EDAGAWA LAB.

[Order in Atomic Arrangement and Physical Properties of Solids]

Integrated Research Center for Sustainable Energy and Materials

Mechanical Properties of Materials

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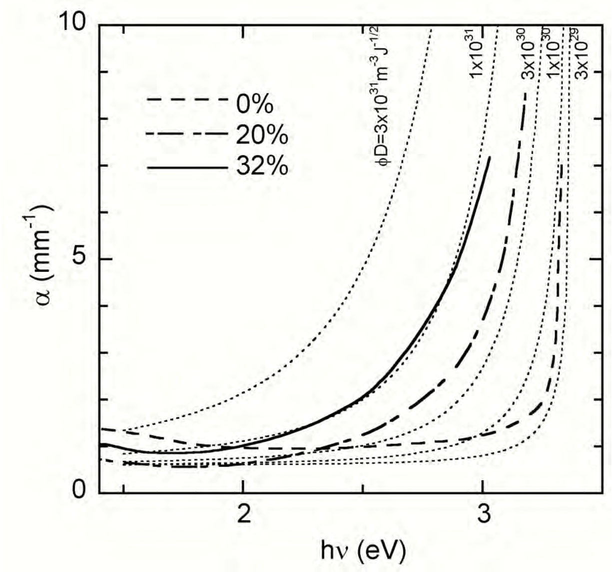
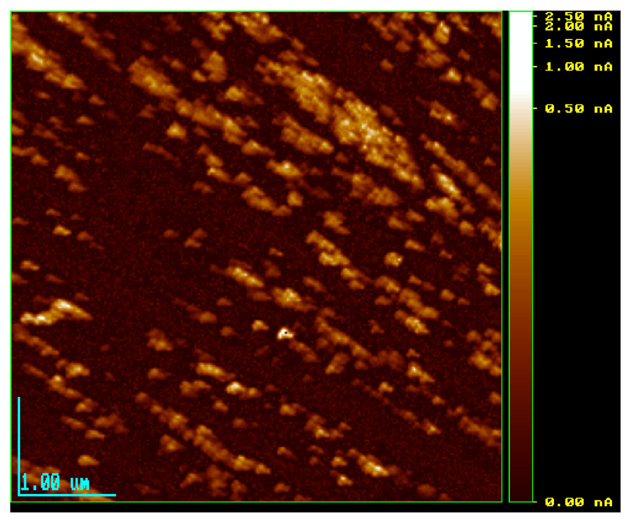
If we look into solids microscopically, we find that atoms are arranged in some ordered manner. Microscopic structures in solids can be classified in view of the atomic order into three groups: periodic structures (crystals), quasiperiodic structures (quasicrystals) and amorphous structures. Such atomic orders often determine the macroscopic properties of solids. We aim at elucidating the relation between the microscopic structure and macroscopic physical properties of solids, and also at developing new materials with desirable properties using the information obtained through such studies.

Photonic and Electronic Properties of Dislocations in Semiconductors

The local electronic behavior may change due to existence of dislocations which are a kind of disturbance in atomic arrangement induced by plastic deformation. We observed some related phenomena such as conductive spots on the surface of semiconductors and the shifts in optical absorption edge.



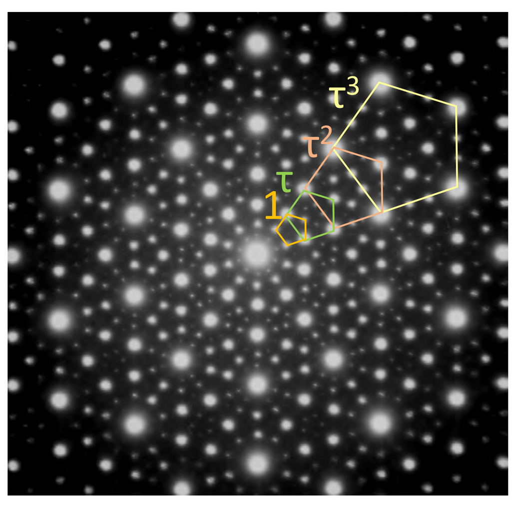
Change in optical absorption spectra by plastic deformation



