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Synthesis of Calcium Silicate ($Casio_3$) Using Calcium Fluoride, Quartz and Microbes

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Abstract
Microbes like bacteria, algae, fungi and virus play an important role to catalyst chemical reactions. In Nature, ores or minerals of different compounds are formed due to microbial environment and other factors like weathering. Microbial environment is also instrumental in forming calcium containing silicate minerals. Chemical reactions occur under microbial environment because microbes have the ability to control or modify different factors like pH, chemical potential and temperature during reactions. In this paper, synthesis of calcium silicate ($CaSiO_3$) using calcium fluoride (CaF_2) and quartz (SiO_2) under microbial environment in a laboratory is being adopted to produce the required material. XRD technique is used to confirm the formation of $CaSiO_3$.
Keywords- Atmospheric $CO_{2,}$ calcium fluoride, $CaSiO_{3,}$quartz, microbes.

I. Introduction

Minerals are inorganic compounds, crystalline, sometimes amorphous with specific chemical composition and structure. The composition of minerals are very simple such as sulphur (S) or quartz (SiO_2) or very complex such as the igneous mineral biotite [$K(Mg,Fe,Mn)_3AlSi_3O_{10}(OH)_2$]. Primary or igneous minerals crystallize during cooling of magma forms feldspars, pyroxenes and amphiboles, olivines, micas and silica. Minerals formed from chemical alteration (weathering or diagenesis) of primary minerals are called secondary minerals such as kaolinites, montmorillonites, illites; hydrated iron and aluminium oxides and carbonates. Microbes play a role in this transformation of primary to secondary minerals. Minerals formed by the precipitation from solution are called authigenic minerals.

Microbes such as Arthrobacter pascens, A. globiformis, A. simplex, Nocardia globerula, Pseudomonas fluorescens, P. putida, P. testosteronii, Thiobacillus thiooxidans; and fungi- Trichoderma lignorum, Cephalosporium atrum and Penicillium decumbens generate mineral acids in their vicinity that may soluble Li and Al or Si.

In nature the mineralization induced by microorganisms in silicate containing calcium ores plays an important role in the formation or dissolution of calcium/zinc/magnesium containing silica and minerals wollastonite ($CaSiO_3$), apophyllite ($KCa_4Si_8O_{20}(F,OH).8H_2O$] and olivine [$(Mg,Fe)_2SiO_4$] [1-12].

Therefore, microbial environment induce certain some chemical reactions in the calcium containing ores. The synthesis of calcium silicate ($CaSiO_3$) is induced using microbial environment under laboratory conditions in our research. The microbes such as Stenotrophomonas maltophilia, Pseudomonas putida, Pseudomonas aeroginosa, Enterobacter cloacae, Staphylococcus sciuri, Acinectobacter cacloaceticus, Pantoeau agglomerans, and Flavobacterium spp. have been used in the chemical process to synthesize $CaSiO_3$. All these microbes were concentrated together in the experimental container at the same time during the synthesis of the material.

The biotechnology utilizes microbial environment to produce required chemical reactions. Chemical reactions take place as a result of interaction of physical, chemical and biological components with each other. These interactions play an important role for the molecule or an element to modify its physicochemical form. This process is called transformation. However, the change is not one way, environment also plays vital role in the modification of temperature/ chemical reaction (pH)/conductivity etc.

Three major forms of transformations have been observed in the cycling of elements in nature:

1. Physical transformations which include fixation, dissolution, precipitation and
volatilization.
2. Chemical transformations which include precipitation and solubilization of minerals and other
molecules.
3. Biochemical transformations in which the physical and chemical changes are brought about by the living microbial processes. For example, the

microbial process is involved in fixation and transformations during biosynthesis or biodegradation.

Besides these, certain other processes such as 'Spatial translocations' of materials (from water column to sediments or from soil to atmosphere) and changes in the physical environment such as pressure due to piling may also be involved [1-12].

In this paper, the synthesis of $CaSiO_3$ has been carried out by using mineralizing agent calcium fluoride (CaF_2) and quartz (SiO_2) under microbial environment. As stated above, we can surmise that microbes such as bacteria, virus, algae and fungi etc. are capable of transformations or perform chemical reactions.

