Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 26(2016) 2197−2208
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Occurrence characteristics and enrichment regularity of indium in pyrite: A case study of Dachang tin ore-field

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Received 6 May 2015; accepted 2 May 2016

Abstract: To reveal the occurrence state and enrichment regularity of the dispersed element indium in pyrite, the petrology, mineralogy, geochemistry, and mineral physics were researched detailedly. The results suggest that the structure of pyrite is mainly composed of massive structure, disseminated structure, vein structure, reticular structure, comb structure and so on. Generally, the pyrite coexists with sphalerite, marmatite, pyrrhotite, chalcopyrite, galena, and arsenopyrite. And the texture of pyrite primarily consists of the metasomatic texture, solid solution texture, idiomorphic−hypidiomorphic granular texture, and disseminated texture. The content of indium in pyrite ranges from 0.491×10^{-6} to 65.1×10^{-6} with an average value of 14.38×10^{-6}. Yet, the indium content in the Gaofeng deposit is higher than that in the Dafulou and Tongkeng deposit, showing a particularly significant supernormal enrichment. Besides, the cadmium content in pyrite is also higher than other dispersed elements, and similarly the abnormal enrichment of cadmium in the Gaofeng deposit is also very significant. An obvious positive correlation exists between In and Cd, or Tl, but a negative correlation between In and Re. It is difficult to find out a positive or negative correlation between In and Ga. The element zinc is of great importance to the enrichment of indium, which can possibly facilitate to the migration and crystallization of dispersed element indium.

Key words: dispersed element indium; pyrite; lattice structure; enrichment regularity; cassiterite-sulfide deposit; Dachang ore-field

1 Introduction

Generally, the dispersed elements mainly consist of eight elements like cadmium (Cd), gallium (Ga), indium (In), germanium (Ge), selenium (Se), tellurium (Te), rhenium (Re) and thallium (Tl) [1−3], and these elements are always characterized by the low content, extremely rare independent mineral, great difficulty to significant enrichment, belonging to urgent needed and dire lacked resources [4,5].

Dispersed element indium (In) is a rare metal element, and also a kind of strategic metal, whose content in the earth's crust is very low and often scattered in geological body [6]. Indium has very unique physical and chemical properties [7], such as low melting point, high boiling point and good conductivity. Therefore, indium is widely used in high-tech fields like electronic computer, energy, electronics, photoelectricity, national defense military, aerospace, nuclear industry and the modern information industry, which has become increasingly important in the national economy, and is also one of the most important support materials in modern electronic industry [8].

Research on indium element began in the 1950s, mainly focused on geochemical characteristics, occurrence state, and thermal dynamics of indium element. According to the existing data, the indium

Foundation item: Projects (41202051, 41672076) supported by the National Natural Science Foundation of China; Project (2015CX008) supported by the Innovation-driven Plan in Central South University, China; Project (2016JJ1022) supported by Hunan Provincial Natural Science Outstanding Youth Foundation of China; Project (CSUZC201601) supported by the Open-End Fund for the Valuable and Precision Instruments of Central South University, China; Project (2014T70886) supported by the Special Program of the Postdoctoral Science Foundation of China; Project (2012M521721) supported by China Postdoctoral Science Foundation; Project (XKRZ[2014]76) supported by the Platform of Scientific and Technological Innovation for Hunan Youth, China
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DOI: 10.1016/S1003-6326(16)64336-4

enrichment shows the obvious specificity of the ore deposit type and mineral type [9], and the indium has obvious trend of enrichment in the zinc-rich and tin-rich deposit. In China, the indium-rich deposits are mainly the cassiterite sulfide deposit and tin-rich Pb−Zn deposit [10,11]. However, LIU and CAO [12] pointed out that the sphalerite is the best mineral for indium enrichment, yet entering sphalerite lattice for indium only under certain conditions. ZHANG et al [13] found out that the indium doesn't enrich in different types of lead, zinc, copper, iron, manganese and other mineral deposits, but it showed supernormal enrichment characteristic in the cassiterite sulfide deposit and tin-rich lead−zinc polymetallic deposit, and was mainly enriched in sphalerite. ZHANG et al [14] also found out that the industrial indium-rich deposit is primarily of tin-rich sulfide deposit, so the finding is synchronous for both of them.

