Synthesis of Copper Silicate ($CuSiO_3.H_2O$) using Copper Oxide, Quartz and Microbes

M. Jagannadha Rao, B. Gopal Krishna

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 copper 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 copper silicate ($CuSiO_3.H_2O$) using copper oxide (CuO) and quartz (SiO_2) under microbial environment in the laboratory is being adopted to produce the material. XRD technique is used to confirm the formation of $CuSiO_3.H_2O$.***

Keywords - Copper oxide, Quartz, $CuSiO_3$, microbes, XRD.

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. The arsenic ores orpiment (As_2S_3), arsenopyrite (FeAsS) and enargite (Cu_5AsS_4) are also solubilized in this manner. Thiobacillus ferrooxidans leaches out 6% arsenic from carbonaceous gold ores and also accelerates leaching from arsenopyrite. Similarly antimony (Sb) minerals tetrahedrite ($4Cu_2S.Sb_2S_3$) and stibnite (Sb_2S_3) are oxidized by T. ferrooxidans to pentavalent antimony. Mechanism for metasilicate polymer depolymerization is not known. However, microbes Proteus mirabilis and Bacillus caldolyticus are capable of doing this [1-12].

Therefore, microbial environment induce certain chemical reactions in the copper ores.

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The synthesis of copper compound 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 $CuSiO_3$. 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 physical, chemical and biological components with each other. These interactions play an important role for molecule or an element to modify its physicochemical form. This process is called transformation. However, the change is not one way, environment also plays a 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 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 $CuSiO_3$ has been carried out by using copper oxide (CuO) and quartz (SiO_2) under microbial environment. Atmospheric moisture (H_2O) also played an important role in this experiment. 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. To synthesize $CuSiO_3$using copper oxide (CuO) and quartz (SiO_2) in a laboratory utilizing microbial environment.
2. The XRD data of the synthesized material is compared with the standard reference XRD data for the confirmation of successful synthesis of $CuSiO_3$.

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III. GEOLOGICAL RELATIONSHIP

Microbial metabolism effects are present wide range of natural environments. Microbial fixation of copper plays an important role in its mineral formation. Supergene oxidation, leaching and sulfide have had an important role in mineralization of copper ores [13,14]. Supergene activity occurs due to the abrupt descent of the water table in the subplanar pediments in response to episodes of cordilleran uplift under semiarid climatic conditions [15-17]. Precipitation of copper minerals and mineraloids occurs from supergene activity through neutralization of strongly acidic water transfer.

Copper silicate precipitation is similarly due to fluid pH increase in an environment dominated by neutral-to-alkaline waters with low contents of SiO_4^{-4} derived through feldspar kaolinization in more proximal zones [18]. Microbes reproduce in such environments under acid rock drainage and supergene processes involving ores are influenced by the metabolic processes of methanogenic and methanotrophic microbes [19, 20]. Moreover, unless the microbial activity is ongoing, the microbes are unlikely to be preserved, so that the only record of their activity would be unambiguous geochemical products of the organisms, such as the carbon isotopes. The pH value have been the dominant control on the precipitation of copper mineral like chrysocolla in exotic deposits, attributing precipitation to the neutralization of a solution containing complexed Cu^{+2} ions and dissolved silica as follows [19]

$$Cu^{++} + H_4SiO_4 \rightarrow 2H^{+} + CuSiO_3.H_2O(amphorpous) \quad (1)$$

Gibbs Energy of reaction for above equation is 35.948 kJ/mol. Because the reaction has a positive ΔG, it is thermodynamically unlikely that amorphous chrysocolla would precipitate from a solution containing Cu^{+2} and H_4SiO_4 unless the pH of the solution increases. So, microbes controls 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 [21].

IV. EXPERIMENT

The existence of pure $CuSiO_3$ was considered non-existent. In physics, $CuSiO_3$ represents a further example of a quasi-one-dimensional spin (½), ant ferromagnetic Heisenberg chain system. These properties $CuSiO_3$ are important in semiconductor technology and other industrial technologies.

