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Enhancement of pentlandite surface magnetism and implications for its separation from serpentine via magnetic separation

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Abstract: The magnetism of pentlandite surface was enhanced through the selective precipitation of micro-fine magnetite fractions on pentlandite surfaces. This was achieved through adjustment of slurry pH and addition of surfactants. The results showed that at pH 8.8 with the addition of 100 g/t sodium hexametaphosphate, 4.5 L/t oleic acid, and 4.5 L/t kerosene, significant amount of fine magnetite particles adhered to the pentlandite surface, while trace amount of coating was found on serpentine surfaces. Thus, the magnetism of pentlandite was enhanced and pentlandite was well separated from serpentine by magnetic separation under the magnetic field intensity of 200 kA/m. Scanning electron microscopy (SEM) and zeta potential measurement were performed to characterize changes of mineral surface properties. Calculations of the extended Derjaguin−Landau−Verwey−Ocerbeek (EDLVO) theory indicated that, in the presence of surfactants the total interaction energy between magnetite and pentlandite became stronger than that between magnetite and serpentine. This enabled the selective adhesion of magnetite particles to pentlandite surfaces, thereby enhancing its magnetism.

Key words: pentlandite; serpentine; micro-fine magnetite; magnetic separation; selective magnetic coating

1 Introduction

Magnetic separation is based on the difference in magnetic properties of constituent mineral particles. However, in nature, most of the minerals own a very weak magnetism or no magnetism except for the iron and magnetite mineral, and consequently it is very difficult to obtain good enrichment or separation. Fortunately, there are a number of researches focused on the enhancement or artificial establishment of the magnetic susceptibility of minerals [1,2].

It is well known that the weakly magnetic properties of minerals (hematite, siderite and pyrite) can be enhanced by roasting or chemically converting them to a more magnetic phase, which consumes large amount of energy. In addition, there exists another method based on the artificial establishment, which is called magnetic coating or magnetic carrier methods without chemically altering the minerals. This is realized by incorporating a discrete magnetic phase onto the particles to be magnetized. It is easy to operate and suitable for a variety of ores or metals, with low cost. PLUMPTON [3] described and summarized diagrammatically these selective magnetic coating methods as follows: 1) selective surface decomposition of iron pentacarbonyl (Magnex process); 2) selective wetting by magnetite laden oil (Murex process); 3) selective co-flocculation with magnetite; and 4) selective surface adsorption of fine magnetite. In this process, individual magnetite fines are added in the highly dispersed slurry containing surfactants added in advance, and the magnetite is selectively attached onto the target grains' surface based on the physicochemical properties of the target minerals and magnetite. This separation technology was initially reported by FRANGISKOS and GAMBOPOULOS [4] to separate the magnesite, serpentine, pegmatite veins, and calcite with surfactants (ARQUAD-2C of 500 g/t, diesel oil of 2.8 L/t and Flotol B of 0.4 L/t) and heavy media grade magnetite or ferrosilicon. In this case, the silica and calcite were coated whereas the magnesite was not coated and then separated using a wet belt-type

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separator under a magnetic field intensity of 1.0 T. Thereafter, plenty of studies have been conducted to deal with other minerals using this process [5−7].

The separation of magnesite fines from serpentine fines by magnetic carrier methods has been described in detail by ANASTASSAKIS [8]. Surfactant, 22.5 mol/L dodecylamine, was required in suspensions (1.0 g of each mineral, 100 mL of water) to allow the adsorption of fine magnetite (less than 5 μm) onto serpentine surfaces in the pH range of 6.0−11.0. At pH>9.0 only slight coating formed on magnesite surfaces [8]. The mixtures were then separated by high-intensity magnetic separation at 0.8 A and pH=8.0. The magnetic products of 92.9% serpentine and 7.1% magnesite with 99.7% recovery were obtained. Meanwhile, the selective separation of quartz coated by extremely fine magnetite particles (less than 5 μm) from magnesite was also achieved by ANASTASSAKIS [9] by adding dodecylamine (7.2×10^{-6} mol/L), kerosene (2.5 L/t), and pine oil (250 g/t), adjusting pH value, and optimizing the amount of magnetite. Quartz particles were strongly coated by fine magnetite in the pH range of 6.0−11.0. After being separated by the magnetic separator (1.0 A), the magnetic products of 96.0% quartz and 4.0% magnesite were obtained at pH=6.0 and the recovery of quartz was 89.5%. SINGH et al [10] recovered iron minerals from the Barsua iron ore slimes containing 56% Fe, 4.8% SiO_2, and 7.2% Al_2O_3 by the addition of synthetic colloidal magnetite and oleate colloidal coating followed by high gradient magnetic separation technique. Meanwhile, the effects of content of colloidal magnetite, pH, and magnetic field strength were studied in detail [10]. Besides, the separation of minerals with weak magnetism, such as separating chalcocite from silica, sphalerite from gangue, coal from ash, ferrihydrite from wastewater, and metallic copper from lead using magnetic coating technique has been also investigated by several researchers [11−13].

