ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 11
Special Issue
3/2011

117 – 120

21/3

Comparison of uroliths and gallstones crystallization with metal crystallization

L. Klimek
Division of Materials Investigation, Technical University of Łodz, Stefanowskiego 1/15, 90-924 Łodz, Poland
Division of Restorative Dentistry, Medical University of Lodz, ul. Pomorska 251, 92-312 Lodz, Poland
Corresponding author. E-mail address: leszek.klimek@p.lodz.pl

Received 25.07.2011; accepted in revised form 27.07.2011

Abstract

The human organism creates different deposits in the form of minerals which play an important role in its functioning. Some of them located mainly in blood vessels, kidneys and urinary tracts, biliary tracts, salivary, pancreatic, new growths etc. have a determinately negative effect. Recognition of these minerals, getting to know the conditions in which they grow and first of all the processes of their appearance have a primary meaning in the possibility of prevention of their crystallization. The work shows the results of microscopic and diffractometric tests of uroliths and gallstones. On the basis of this research it is possible to state that there is a certain analogy in the crystallization process of these deposits with crystallization of metals. As far as the process of nucleation is concerned, only heterogenic nucleation takes place. But in the process of growth faced crystals and non-faced crystals appear. Thus, it can be assumed that there are some analogies in the process of metal crystallization with the crystallization of deposits in the human body.

Keywords: Uroliths, Gallstones, Crystallization, Nucleation

1. Introduction

The human body creates different kinds of minerals and in large quantities. They play an important role in its functioning. They can be divided into two groups:

a) essential for the organism,
b) disadvantageous or sometimes dangerous.

Minerals of the first group usually found rather in bones and teeth and are the most important stock of elements for the human. The second group includes different deposits located mainly in blood vessels, kidneys and urinary tracts, biliary, salivary and pancreatic tracts, new growths etc. Recognition of these minerals, getting to know the conditions in which they grow and first of all the processes of their appearance have a primary meaning in the possibility of prevention of their crystallization.

In the process of crystalline growth there is a period of nucleation and the period of crystal growth, that is crystallization.

The first stage is crystal nucleation. Taking into account complexity of the deposits present in the organism it seems that the process of their nucleation is heterogeneous. For example, gallstones are usually cholesterol stones. However, the research on the phase composition by x-ray diffraction method showed that in the external layers only cholesterol appears (fig. 1), although inside the stone there is calcium carbonate in the form of calcite (fig. 2).

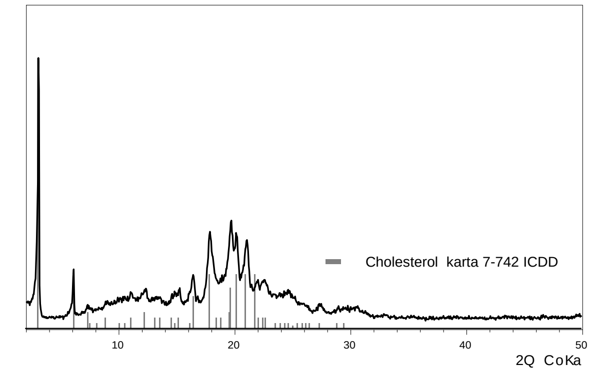


Fig. 1. Gallstone diffractogram – external layer

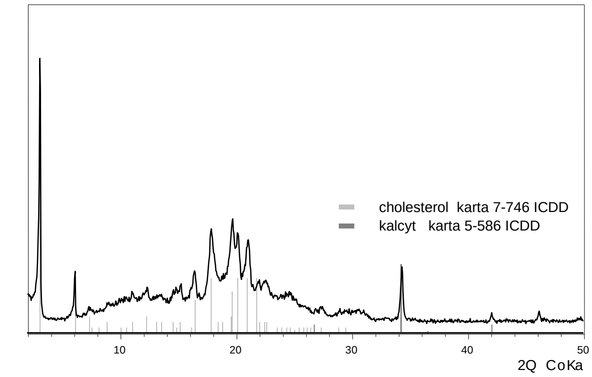


Fig. 2. Gallstone diffractogram – stone core

Some information appears in scientific sources that there are other components, for example, Xia [1] stated the presence of magnetite, pyrite and gypsum as well as zinc and aluminum, Lin and others [2] in the internal layer stated the presence of calcium, magnesium, iron, cobalt, zinc, potassium and chlorine. Been and others [3] additionally found tin and copper, though Moesch and co-authors – the presence of medicines [4]. As all these components were present only in the internal layer it can be supposed that they can be the nucleus of crystallization. In pathogenesis of urolithiasis the attention is paid to the influence of foreign matters (for instance, the urine proteins, organic matrix) on the uroliths crystallization [5]. As a support for the heterogenic thesis of uroliths nucleation it is possible to exemplify the fact of their appearance in the urine system in the catheter for a short time (fig. 3)