In our research, $CuSiO_3$ is synthesized in laboratory. To synthesize the required material, 100 mg copper oxide (CuO) and 100mg quartz (SiO_2) were mixed in a cylindrical container made up of non magnetic material. 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 CuO 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 papers that microbes move along a specific direction and they show some unique characteristics [22, 23]. 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 $CuSiO_3$. The microbial system concentrated around the mixture of CuO and SiO_2 played an important role to combine the molecules to form $CuSiO_3.2H_2O$. These microbes controlled the temperature, pH value, chemical potential of the reaction and various other parameters like physical environment to carry out chemical reaction [24,25]. The systematic arrangement of the experiment is shown in the figure 1.

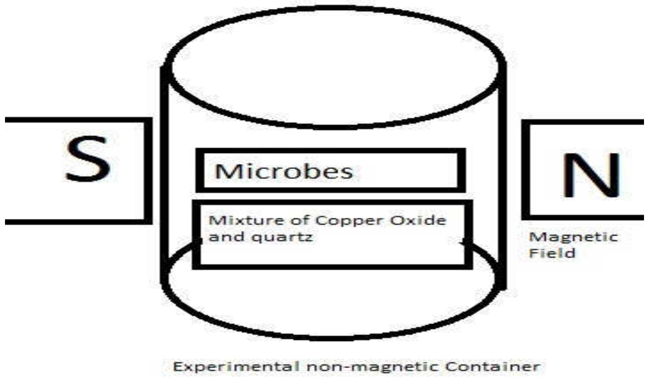

Figure 1 Experimental arrangement for the synthesis of $CuSiO_3$

The reaction between CuO and quartz involved the following steps in microbial environment in presence of atmospheric moisture [26].

Copper oxide dissociated into ion Cu^{++} in presence of moisture, XRD results showed the presence of Cu in the synthesized sample of $CuSiO_3.H_2O$

$$CuO \rightarrow Cu^{++} + O^{2-} \quad (2)$$

The quartz reacts with water molecules in atmosphere to form silicic acid.

$$SiO_{2(qrt)} + 2H_2O \rightarrow H_4SiO_4 \quad (3)$$

The Cu^{++} ions react with silicic acid to form $CuSiO_3.H_2O$

$$Cu^{++} + H_4SiO_4 \rightarrow 2H^{+} + CuSiO_3.H_2O \quad (4)$$

V. XRD ANALYSIS

The x-ray diffraction analysis was carried out on x- ray diffractrometer. The synthesized $CuSiO_3$ 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 CuO, SiO_2 compounds and from 5˚ to 120˚ for synthesized $CuSiO_3$ 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 copper silicate ($CuSiO_3$) using copper oxide, quartz and microbes was carried out successfully

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under laboratory conditions at room temperature 27˚C. The formation of $CuSiO_3$ is confirmed by XRD data by comparing it with standard reference data given in table 1. The XRD pattern of CuO and SiO_2 are shown in figure 2 and figure 3 respectively. The XRD pattern of synthesized $CuSiO_3$ is shown in figure 4. XRD results showed the presence of Cu which is important formation of Copper silicate ($CuSiO_3.H_2O$).

Table 1 XRD analysis data for synthesized $CuSiO_3$ sample and reference data

S. No.	Interpretation of XRD data for the synthesized sample			d-spacing from the reference XRD data file	
	2θ values	d-spacing	Relative intensity	d-spacing	Relative intensity
1	35.66	2.58	100	2.59	100
2	36.59	2.45	14.03	2.44	40
3	42.51	2.12	3.22	2.11	50
4	61.64	1.50	23.34	1.50	40
5	66.37	1.41	17.19	1.42	50

