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Review on Distinct Techniques of Several Crystal Growth Methods

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ABSTRACT

Precise review of crystal growth and various techniques are mentioned in order to grow a single crystal from the state of saturation to nucleation.

The basic principle is to accomplish the state of nucleation from saturated solution followed by the combinations of atoms in definite manner with specific reactions results in the formation of single crystals and the method employed to grow a material depends on the characteristics of material

Keywords: Crystal Growth, crystal growth techniques

I. INTRODUCTION

In this modern era, Crystals has become the spine support of modern technology which has magnetized human beings since pre historic age with their beauty and rareness. But the real study has been seen on the large scale based upon applications for devices and in nonlinear optics.[1]

Crystal growth is highly bounded subject with the binded hands of crystallographers, process engineers, material scientist, physicist, chemist and biologist. Prior, the study of crystal growth was dependable on natural bases but day to day improvement in research has popped up the physiochemical environment of crystals with its vast or wide range of applicability in the field of photonics, optoelectronics, optical fiber communication system, nonlinear optical devices.[2]

Crystal growth is the process of arranging atoms, ions, molecules or molecular assemblies in a periodic arrangement and it is one of the most important branches of material science which leads technological materials of different sizes which covers up the crystals from bulk to nano size crystals.[3]

Its main aim is to grow a desired single crystal with perfection in shape and size for nonlinear optical applications by analyzing their pure quality throughout characterizations.[4]. Advance research in crystal growth techniques and characterization has handed us large number of technologically important single crystals in different varieties.[5]

II. THEORY OF CRYSTAL GROWTH

Crossing the several phases of solid, liquid and gaseous state, a solid-state transformation of crystal is seen with exception for certain metals and metal alloys at the other hand liquid to solid and gaseous to solid plays a keen role in the formation of crystal growth which is step froth with three stages [6]

- To be at the achieving state of supersaturation

- Nucleation
- Growing nuclei to single crystal of different phases.

During crystal growth the steady temperature is to be maintained at the supersaturation to form the best quality of crystal. whereas nucleation is the powerhouse for the crystal growth which leads to cell formation of crystal to the high quality of its crystal nature. which is studied till now by the various scientist. Thus, nucleation is very important for crystallization process [7].

III. CRYSTAL GROWTH TECHNIQUES:

crystal growth is known as interdisciplinary subjects which binds different branches and thus its difficult to review such a vast subject in this paper still some of the important techniques are reviewed below:

1. Solution growth
2. crystal growth from melt
3. crystal growth from vapor
4. Solid Growth

the technique uses to grow a crystal material depends on the characteristics of material like melting point, Volatile nature, solubility in water or other organic solvents.

1. SOLUTION GROWTH

The process of growth material has moderate to high solubility in temperature range ambient to 100°C temperatures. Further it is divided into

A. Low temperature solution growth method.
B. High temperature solution growth method.
C. Hydro Thermal growth method.
D. Gel Growth method.

A) LOW TEMPERATURE SOLUTION GROWTH:

low temperature solution growth further has trios of methods which consist of Slow cooling method, Solvent Evaporation method and Temperature Gradient method.

- **SLOW COOLING METHOD:** at the room temperature, a saturated solution is poured and sealed up thermally. After suspension of seed crystal in solution, crystallizer is kept in water thermostat. The temperature is reduced according to pre assigned plan which shows the large single crystals [8].
- **SOLVENT EVAPORATION METHOD:** here the difference between the rate of evaporation of solvent and solute established the excess of given solute. As compared to cooling method where total mass of the system remains constant in this method, the loose particles are seen in the solution which further weekly bound to other components due to which the volume of solution decreases. This is one of the oldest method of crystal growth which is technically very simple but consume much more time [9].
- **TEMPERATURE GRADIENT METHOD:** here maintenance of temperature plays a crucial role in the formation of crystal where a transport of material forms a hot region containing the source of material to be grown to a cooler region in supersaturated solution which results in the growth of crystals. Minute variation in the temperature between the source and crystal show larger effect on crystal growth [10].

B) HIGH TEMPERATURE SOLUTION GROWTH METHOD:

The most widely used high temperature solution growth is the flux growth. In this method, the constituent of the material which is to be crystalized are dissolved in suitable solvent and crystallization occurs as soon as the solution becomes supersaturated [11].

C) HYDRO THERMAL GROWTH METHOD:

In this method, growth is carried out in steel autoclave with gold and silver lining. The concentration gradient required for the growth is provided by the temperature difference 10°C to 100°C between the nutrients and growth areas. Materials like antimony, alumina, barium titanates, diamond can be grown with this method [12].

