Desilication from titanium–vanadium slag by alkaline leaching

De-sheng CHEN1,2, Long-sheng ZHAO1,2, Tao QT1,2, Guo-ping Hu1,2, Hong-xin ZHAO1,2, Jie LI1,2, Li-na WANG1,2

1. National Engineering Laboratory for Hydrometallurgical Cleaner Production Technology, Institute of Process Engineering, Chinese Academy of Sciences, Beijing 100190, China; 2. Key Laboratory of Green Process and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, Beijing 100190, China

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Abstract: A hydrometallurgical process for the selective removal of silicon from titanium–vanadium slag by alkaline leaching was investigated. X-ray diffraction, scanning electron microscopy and electron dispersive spectroscopy were used to characterize the samples. The results show that anosovite, pyroxene and metallic iron are the major components of the titanium–vanadium slag. Anosovite is presented in granular and plate shapes, and pyroxene is distributed in the anosovite crystals. Metallic iron is spheroidal and wrapped in anosovite. Silicon is mainly in the pyroxene, and titanium and vanadium are mainly in the anosovite. The effects of agitation speed, leaching temperature, leaching time, sodium hydroxide concentration and liquid–solid (L/S) mass ratio on the leaching behavior of silica from titanium–vanadium slag were investigated. The leaching temperature and L/S mass ratio played considerable role in the desilication process. Under the optimal conditions, 88.2% silicon, 66.3% aluminum, 27.3% manganese, and only 1.2% vanadium were leached out. The desilication kinetics of the titanium–vanadium slag was described by the chemical control model. The apparent activation energy of the desilication process was found to be 46.3 kJ/mol.

Key words: desilication; titanium–vanadium slag; alkaline leaching; kinetics

1 Introduction

Panzhihua titanomagnetite deposits account for more than 90% titanium and 60% vanadium reserves in China [1]. Presently, titanomagnetite concentrates in China are smelted in a blast furnace to produce vanadium-bearing cast iron and titanium slag. The obtained vanadium-bearing cast iron is converted to yield steelmaking iron and vanadium slag [2]. The titanium slag contains 22%–25% titanium dioxide (TiO₂) [3]. More than three million tons of titanium slag is produced every year. Due to the dispersed distribution of titanium components in various fine grained (<10 μm) mineral phases with complex interfacial combination, the recovery of the titanium components is difficult [2,4]. Therefore, titanium slag results in wasted resources and pollutions to the environment. In addition, the vanadium slag with alkali additives or limestone is subjected to an oxidizing roast to transform vanadium into its soluble form. Vanadium is deposited from the solution, either in the form of metavanadate or ammonium polyvanadate, in the presence of ammonium sulfate or as commercially pure vanadium pentoxide upon hydrolysis [5,6]. This process is costly and complicated, with a low vanadium recovery rate. Moreover, the resulting poisonous gas and water cause serious environmental pollution [7].

More than 90% of TiO₂ pigment plants in China are operated using the sulfate process [8]. However, the sulfate process faces severe environmental challenges. The digestion reaction of titanium slag with concentrated sulfuric acid is highly exothermic, which can be catastrophic if not properly controlled [9]. In addition, the dilute spent acid (~20% in mass fraction) formed during hydrolysis is not recycled into the process, not only causing environmental problems, but also resulting in a waste of sulfur resource.

To utilize the titanomagnetite concentrates in China, a new process based on the novel metallurgical process for preparing TiO₂ was proposed by CHEN et al [10,11].
Other factors, such as agitation speed, leaching time, and NaOH concentration, also have a certain influence. Three conditions, 88.2% silicon, 66.3% aluminum, and 27.3% manganese, and only 1.2 2% vanadium in the titanium–vanadium slag are leached out.  

4 Conclusions  

1) Anosovite, pyroxene, and metallic iron are the major components of the titanium–vanadium slag. Anosovite is presented in granular and plate shapes. Pyroxene is distributed in the anosovite crystals. Metallic iron is spheroidal and wrapped in anosovite, and the spheroidal edge is oxidized. Silicon is mainly in the pyroxene. Titanium and vanadium are mainly in the anosovite.  

2) The leaching rate of silicon is significantly affected by the leaching temperature and L/S mass ratio. Other factors, such as agitation speed, leaching time, and NaOH concentration, also have a certain influence.  

3) The optimal alkaline leaching conditions for the titanium–vanadium slag are as follows: leaching temperature of 110 °C, leaching time of 120 min, NaOH concentration of 40%, and L/S mass ratio of 4:1. Under these conditions, 88.2% silicon, 66.3% aluminum, 27.3% manganese, and only 1.2% vanadium in the titanium–vanadium slag are leached out.  

4) The desilication kinetics of the titanium–vanadium slag by alkaline leaching is described by the chemical control model. The apparent activation energy of the desilication process is 46.3 kJ/mol.  

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