II. Objectives

1. Synthesis of $CaSiO_3$ has been carried out by using calcium fluoride (CaF_2) and quartz (SiO_2) in the laboratory utilizing microbial environment.
2. The XRD data of the synthesized material is compared with the XRD data of normal sample of $CaSiO_3$ for the confirmation of successful synthesis of $CaSiO_3$.

III. Geological Relationship

Microbial carbonate mineralization has vast ecological and geological significance and takes place due to many factors like microbial environment. The microbial environment can trigger and control calcification process i.e. mineralization of CO_2 to calcium carbonate ($CaCO_3$) in presence of mineralizing agent like calcium fluoride (CaF_2). A biochemical system allows the cells like microbes to raise the concentration of CO_2 at the site of the carboxylating which is called as carbon dioxide concentrating mechanism (CCM). Mineralization by microbial calcification is biologically induced and microbes exert a high degree of control over nucleation and crystallization. This type of mineralization is more of a diffuse phenomena which depends on the metabolic activities and nucleation sites for mineralization [13-15].

In nature, microbial calcification takes places mostly in oceans, considered as net source for atmospheric CO_2. The microbial environment in ocean provides a net source or sinks for CO_2 such that the system incorporates enough CO_2 into biomass. The field and laboratory measurements of systems with calcifying organisms showed released CO_2/precipitated carbonated ratios. Carbonate mineralization by microorganisms can also be biogeochemically coupled to weathering of silicate minerals. Biologically accelerated weathering (BAW) of silicates occurs both chemically and mechanically via production by microorganisms of extracellular enzymes, chelates, simple and complex organic acids, alcohols, and EPS [16-21].

Silicate minerals offer an abundant supply of calcium; calcium and magnesium silicates are plentiful in the Earth's crust. The potential capacity for sequestration of anthropogenic CO_2 as stable carbonates by accelerated weathering linked to carbonate mineralization is exceptionally large. Important calcium silicates include wollastonite ($CaSiO_3$) and plagioclase feldspars $(Na,Ca)(Si,Al)_4O_8$ and $CaAl_2Si_2O_8$), which is abundant in mafic and ultramafic rocks [22-26].

So, microbes control the chemical environment required for mineral formation in nature. This results in the geochemical process in the ores. This control of chemical environment by microbes to modify the material is called as catabolic plasmids [27].

IV. Experiment

In industries, calcium fluoride comes in contact with oxides at elevated temperatures in commercial applications to form multicomponent systems. Blau and Silverman proposed that fluoride bearing glasses of reaction type [28]

$$CaF_2 + SiO_2 + H_2O \rightarrow CaSiO_3 + 2HF \qquad (1)$$

In our research, $CaSiO_3$ is synthesized in the laboratory. To synthesize the required material, 100 mg mineralizing agent calcium fluoride (CaF_2) and 100mg quartz (SiO_2) were mixed in a cylindrical container made up of non magnetic material. The atmospheric CO_2 and moisture (H_2O) also plays an important role in this experiment. The microbes such as Stenotrophomonas maltophilia, Pseudomonas putida, Pseudomonas aeroginosa, Enterobacter cloacae, Staphylococcus sciuri, Acinectobacter cacloaceticus, Pantoeau agglomerans, and Flavobacterium spp. were concentrated together around the mixture of CaF_2 and SiO_2 with some moist air already present inside the container. The experimental container which contained the mixture of compounds and microbes was kept under low magnetic field of around 10^{-2} tesla. Under magnetic field, it was observed in some research paper that microbes move along a specific direction and they show some unique characteristics [29-30]. The experiment was carried out for 12 hours at room temperature 27◦C. After 12 hours the sample was taken out from the experimental container. Then XRD was carried out on the prepared sample which confirmed the formation of $CaSiO_3$. The microbial system concentrated around the mixture of CaF_2 and SiO_2 played an important role to combine the molecules to form $CaSiO_3$. These microbes controlled the temperature, pH value, chemical potential of the reaction and various other parameters like physical environment to carry out chemical reaction [31-32]. The systematic arrangement of the experiment is shown in the fig. 1.