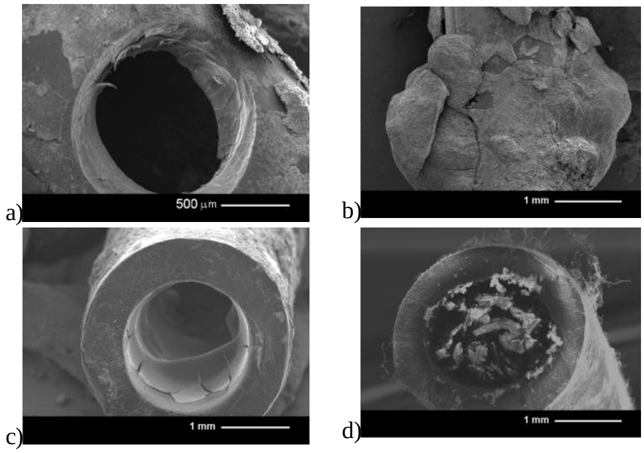


Fig. 3. Crystallization of the uroliths on the catheters
a) the surface of the catheter covered with relatively thin layer of urolith, b) large deposits of the urolith on the urethra's surface, c) urethral stricture, d)almost complete obstruction of the urethral lumen by the urolith

A spectacular confirmation of heterogenic nucleation in the urinary system is the case when a struvite-apatite stone appears on the urinary bladder raphe (ryc. 4)

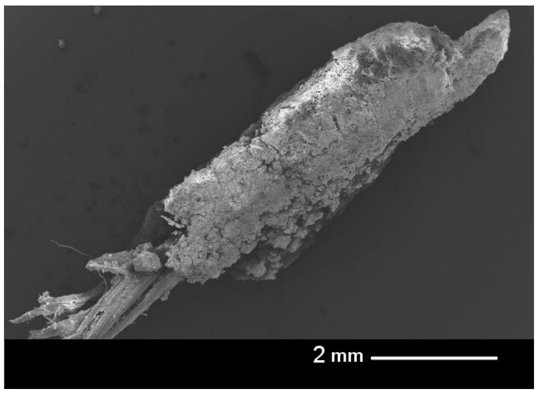


Fig. 4. The picture of the stone appearing on the urinary bladder raphe

After the crystals nucleation their growth takes place. Crystal growth as an atomic process is made up of atoms connection to the nuclei (of the solid phase) on the border of the liquid – solid phase. The topography of the border is determined by entropy of plastic melting [6]. The dimension which enables estimating face crystallization topography is the proportion

$$\Delta S/k$$

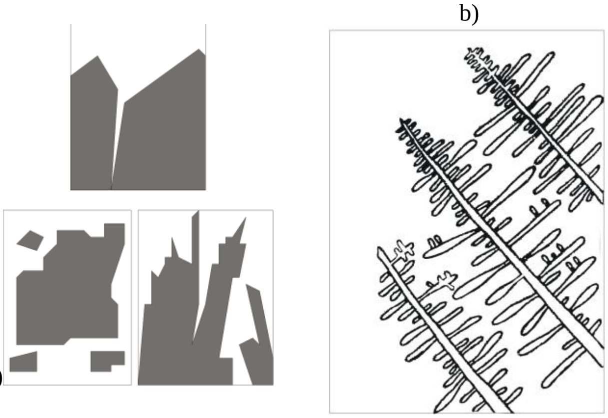
where: $\Delta S = S_S - S_L$ – the difference of the entropy of the solid and liquid phase
k – Boltzman's constant

If this proportion is closely adjacent to the unity element then the border between the liquid and the solid state is not equal. The border between the liquid and the solid body does not have a strong division but spreads along the length of some atomic sections. The growth is continuing in all boarding points. The crystallizing front of this type is characterized by a transitional layer [7]. Some authors [8] determine this front type as a diffusive front of crystallization. Pure metals are first of all characterized by the rough front of crystallization [7].

