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Microwave heating behaviour and dielectric characteristics

[1]Sahil Singh, Ph.D., Scholar, Shri Jagdish Prasad Jhabarmal Tibrewala University, Jhunjhunu

[2]G .D. Rewar, Associate Professor, Shri Jagdish Prasad Jhabarmal Tibrewala University, Jhunjhunu

Abstract

Microwave-roasted germanium-containing neutral leaching slag is used to improve the process. The experiment made use of microwave roasting, temperature measurement, and dielectric constant measurement equipment. Microwaves may be converted into heat by the neutral leaching slag. After being microwave roasted, the claimed slag, including the neutral leaching slag, has a greater specific surface area, and the microwave radiation may have also decreased the particle size of the mineral particles. Meanwhile, the surface of the sand has broken after being microwave-roasted. During microwave roasting, extra oxygen is delivered to the reaction zone by recreating surface cracks in the slag, speeding up the leaching process and enhancing reaction conditions for the germanium oxide. The dielectric constants and thermal properties of neutral leaching residue may be used to provide a theoretical and experimental foundation for microwave-enhanced roasting.

Keywords: Microwave Roasting, Microwave Heating Behaviour Curves, Dielectric Constants.

Introduction

There are more than 1.5 million atoms of germanium in the Earth's crust, making it a very important rare metal. The strategic metal germanium [2] has several applications in military and cutting-edge manufacturing. Optical fibers, infrared detectors, and polymerization catalysts are the most common applications for germanium. Due to the increasing demand for germanium in a variety of new industries, the disposal of germanium scraps and byproducts has emerged as a pressing problem [3]. The future of germanium demand is promising due to growth in germanium use [4,5]. Often, germanium may be found in non-ferrous metals, coal, and other minerals [6]. Neutral leaching slag, formed from the hard zinc slag produced during the pyrometallurgical processing of zinc, is a primary resource for the germanium metallurgy industry [7]. When zinc is smelted, the neutral leaching slag is produced as a byproduct. Neutral leaching residues are now roasted in oxide before being leached again with HCL [8]. In order to oxidize the inexpensive elements, a lengthy roasting procedure at a high temperature (about 24 hours at 700 degrees Fahrenheit) is required. The pace at which Ge was leached and the amount of pressure applied by the leaching apparatus were both significantly impacted by the oxidizing roasting process. The roasting procedure took a very long time and utilized a lot of energy, putting a significant strain on both.

These days, microwaves are being used more and more often in the metallurgical industry as a means of providing clean heating. Microwaves are superior to other heating technologies [9, 10, 11] because they can heat minerals selectively, effectively, and automatically.

The ability of minerals to absorb energy from microwaves, as expressed by their dielectric characteristics, is a crucial factor in the practical use of microwave heating [14]. Due to the fast changes in the microwave field, the material generates electric dipole torque. The dielectric loss was formed because the polarization of the dipoles could not rotate at the same rate as the alternating electric field. The material's dielectric constant and dielectric loss are directly connected to the amount of heat it emits in a microwave field. Energy conservation and environmental protection depend on precise measurement of the complicated dielectric constants of metallurgical dielectric materials. In addition, the method of roasting by microwave itself adhered to the energy-saving and consumption-reducing standards of the metallurgical process and improved upon them. The key idea is that leaching after microwave roasting may be improved.

Microwave propagation and reflection are essential concepts in this theory. When modeling electromagnetic processes in a structure, high-frequency electromagnetic field analysis uses a signal wavelength that is the same order of magnitude as or less than the model's dimensions. Power transfer through electromagnetic waves, power dissipation as a result of electric loss tangent, wave scattering qualities, and frequency dependent parameters (S-parameters) are commonly analyzed. The fields can only be described by analytical formulas in the context of simple geometries. As soon as non-ideal material qualities are included into a structure, analytic solution of the resulting equations becomes challenging, if not impossible. Parameters like electric and magnetic field strengths and the amount of power absorbed by the structure may be calculated with high accuracy using numerical modeling in these situations.

Properties of dielectrics are described. Induced electronic, atomic, and space charge polarizations are some of the phenomena that occur when electromagnetic waves interact with matter. The strength of this interaction is proportional to the intensity of the wave's reflection or transmission. Transmission and reflections are regulated by the Maxwell equations:

$$\nabla \mathrm{x} E \rightarrow = i\omega\mu^{*}H$$

$$\nabla(\varepsilon^{*}E \rightarrow) = 0$$

$$\nabla \mathrm{x} H \rightarrow = i\omega\varepsilon^{*}E$$

$$\nabla . H \rightarrow = 0$$

Modern communication systems, such as satellite modules and cellular mobile phones, typically include dielectric ceramic materials. Several studies have looked at the possibility of using layered-structured dielectric materials in piezoelectric and ferroelectric random-access memory (FeRAM). Sensors, actuators, transducers, pulse signal circuits, aerospace, X-ray, weaponry, medicine, transportation, and more all make use of ferroelectric and piezoelectric ceramic materials. Dielectric resonators are the name given to the dielectric component employed in these gadgets (DR).

Miniaturization of devices necessitates a high dielectric constant, and zero-f-zero noise reduction necessitates a low tangent loss, both of which are crucial to the DR2's thermal stability. From a production standpoint, it is very challenging to produce compounds with all three ideal qualities and at a reasonable price. $BaTi_4O_9$ (BT4), an oxide compound, is one of the dielectric materials that may be employed in the microwave domain, as initially described by Rase and Roy10. By doing so, Veenhuis et al. (16) were able to produce compounds with high dielectric constants, which have found use in high-tech fields like lasers and optical storage.

Nowadays, BT4 has been extensively studied because of its advantageous Qf, high r, and low f values. As they find such widespread usage in microwave patch antennas, dielectric resonators, microwave communication devices, etc. Densifying these titanates at extremely high sintering temperatures causes phase and compositional defects resulting in improved dielectric properties[17].

Materials

This research makes use of neutral leaching slag collected in Yunnan, China, from the waste of the germanium industry's manufacturing of hard zinc by neutral leaching and vacuum distillation. The dielectric characteristics of strong samples may be measured using a variety of tools, such as open-ended coaxial probes, cavity perturbation, wave-guide transmission lines, and free space. Since it is simple to implement and does not depend on the geometry of the sample, the open coaxial probe technique has become the standard for measuring complicated dielectric permittivity of materials.

Conclusions

This study draws the following findings based on experimental research:

- Neutral leaching of the residue from a microwave roast that contains germanium is possible. The electric constants and the increasing temperature both indicate that the neutral leaching slag may convert microwave energy into heat.
- At a thickness of 0.95 centimeters, 1200 watts, and 2.45 gigahertz, the maximum temperature that can be achieved in a microwave field is 813 degrees Celsius.
- To further enhance the germanium oxide reaction conditions, the microwave roasted neutral leaching slag surface reformed cracks that helped to open reaction channels causing the oxygen within to participate in the oxidizing process. Also, it has the potential to boost the reaction area and leaching rate of the succeeding germanium leaching procedure.

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