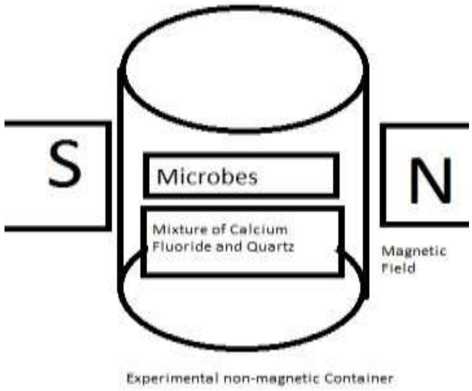

Fig. 1 Experimental arrangement for the synthesis of CaSiO3.

The reaction between Calcium fluoride (CaF_2) and quartz SiO_2 involved the following steps in microbial environment in the presence of atmospheric CO_2 and moisture [33]

$$CaF_2 + H_2O \rightarrow CaO + 2HF \qquad (2)$$

XRD results showed the presence of SiF_4 in the synthesized lab sample of $CaSiO_3$.

$$SiO_{2_{(qrt)}} + 4HF \rightarrow SiF_4 + 2H_2O \qquad (3)$$

$$CaO + CO_2 \rightarrow CaCO_3 \qquad (4)$$

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2 \qquad (5)$$

V. XRD analysis

The x-ray diffraction analysis was carried out on x-ray diffractrometer. The synthesized $CaSiO_3$ sample, which was analyzed on XRD, consisted of x-ray tube with Cu k-Alpha. The chart depicted had peaks which ran from 5˚ to 90˚ for CaF_2, SiO_2 compounds and from 5˚ to 120˚ for synthesized $CaSiO_3$ material consuming current of 30mA and voltage of 40 kV at temperature 25˚C. The XRD chart was given numbers coinciding the numbering of the sample peaks.

VI. Results

The synthesis of calcium silicate ($CaSiO_3$) using calcium fluoride, quartz and microbes was carried out successfully under laboratory conditions at room temperature 27˚C. The formation of $CaSiO_3$ was confirmed by XRD data by comparing it with normal $CaSiO_3$ XRD data given in table 1. The XRD pattern of CaF_2 and SiO_2 are shown in figure 2 and figure 3. The XRD pattern of synthesized $CaSiO_3$ is shown in figure 4. The XRD pattern of normal $CaSiO_3$ is shown in figure 5.

Table 1 XRD analysis for synthesized $CaSiO_3$ and normal $CaSiO_3$.

Sno.	XRD data for synthesized $CaSiO_3$ sample			d-spacing from the XRD data of normal $CaSiO_3$ sample		
	2θ values	d-spacing	Intensity	2θ value	d-spacing	Intensity
1	26.84	3.318	100	26.86	3.316	91.13
2	36.66	2.448	11.06	36.89	2.434	16.25
3	50.23	1.814	26.46	50.37	1.809	27.00
4	60.08	1.538	23.44	60.25	1.534	34.77
5	68.08	1.375	9.93	68.52	1.368	27.81

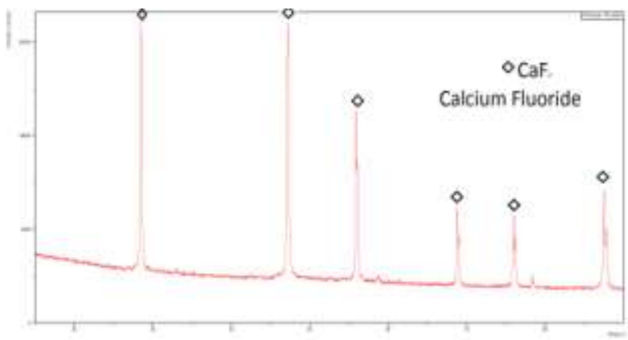

Fig. 2 XRD Pattern for Calcium fluoride (CaF_2).

