8.1 Summary of the Work

The study of materials science has catered the need for new materials with specific properties and has aided in exploring the characteristic properties of certain materials that finds application in day-to-day life. Many such materials that require such extensive study are found to mineralize in biological systems. This mineralization often leads to crystallization resulting in serious pathological disorders. Of the various biological crystallization mechanisms, formation of crystalline components within urinary systems has attracted considerable attention worldwide due to the large increase in the number of cases reported day by day. The technical advancement in the treatment of the disease does not throw much light on the formation mechanisms of these crystals. The objective of the present investigation was three-fold. The first was to identify the materials that crystallize within the human urinary system and optimize the growth parameters. The second was to characterize these crystals whereby the classification of these crystalline constituents was possible often aiding in the identification of these materials and the third was to study the
specific properties of these grown crystals like thermal properties, mechanical strength, electrical properties and microwave absorption.

The gel method was very effective to grow urinary crystals for in-vitro studies. The simplicity of the method and its close resemblance to growth in biological systems is an added advantage of the method. A day-to-day observation of the growth rate and growth patterns is possible using gel technique. The growth kinetics of the five major types of urinary calculi namely whewellites, brushites, struvites, uric acid and cystine were studied in detail. The optimized parameters under which the crystals grow are elucidated.

Micro topographical studies were carried out on the crystals using optical microscope and scanning electron microscope. The results show that the crystals grow by a two-dimensional spreading and piling up of layers. Small crystallites bunch up to form an irregular agglomeration of the crystals. Screw dislocation plays a significant role on the growth of these crystals. The morphologies of these crystals closely resemble the pathological stones.

The crystalline nature of the grown samples were confirmed by the X-Ray powder diffraction analysis. A perfect match between the observed d values and the standard d values are obtained from JCPDS charts. The different planes of the crystals were indexed. The vibration of the different bonds and the presence of hydrated water molecules were confirmed by the FT-IR and Raman analysis. These vibrational data are the standards to assess the constituents of the particular type of urinary stone procured by the patients.

The thermogravimetry and differential thermal analysis of the samples reveal the thermal stability of these samples. A perfect match between the theoretical predicted and experimentally observed mass loss was obtained. The different decomposition stages were designated. Brushites, struvites and cystine undergo a two-stage decomposition pattern whereas whewellites alone has a three-stage decomposition.
Uric acid has mono stage decomposition. The activation energy and order of reaction were determined using the Coats-Redfern method. Since cystine and uric acid are pure organic compounds, carbon is obtained as end product. Calcium oxide is the end product obtained in the decomposition of whewellites. Pyrophosphate derivatives are obtained as the end products for brushites and struvites.

The micro hardness of the grown crystals varies with the applied load. Micro hardness of the crystal is a measure of the strength the crystal can withstand and it stumbles the easy removal of the crystals from human body by shockwave lithotripsy. Whewellites, brushites and struvites show an increase in micro hardness in the low load region and attain a constant value in the high load region. For uric acid and cystine there is a decrease in micro hardness with applied load in the low load region and it attains a constant value in the high load region. The load independent micro hardness values obtained is a measure of the first order elastic constant of the crystal. The influence of inorganic species like nickel, cadmium, lead, and magnesium on the crystals of brushites and struvites were investigated. These materials often enter the body as natural pollutants and from food intake. The micro hardness of these doped crystals show considerable variation from the corresponding pure species.

The electrical properties of the crystals were studied in detail in the frequency range 100kHz to 3MHz and in temperatures ranging room temperature to 120°C. Dielectric parameters like conductivity, loss, permittivity and their variations with temperature and frequency were studied in detail. The frequency and temperature dependence of the dielectric parameters were different for different crystals and throws light on the polarization mechanisms in these crystals.

The dielectric properties of these crystals were studied at microwave frequencies in the S-band. A comparative evaluation of the dielectric properties of the natural samples and the grown crystals were obtained. Natural samples were procured from the patients who had
undergone stone removal in nearby hospital. These samples were characterized and pre-treated. Within the limits of the experimental error a one to one correspondence between the grown and natural samples were obtained. The aim of this study was to pre-determine the dielectric properties of these different types of urinary crystals. This could pave way for identification of these crystals within the biological system using microwave tomography. This could enable the specific treatment for the specific type of stone procured. The water inclusion within the crystal could be pre-estimated.

8.2 Scope for Further Work

Only individual crystals were studied in these cases. Studies have revealed that the layered overgrowth of these crystals can take place and the growth parameters of the overgrowth of the crystals can open new windows for the studies on mixed urinary crystals. The magnetic properties of these crystals could be investigated and if suitable magnetic properties were obtained magnetic therapy can be used as another cure method for the disease. Second harmonic generation effect of these crystals is another area, which could be investigated in detail. The influence of the extract of the medicinal herbs on the different crystalline materials will be useful in devising new natural drugs for treatment. The influence of the epidemiological factors like sex, dietary, working atmosphere, geographical location, age, etc. of different patients could give more information regarding the growth of these crystals.