D) GEL GROWTH METHOD

The importance of gel growth and it's application is seen broadly due to it's simple and effective techniques for crystal growth as compared to others. Here, it is also seen in the study of medical science. the gel method has helped them for the study of crystal formed in urinary calculi and rheumatic disease, cholesterol stores.[13].

Gel obtained from physical process such as cooling is called physical gel such as clay and gelatin. Whereas gel formed by chemical reaction such as polymerization or hydrolysis are called chemical gels e.g., silica and polyacrylamide

In this method, the absence of convection is seen.

2. CRYSTAL GROWTH FROM THE MELT

Melt growth is the most important method of crystal growth which is commercial. Here, the pure material derived from recrystallization of fusion and re solidification

This method is popularly used for the crystal growth. The study seems that most of the technological crystals are recently obtained through this technique only. The selection of material must exhibit less chemical activity with no polymorphic transition and should melt without decomposition. The notable point is chemical reaction can disturb the stoichiometry of the crystal in the melt which has shown its physical and chemical defects. The main thermodynamic and kinetic principles are considered as driving forces for the generation of defects and incorporation, respectively. Futher, it can be classified into the techniques given below

A) VERNUIL METHOD: The finely powdered starting material is placed in a container within a Verneuil furnace with it's opening at the bottom.

When the container is vibrated, the powder can escape through it where oxygen is supplied into the furnace and travels down the powder in narrow tube which is located within large tube through which hydrogen is supplied and here the combustion occurs with a flame of suitable temperature at its core. When the powder passes through the flame, small droplets forms due to melting which when fall on onto an earthen support rod. It forms a sinter cone on the rod. the tip of which is close enough to the core to
remain liquid and here at this peak point, the seed crystal eventually forms. As more droplets falls on to the tip, a single crystal, called a boule starts to form and support to move downward slowly allowing it to crystallize [14].

B) CZOCHRALSKI METHOD: In this method, the charge is melted at constant temperature slightly above the melting point which is used to grow large single crystal which are seen in semiconductor industry [15]. Here is no direct contact between the crucible wall and crystal which is most beneficial for the production of single unstressed crystals. It is not suitable for incongruent melting compound. The need for such a seed

crystal of similar composition limits is used as a tool for exploratory synthetic research [16].

C) **KYROPOULOS TECHNIQUE:** Here the crystal growth is seen in larger diameter. In this process, continuously heat removing is done by controlling the furnace temperature for proper growth of crystal [17]. It is very much useful for lenses, prism and other different optical components [18]

D) **SKULL MELTING:** This process is used for high melting point materials which are most widely accepted such as diamond imitation

Skull melting process is a technique suitable for the growth of high-temperature crystals by radio frequency (RF) heating the raw materials and forming a thin skull around the outside of the melt as a crucible. The process is crucible less. a thin skull separates the molten mass from the water-cooled container [19]. Thus, contamination problems or exsolution processes associated with contact between melts and hot crucibles are avoided [20].

E) **ZONE MELTING:** This is a technique of purification by melt crystallization. It is a crucial way for the evolution of transistors. It also known as Zone refining and it can be applied to the purification of those material which can be melted and solidified such as elements, organic and inorganic compounds [21]. In order to attain high purity, it is usually combined with other techniques due to non-agreeable impurities of solid liquid phases [22].

F) **BRIDGMANN METHOD:** There are two similar methods used to grow single crystals on a controlled temperature gradient surroundings are Bridgman and Stock Barger methods. The gradient can be accommodated by varying the temperature of the system. Single crystals developed from these techniques is adapted in many electronic devices [23].

In both methods, a polycrystalline material is heated above its melting point in the hot zone of an oven. The crystals can be grown in both vertical and horizontal orientation. slightly different cooling systems is only the deviation between them. Stockbarger method is in fact a modification of the Bridgman method [24].

3. CRYSTAL GROWTH FROM VAPOUR

Vapour growth technique is well known for the formation of bulky crystals. Crystals of diamonds, silicon, gas, semiconductor compounds can be grown by this method [25]. This vapour growth method has further divided into physical transport method and Chemical transport method [26].

A) **PHYSICAL TRANSPORT METHOD:** In this method with a moving gas stream or either in vacuum (Zns and Cds) are widely grown. It involves direct transport of materials from hot source zone to a cool region with sublimation or evaporation

B) **CHEMICAL TRANSPORT METHOD:** Here, the transportation of chemical compound is seen which decompose in the growth area. The temperature either hotter or cooler is based upon the nature of reaction involved.

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