So far, magnetic coating method, however, has not been a well-known process in the separation of sulfide ores or copper−nickel sulfide ores. As we all know, in nickel sulfide flotation, serpentine, as a common magnesium silicate, is usually reported into the flotation concentrate via absorption on the pentlandite surfaces as slime coatings, causing downstream processing problems and increasing smelting costs [14,15]. In addition, hydrophilic serpentine minerals may interfere with the flotation of pentlandite and decrease the hydrophobicity of sulfide minerals. In order to eliminate the effect of serpentine minerals, high dosage of dispersants such as sodium hexametaphosphate, sodium silicate, or carboxymethyl cellulose are usually added to depress these magnesium silicates and hence may bring about considerable economic pressures [16−18]. Therefore, the challenging issues during the processing of such a nickel sulfide are to reduce the serpentine (MgO) content and increase nickel recovery. The present work provides a new method of separating pentlandite from serpentine by magnetic coating. Surfaces of pentlandite were coated selectively by fine magnetite particles to enhance its magnetic property for magnetic separation.

2 Experimental

2.1 Materials

The experimental samples, pentlandite, serpentine and magnetite were obtained from Jinchuan Group Co., Ltd., Xiuyan Serpentine Mine and Benxi Steel Group Co., Ltd., China, respectively. Sodium hexametaphosphate (SHMP), oleic acid and kerosene were chemical reagents supplied from Tianjin Kermil Inc., China. Pentlandite and serpentine were mixed in a mass ratio of 1:2 and different amounts of magnetite were added to mixtures.

The mineral compositions of pentlandite, serpentine, and magnetite samples were identified by XRD and the XRD patterns are shown in Fig. 1. The XRD patterns of pentlandite confirmed that the sample was of high purity with minor amount of pyrite. The fraction of particle size less than 45 μm was used for the magnetic coating tests. The XRD patterns of serpentine showed that the sample contained 99% serpentine with trace amount of quartz. The natural magnetite mineral with 69.98% Fe was ground in a stirred mill for 90 min so that mineral particles were less than 5 μm. The ground sample was used as magnetic seeds.

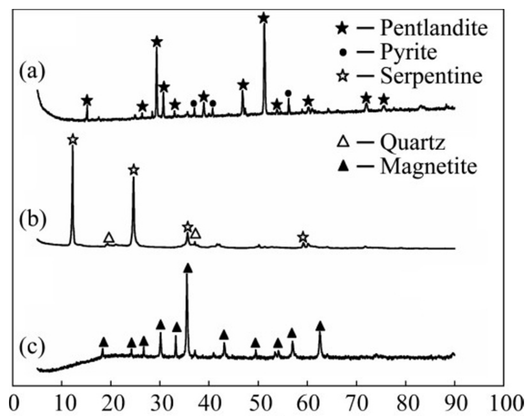

Fig. 1 XRD patterns of pentlandite (a), serpentine (b) and magnetite (c)

The particle size distributions of samples were analyzed by a Malvern laser particle size analyzer (model 2000). The results showed that the volume average diameters of pentlandite, serpentine and magnetite were 32.22, 24.46 and 2.28 μm, respectively, as shown in Table 1. The chemical analysis results of