So far, the study of indium resources is mainly concentrated in the economic significance and application value [15], etc. However, its geological characteristics, genesis and background are seldom researched, and the existing research work is mainly focused on its mineralogy [16], but the researchers are less. Furthermore, the relevant literature information, which is related to geological characteristics and genesis of indium, is also very limited. So, for the purpose of finding new indium resources, much more effort should be spared on scientific research, such as coming up with the favor geological conditions for indium, and establishing indium metallogenic pattern and prospecting model [17], so as to guide the prospecting practice. Therefore, in order to further develop the indium deposit geological theory, it's very urgent to establish a scientific metallogenic model of indium to guide the ore-prospecting. Through long-term research, TU et al [18] found out that, under certain geological and geochemical conditions, not only enrichment but also supernormal enrichment of dispersed element can occur and it is also possible to mineralize independently, the dispersed elements independent deposit can be enriched by the form of independent mineral, but more complex geological process is needed, indicating quite a demanding metallogenic condition. In China, a series of disperse elements independent ore deposits have been found, such as Dashuigou tellurium deposit in Sichuan, Yutangba selenium deposit in Hubei, Lincang germanium deposit in Yunnan, Lanmuchang thallium deposit in Guizhou, La'erma independent selenium deposit, Nanhua independent thallium deposit, Dulong cadmium deposit, Muchuan independent rhenium deposit, Niujiaotang zinc−cadmium deposit in Guizhou and Xiangquan independent thallium deposit in Anhui. There are also some reports about independent dispersed element deposits in other countries [19,20], such as Apex Ga−Ge deposit in the US, Pekka Haka Se deposit in Bolivia, Tsumeb Ge deposit in Namibia. However, the independent indium deposit or predominantly indium-rich deposit has not been found.

China has the world's largest indium geological reserve, and is also currently the largest native indium producer and exporter, but the distribution of proven indium resources is not uniform, mainly in south China folded belt and ancient Asia folded belt, including Guangxi, Yunnan, Inner Mongolia, Guangdong, Qinghai, Hunan, Jiangxi, Guizhou and Sichuan provinces, among which the provinces of Guangxi, Yunnan, Inner Mongolia and Guangdong have approximately 80% of the total indium reserves [3,18]. The reserve of Dachang ore field in Guangxi has already exceeded 5000 t (Fig. 1), ranking the first place in the world. The ore-field is an important tin-polymetallic base in China, with a number of world-class large and super-large cassiterite sulfide deposits [21], and also are characterized by high degree of research, abundant basis data, typical deposit features [22], and indium supernormal enrichment, the mineralization information of core and tunnel is fresh and colorful, being the best natural laboratory for researching on indium-rich deposit.

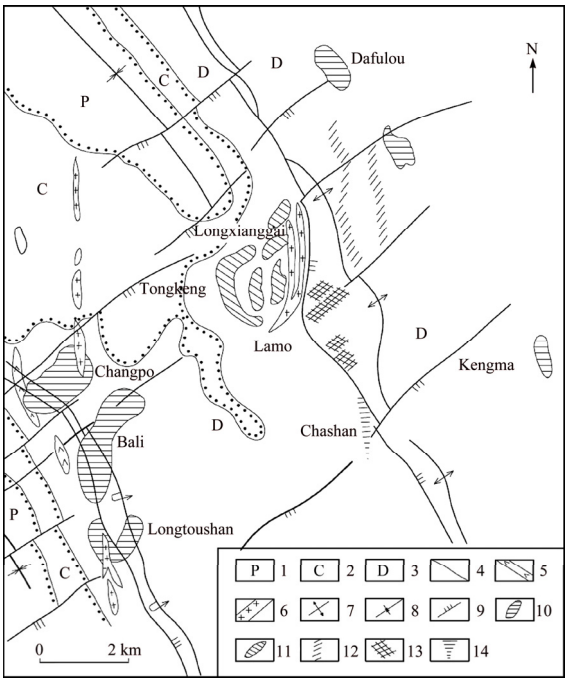

Fig. 1 Mineralization zones of Dachang ore field (compiled from China Nonferrous Metals Industry Corporation, 1987) (1 — Permian limestone and siliceous; 2 — Carboniferous limestone; 3 — Devonian limestone, shale and siliceous; 4 — Parallel unconformity stratigraphic contact; 5 — Diorite porphyrite; 6—Granite and granite porphyry; 7—Anticline axis; 8—Syncline axis; 9—Faults; 10—Tin ore; 11—Zn−Cu ore; 12—Scheelite veins; 13—Wolframite veins; 14—Antimony veins)