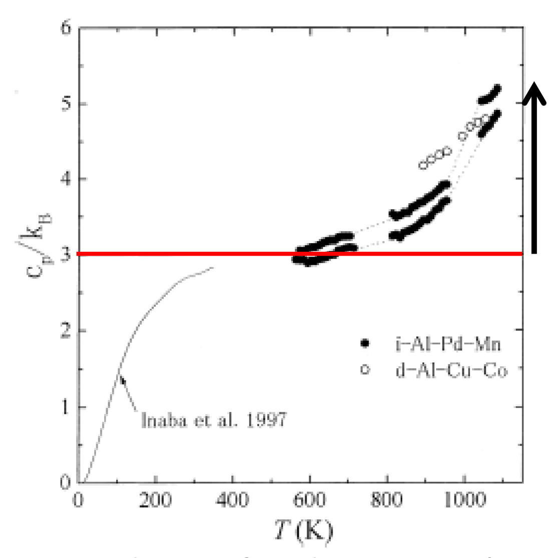
Conductive spots on surface of GaN introduced by plastic deformation

Physical Properties Inherent to Quasicrystals

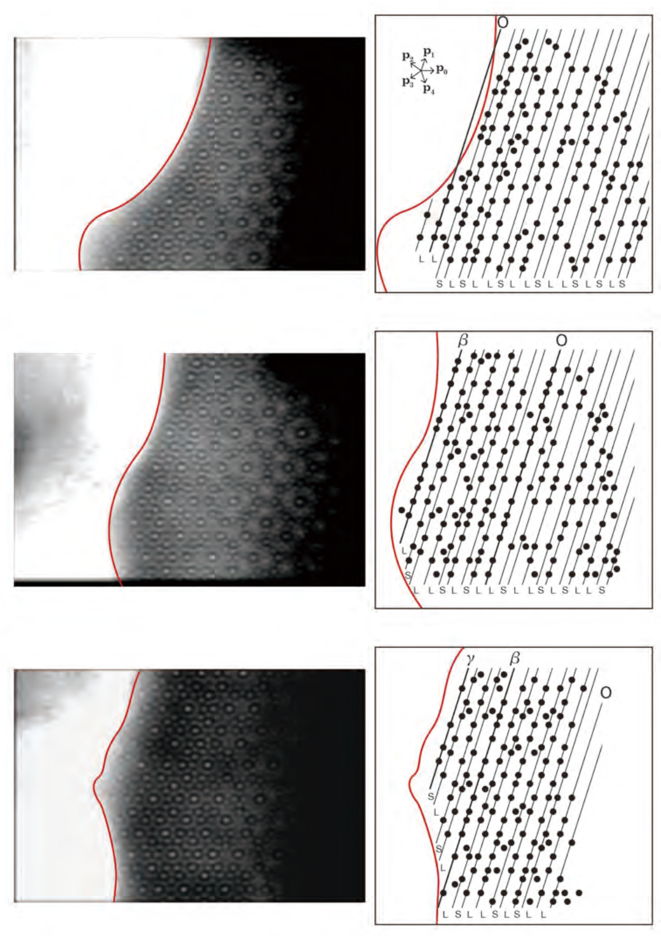
Quasicrystals, which have both the long-range order of the atomic arrangement and the rotational symmetry that is unallowable for crystals, show some unique properties. We observed the anomalous increase of specific heat at high temperature.
Also, the growing mechanism of quasicrystals is still unknown because their structure is not described by the simple repetition of a unit cell. Our high-temperature in-situ HRTEM observation showed the dynamic process of quasicrystal growth under a specific condition.



Electron diffraction pattern of Al-Cu-Fe icosahedral quasicrystal with the incident beam parallel to a fivefold axis



