obtained in Zr-/Cu/Hf-based bulky metal based-glass on alloying with noble metals [27].

Densities of quasi-crystals own no such local rotational symmetries, e.g., if 2D quasi-crystals hold more than solo point, about an n-fold rotation (n>2) conveys a good coincidence with it so as to be inevitably periodic in nature. If a quasi-crystal own just a single point of "exact" 5-fold symmetry, on a definite chunk cannot ever find that single point, thus by crystal symmetry rule not trust on the criterion of "*invariance to within a translation*"[28]. Yet, definite rotations can be applied to such quasi-crystal to yield into one which is alike to an original un-rotated crystal.

Quasi-crystals uses: Quasi-crystal structures rise as hard, non-sticky owing poor electrical and heat/thermal conductance thus, are used for coatings frying pans and insulating electric wires [29-30]. Quasi-crystals found in the toughest steel based razor blade and surgical ultra-fine spike/needles [31]. Quasi-crystalline metallic coats are done by plasma/magnetron sputtering to impart remarkable ductile strain/pelt onto frying pans to be operative in high temperature conditions [32]. Certain quasi-crystals implant plastics appear robust, hard-wearing, low-friction gears, low thermal conductive apt for heat insulating coatings [33]. This uniquely discovered ico- sahedrite being the 1st quasi-crystal establish in nature, was great significant, although its inventor Daniel Schechtman saw no practical applications.

Conclusion

Quasi-crystals is a greatest discovery with impending uses way from LED to amended diesel engines. Shechtman's quasi-crystals have extensively augmented the mechanical features of engineered materials, thus set totally novel outlets of structural and crystallography sciences.

"If any moral are taking from the research outcome of Nobel laureate Daniel Schechtman is that not to underrate or misjudge the imagination or competency of nature and research of anyone, apparently howsoever absurd and whatever crude results may/may not be."

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