If the value ΔS/k is between 10 and 1 then the boarding surface between the liquid and the solid phase is distinct. This front type is determined as smooth. Humps and displacements make the atom connections easier, thus the growth consists mainly of the side growth of monoatomic humps on the surfaces [7]. On the connection with this, the real border between the liquid and the solid phase is made of some faces. It is typical of semi-conductive materials, organic compounds and some inorganic compounds [7].

The topography of the front crystallization in the atomic scale has an important influence on the external shape of the crystals (ryc. 5). Crystallization with atomically smooth front of crystallization causes appearance of the so called "faced crystals" whose external outline is limited by rounded surfaces [9]. Sub-cooling and oversaturation of the solution also influence the front of crystallization [10, 11, 12].

a) b)

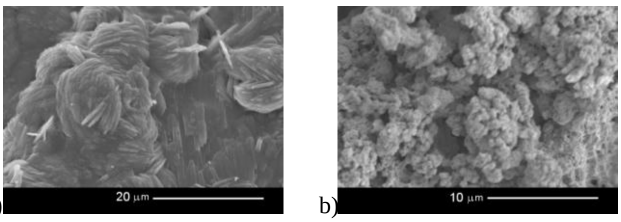


Ryc. 5 Crystals diagrams [7]
a) faced, b)non-faced.

It follows from the presented speculations that when analyzing the external crystals construction (e.g. in scaling electronic microscope) it is possible to determine the conditions in which they appeared.

Exemplifying pictures of faced crystals appearing in uroliths and gallstones are presented in illustrations 6 – 10.

a) b)



Ryc. 6. Examples of crystals which appear in uroliths
a) Whewellite ($CaC_2O_4 \cdot H_2O$) – non-faced crystal, b) hydroxyapatite ($Ca_5(PO_4)_3 \cdot (OH, F, Cl)$ - non-faced crystal,

a) b)

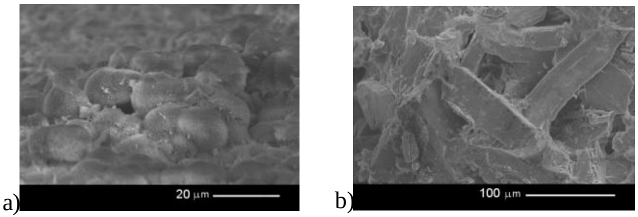


Fig. 7. Examples of crystals which appear in uroliths
a) uric acid ($C_5H_4N_4O_3$) – non-faced crystal, b) struvite ($MgNH_4(PO_4) \cdot 6H_2O$) – faced crystal,

a) b)

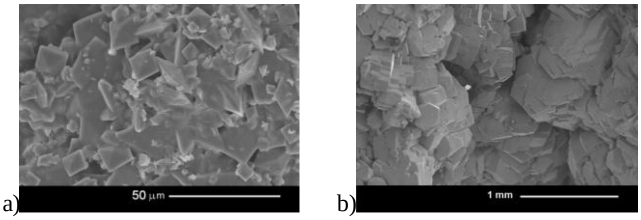


Fig. 8. Examples of crystals which appear in uroliths
a) weddelite ($CaC_2O_4 \cdot 2H_2O$) – faced crystal, b) cystyne ($(SCH_2CH(NH_2)COOH)_2$) – faced crystal.

Observation of the uroliths revealed appearing of crystal compounds which crystallize as faced and non-faced crystals. In the stones analyzed by the author of the work it was noted that the most frequently appearing compounds are: as faced crystals – struvite (ryc. 7b), weddelite (ryc. 8a), cystine (ryc. 8b), though as non-faced crystals – whewellite (ryc. 6a), hydroxyapatite (ryc. 6b), uric acid (ryc. 7a). Appearance of both faced and non-faced crystals can be explained by the fact that substances with a different chemical composition are present in the uroliths. Thus they have different values of the proportion **ΔS/k**. In some chemical compounds the values can be close to the unity element, so it results in the rough atomic front of crystallization and the growth of non-faced crystals. In other compounds this proportion can have a value within the range of 10 and 1, thus we deal with an atomically smooth front of crystallization leading to faced crystals growth.

