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Development of an electrochemical process for production of nano-copper oxides: Agglomeration kinetics modeling

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Abstract

The main objective of this study was the development of a simple, clean, and industrial applicable electrochemical process for production of high pure nano-copper oxides from mining and industrial resources (e.g., ore, spent, slag and wastewater). To conduct the proposed process, a special set up containing an electrochemical cell in an ultrasonic system (28 kHz and 160 W) was proposed. Accordingly, using this set up and applying appropriate voltage (≈ 5 V) at 25°C, in the presence of N_2 gas, the simultaneous anode dissolution and nano-copper oxides formation (≈ 24 nm) can be occurred, rapidly (less than 45 minutes). Then, the effect of N_2 gas and free radicals generated by ultrasonic irradiation was studied. The results showed, in the absence of ultrasonic irradiation and N_2, an increase of electrolyte pH from 6.42 to 10.92, a decrease of electrolyte Eh from 285 mV to –1.14 V, and formation of copper nanoparticles. While, in the presence of ultrasonic and N_2, the CuO nanoparticles were formed due to presence of H_2O_2 generated by interaction of free radicals. Moreover, a novel method for kinetics modeling of nanoparticles agglomeration was proposed according to distributed activation energy model and Arrhenius parameters variation. The results showed that, in the absence of ultrasonic irradiation, the nanoparticle agglomerates were firstly formed (interface controlled mechanism) and then, the diffusion of nanoparticle agglomerates was occurred (diffusion controlled mechanism). Therefore, the control of nanoparticles size and shape may be impossible without surfactant. Also, in the presence of ultrasonic irradiation, the whole of agglomeration process followed interface controlled mechanism. Therefore, using ultrasonic irradiation, the nanoparticles shape and size don't change due to prevention of agglomerates diffusion.

Keywords: Nano-copper oxide, Sonoelectrochemical process, Solid state kinetics, Ultrasonic irradiation, Environmental-friendly method.