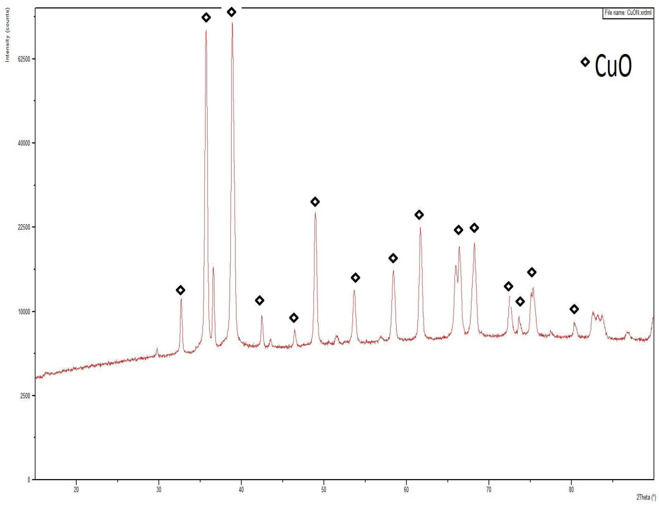

Fig. 2 XRD Pattern for copper oxide (CuO) used in the experiment.

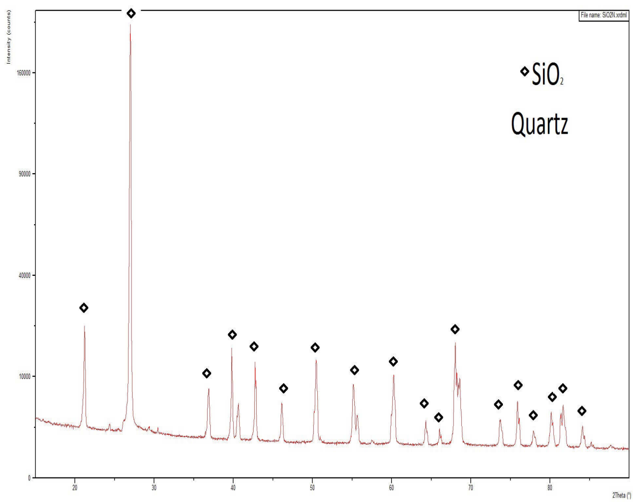

Fig. 3 XRD Pattern for Quartz (SiO_2) used in the experiment.

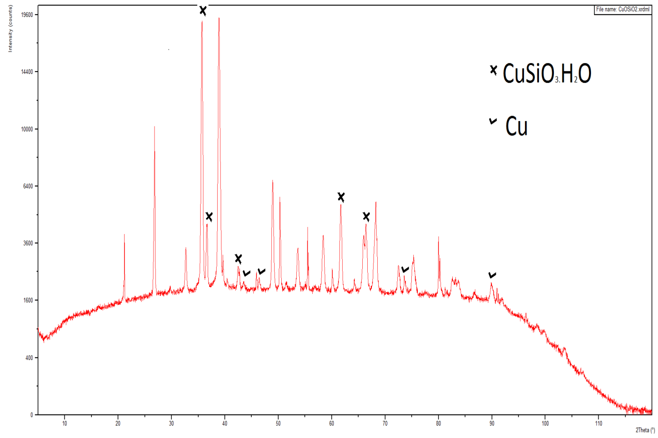

Fig. 4 XRD Pattern for synthesized Copper Silicate ($CuSiO_3.H_2O$).

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 [27-29]. 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. The 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 [21].

In nature, geochemical reactions occurred in the copper ores where microbes played an important role for their transformation into a key or important mineral. For example precipitation of copper mineral like chrysocolla (copper silicate) was carried out by specific microbes [19]. So, copper silicate can be prepared in laboratory by using microbes. In this paper, an experiment was carried out to synthesize the $CuSiO_3$ compound under microbial environment in low magnetic field. The microbes modified the molecules copper oxide (CuO) and quartz (SiO_2) mixture in presence of moisture (H_2O) to a chemical formula Copper silicate ($CuSiO_3$). The confirmation of formation of copper silicate was done by XRD data. The difference between the above discussed experiment and geochemical process in natural copper 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 [24,25].This experimental result concludes that microbes

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have the ability to carry out chemical reaction between copper oxide and quartz to transform them into copper silicate.

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