STM study on micromorphology of pyrite and dynamic significance of ore-formation

YE Rong[1,2], ZHAO Lunshan[2], MA Zhesheng[2], SHEN Yongli[2] and ZHAO Xiaoping[3]

1. *Institute of Geochemistry, Chinese Academy of Sciences, Guiyang* 550002, *China*;
2. *China University of Geosciences, Beijing* 100083, *China*;
3. *Jiangsu University of Technology, Zhejiang* 212000, *China*

Abstract A careful scanning tunneling microscope (STM) observation has been made on the micromorphology structure of the crystal faces for a group of pyrites which include two types of pyrite specimens: natural pyrites, from the different stage of hydrothermal ore deposits and artificial crystal of pyrite. It has been discovered that there is a set of micromorphological structures on the surfaces of pyrite crystals, including pisolitic hillocks, lotus root-like hillocks and spiral steps. This study reveals that the micromorphology of pyrite crystals, which are closely related to thermodynamic conditions and dynamic environment of the ore-forming systems, carries a lot of genetic information.

Keywords: STM, micromorphology of pyrite, dynamics of ore-forming processes.

WE noticed that previous STM studies were mainly focused on the deduction of the crystal structure and its relationship with material properties based on the micromorphology of mineral. The present study makes a careful STM observation on the micromorphology structure of crystal faces for a group of pyrites: natural pyrites, from the different stages of hydrothermal ore deposits and artificial crystal of pyrite. We discovered that there is a set of micromorphological strucutres on the surfaces of pyrite crystals, including pisolitic hillocks, lotus root-like hillocks and spiral steps. This study reveals that the micromorphology of pyrite crystals, which are closely related to thermodynamic conditions and dynamic environment of the ore-forming systems, carries a lot of genetic information.

1 Experimental

The STM device used in this study is CSTM-9000 type; the Pt-Ir tip was prepared by cutting. The experiments were performed in air at room temperautre and the constant-current model. The experimental conditions are shown in Plate Ⅰ. Natural samples of pyrite were collected from the Yixingzhai gold deposit, Shanxi and Linglong gold deposits, Jiaodong and artificial pyrite crystals are synthetic. STM experiments were carried out on the crystal face {100} of pyrites.

2 Results and discussion

Plate Ⅰ is particular micromorphologcal images observed in the present study. The microstructures of the pyrite are marked by orderly-arranged hillocks and pits. By employing the methodology of crystallography and mineralogy, these micromorphological structures are classified as the following groups.

(i) Pisolitic hillocks. The growth hillocks (Plate Ⅰ-1) are round pisolite shaped with longitudinal axes of about 25—40 nm and short axes of about 15—25 nm. The ratios of long to short axes are nearly 2:1. The sizes are almost the same and the surfaces are smooth. This kind of micromorphological structure is mainly found in the pyrite from the massive sulfide ore of brittle slitting stage in the Yixingzhai gold deposit.

(ii) Wavy hillocks. The hillocks (Plate Ⅰ-2) are not symmetric. They are nonhomogeneous in size with domic apexes. Between the hillocks are pits or depressed trench. On the profiles of the images they are found different in depth and width with nonsymmetric slopes. This type of micromorphologic structures is observed on the surface of pyrite from the ore of brittle-tough tensile stage in the Yixingzhai gold deposit.

(iii) Lotus root-like hillocks. The hillocks (Plate Ⅰ-3) are shaped like ellipsoids with end to end joint in major axis or lotus root-shaped. Longitudinal axes about are 59—121 nm and short axes are 31—40 nm. This type of micromorphologic structures is noticed on the crystal face of pyrite from the brittle-tough tensile stage of Linglong gold deposit in Jaodong.

(iv) Growth steps with hillock spires. The hillocks are connected into different spires (Plate Ⅰ-4) with curve or polygonal forms. These spires can be divided into quite a few groups, which are separately located in different centers. The sample is collected from the brittle-tough tensile stage of the Yixingzhai gold deposit.

(v) Smooth growth step. The step panes are even and smooth (Plate Ⅰ-5) with a width of 39.6 nm. The surfaces of artificial pyrite observed are this type of microstructure.

According to genetic mineralogy[1], the micromorphology of mineral is an important typomorphism, and its formation is mainly controlled by such thermodynamic and dynamic conditions as: i) temperature and its declining grade; ii) pressure and its declining grade; iii) oversaturation level; iv) space freedom for crystallization; v) strength and orientation of material recharge; vi) dynamic state of the fluid flowing; vii) velocity of crystal growing.

The micromorphologic structure with the densely distributed pisolitic hillocks of the single hillock (Plate Ⅰ-1) and connected hillocks (Plate Ⅱ-2) on the crystal faces of pyrite reveal that the growth of the faces is a course of growth with multiple centers (crystal buds) and gradual connection[2]. The formation of micromorphologic structures of hillocks observed on the pyrites both from Yixingzhai and Linglong gold deposits is closely related to the metallogenetic conditions. According to the theory of crystal growth, the rate of nucleation and the size of critical nucleuses are affected by the temperature gradient and the oversaturation level in the hydrothermal system. Our previous researches[3,4] showed that the densely distributed pisolitic hillocks with multiple centers on the pyrites of the two gold deposits mentioned above are the growth phenomena at the brittle slitting stage, these hillocks formed when the hydrothermal fluid intruded into the metallogenetic space at a rapid speed, leading to a sharp decrease in temperature-pressure gradient, a strong oversaturation level of the fluid and a rapid growth of many crystal buds. At the brittle-tough tensile stage[3, 4], as the grade of temperature-pressure decreasing and oversaturation level were relatively low, the growing rate of the hillocks was slow, the hillocks are separated spatially, forming the wavy, thick and smooth lotus root-like hillocks (Plate Ⅰ-3). Due to the flowing feeding of ore-forming fluid, the growing rate of the hillocks is different in different directions. In the direction against the feeding flow, the accumulation rate of crystal nets was rapid, and in the direction opposite the feeding flow, it was slow. In this way, the hillocks at last formed to be nonsymmetric which decline towards the feeding direction. The spiral growth steps formed at the brittle-tough tensile stage when the ore-forming fluid was low in the oversaturation level.

By the modern high resolution STM technique, the nm-scale micromorphologcal structures on mineral surfaces can be observed. These microstructures bear rich information in thermodynamic and dynamic conditions for mineral growth, and are of great significance in genesis. The present study makes a probing in the drawing and explanation of the conformation, as only a few phenomena have been observed, some problems still await further study.

Acknowledgement This wrok was supported by the National Natural Science Foundation of China (Grant Nos. 49573187 and 49773192).

References

1 Chen Guangyuan, Sun Daisheng, Yinhuian, *Genetic Mineralogy And Prospecting Mineralogy* (in Chinese), Chongqing: Chongqing Publishing House, 1987.

2 Zhang Kecong, Zhang Lehui, *Crystal Growth* (in Chinese), Beijing: Science Press, 1981, 77—281.

3 Zhao Lunshang, Wu Yuebing, Ye Rong *et al.*, Study on tectonic-geochemical dynamics of ore-formation in Jiaodong auriferous area, *Geoscience-Journal of Graduate School*, *China University of Geosciences* (in Chinese), 1996, 6(2): 213.

4 Ye Rong, Zhao Lunshang, Sheng Yongli *et al.*, Study on geological-geochemical dynamics of ore-formation of Yixingzhai gold deposit, *Geoscience-Journal of Graduate School*, *China University of Geosciences* (in Chinese), 1997, 11(1): 58.

(*Received March* 26, 1999)