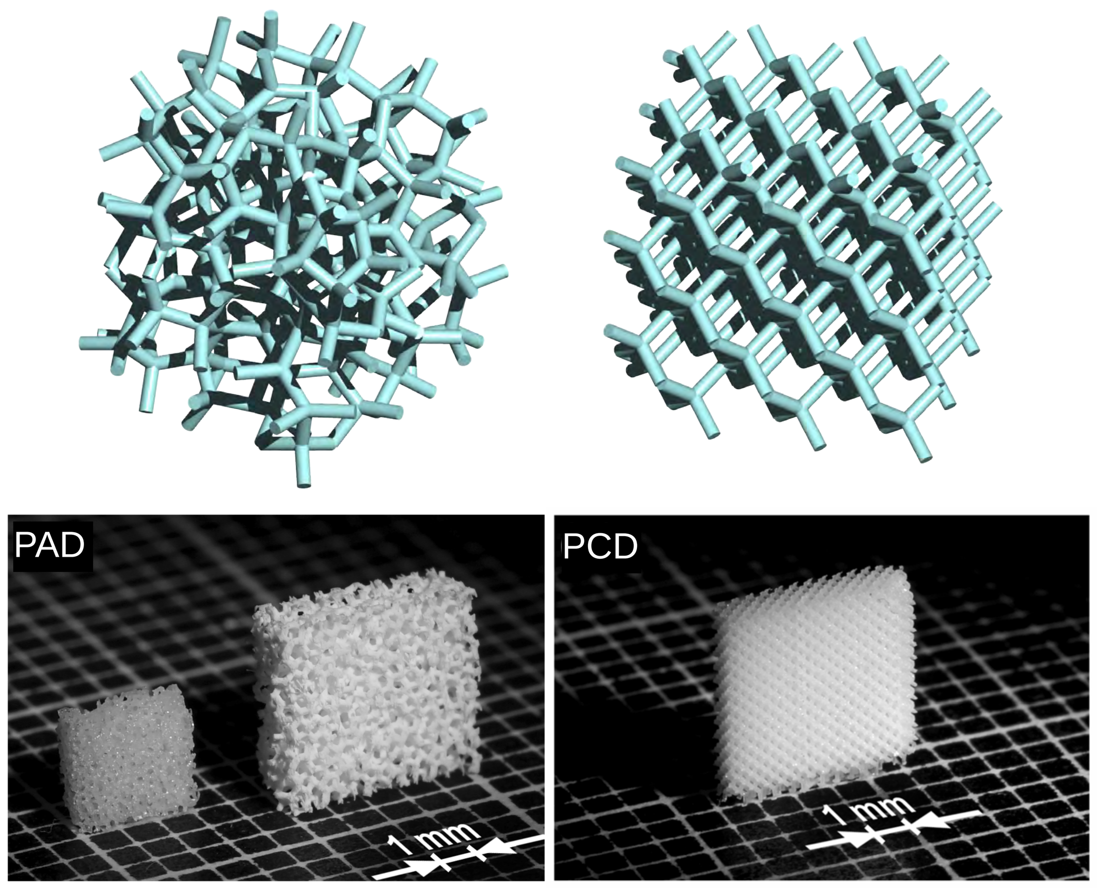
Braking of Dulong-Petit's law in high-temperature specific heat



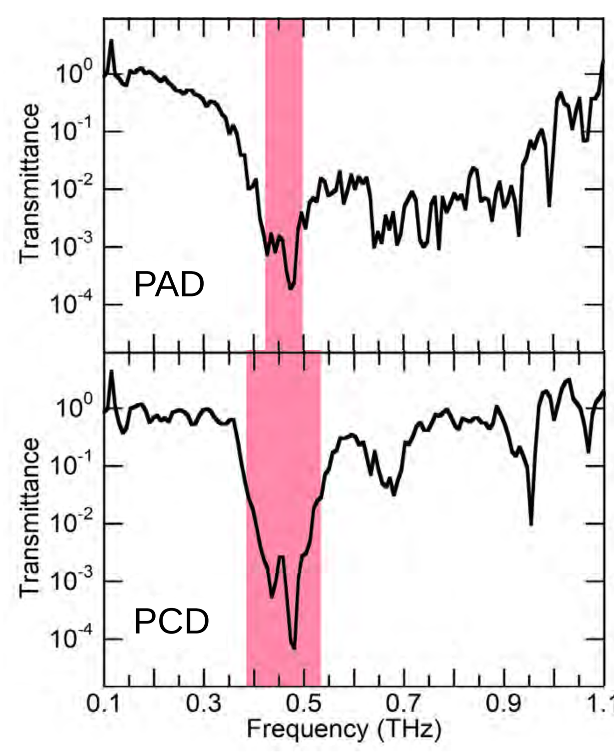
In-situ TEM observation of Al-Ni-Co icosahedral quasicrystal growth

Development of Random Network Photonic Devices

In an artificial structure of dielectrics designed in a suitable manner, it is known that the electric wave in a certain wavelength region cannot propagate. Such region as known as 'photonic band gap' arises for the analogical mechanism of electric band gap arising in an ordered atomic arrangement. Although it was thought that only periodic structures shows those property, our laboratory showed that the same phenomena can be realized even in a certain type of amorphous structure.
We fabricated the specimens for millimeter- and terahertz-wave regime by the 3-D manufacturing and sintering technique, and observed a large drop in the transmittance spectrum at corresponding region to the photonic band gap.



(Upper) structural models expected to have photonic band gap. (Lower) fabricated photonic structures in a terahertz regime. (Left) amorphous structure and (right) crystalline structure, respectively.



Measured electric wave transmittance spectra in terahertz regime of fabricated (upper) amorphous structure and (lower) crystalline structure.