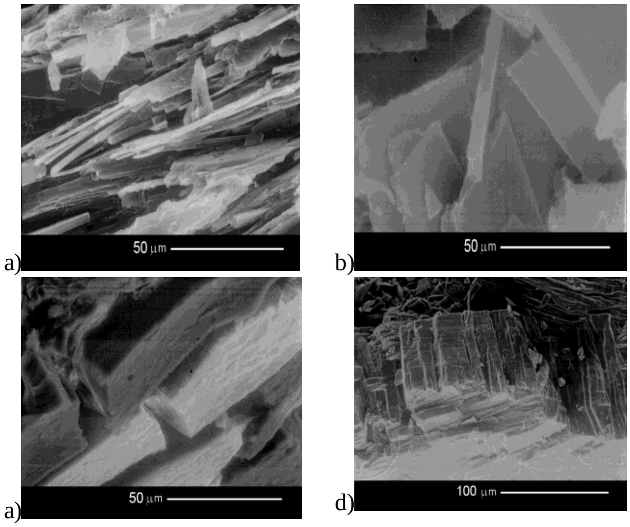


Fig. 9. Examples of faced crystals in gallstones

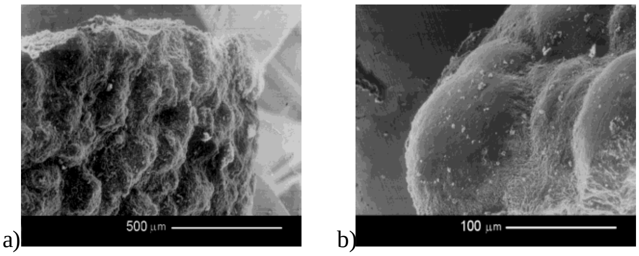


Fig. 10. Examples of non-faced crystals in gallstones

Analyzing external shapes of the gallstones presented in illustrations 9 and 10 it is seen that there are faced crystals in them (fig. 9 a,b,c,d) and non-faced ones (fig. 10 a,b). That is both smooth and rough front of crystallization can appear. Regarding the fact that these stones mostly consist of one compound (cholesterol) their proportion **ΔS/k** is of a constant value and thus there should be one front of crystallization. Appearance of both faced and non-faced crystals gives evidence to the fact that not only the chemical composition defines the type of the front of crystallization and thus the cross-section of the appeared crystals but other factors as well.

On the basis of the conducted research it can be stated that there are significant analogies in the processes of crystallization of metals and deposits in the human body.

References

[1] Xia L. F.: A study of the mineral component of gallstones. H. P. B. Surg. 1992, suppl. 5: 107,

[2] Lin S. M., Ker C. G., Tseng C. L., Yang M. H.: Instrumental neutron activation analysis of gallstones. Int. J. Rad. Appl Instrum. A., 1990, 41, 12: 1217,

[3] Been B., Billes S., Lewis P.: Microstructure of gallstones. Gastroente-rology, 1979, 76: 548,

[4] Moesch C., Sauterean D., Berry P., Cessot F., Gainaut A., Raby C., Pillegand B.: Library of reference infrared spectra for the analisys of gallstones. Gastroenterology, 1991, 100, 2: A776

[5] Różański W.: Własności macierzy organicznej kamieni moczowych. rozprawa habilitacyjna, Wojskowa Akademia Medyczna, Łódź 2001,

[6] Guy A. G.: Wprowadzenie do nauki o materiałach. PWN Warszawa 1977,

[7] Pietrowski S.: Krystalizacja tworzyw metalowych. Wydawnictwo Politechniki Łódzkiej, Łódź 1993

[8] Flemings M. C.: Solidification Processing. Mc Graw-Hil Book Company, New York 1974

[9] Jackson K., Uhlman D., Hunt J.: On the Nature of Crystal Growth from the Melt. Journal of Crystal Growth, v. 1, 1967

[10] Sali J., Samojlenko L., Dolinskaja W.: O formach rosta kristałłow surmy w spławach ewtiekticzeskowo tipa. Kristałłografia v. 18, z 5, 1973,

[11] Sali J., Dolinskaja W., Samojlenko L.: Wlijanie usłowij ochłazdienija na strukturoobraziwanije w spławach swiniec – surma. Fizyka Mietałłow i Mietałłowiedienije, t. 38, nr 1, 1974

[12] Taran J., Mazur W.: Struktura ewtiekticzeskich spławow, Mietałłurgija, Moskwa 1978