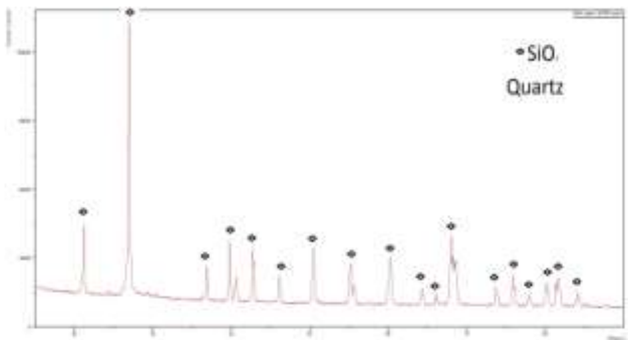

Fig. 3 XRD Pattern for quartz (SiO_2).

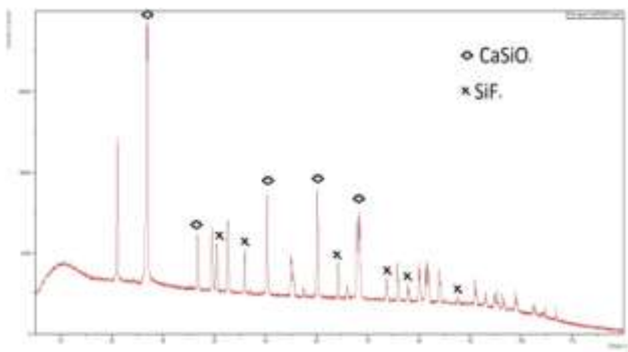

Fig.2 XRD Pattern for synthesized Calcium Silicate (CaSiO3).

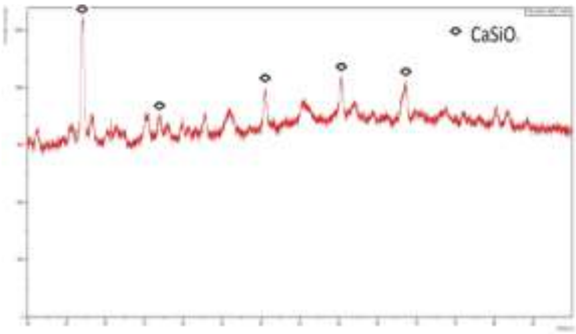

Fig. 3 XRD Pattern for normal Calcium Silicate (CaSiO3).

VII. Conclusions

Microbes carry out oxidation-reduction reactions in order to obtain energy for growth and cell maintenance. The amount of energy released per electron equivalent of an electron donor oxidized varies considerably from reaction to reaction. Reduction reaction requires electron acceptor type reaction. Full energy reaction ΔG is obtained; the free energy for the donor half reaction is added to the acceptor half reaction[34-36]. The microbes play an important role in many chemical reactions like photosynthesis, fermentation, leaching and oxidation-reduction reactions in Nature. The microbes have an accessory DNA element present in the cytoplasm called as catabolic plasmids [27]. These plasmids are circular and confer on their host the ability to transform or recycle not only complex molecule but naturally occurring and synthetic molecules as well.

In nature, geochemical reactions occurred in the silicate containing calcium ores where microbes played an important role for their transformation into a key or important mineral.

In this paper, an experiment was carried out to synthesize the $CaSiO_3$ compound under microbial environment in low magnetic field. The microbes modified the molecules calcium fluoride (CaF_2) and quartz (SiO_2) mixture in presence of atmospheric CO_2 and H_2O to a chemical formula Calcium silicate ($CaSiO_3$). The confirmation of formation of calcium silicate was done by XRD data. The difference between the above discussed experiment and geochemical process in natural calcium silicate ores is the change in microbial environment and respective compounds used for synthesis.

In the above discussed experiment, all the microbes Stenotrophomonas maltophilia, Pseudomonas putida, Pseudomonas aeroginosa, Enterobacter cloacae, Staphylococcus sciuri, Acinectobacter cacloaceticus, Pantoeau agglomerans, and Flavobacterium spp. have the ability to change or modify the substance. All these microbes have the ability to control or change chemical potential, free energy, pH value, temperature, oxidation-reduction process and physical environment like pressure required for proper chemical reaction between two or more molecules [31-32].

This experimental result concludes that microbes have the ability to carry out chemical reaction between calcium fluoride and quartz to transform them into calcium silicate in laboratory conditions.

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