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SIMS techniques and application to refractory gold deposits

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In recent years, advanced mineral techniques have gained significant development and played an important role in academic and applied research of resource sector due to the advancement of hardware and software and the needs for in-situ and quantitative analysis. This paper introduces and discusses the principles, capabilities and advantages of Dynamic Secondary Ion Mass Spectrometry (D-SIMS) and Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS) and application to refractory gold deposits.

D-SIMS is one of a few most important microbeam techniques applied in economic geology (especially gold ores) because of its unique quantification and mapping capabilities for trace elements. Theoretically, it can detect and measure all the elements in the periodic table in concentration from ~1% to 10 ppb and has the ability to discriminate between the isotopes of many elements. Its exceptional operational capabilities include (1) small beam size (~20 μm); (2) low detection limit for Au (0.2 – 0.5 ppm); (3) shallow beam sampling depth (0.5 – 1 μm); (4) individual particle analysis; (5) depth concentration profiling and (6) element mapping. High sensitivity makes SIMS an excellent analytical tool for the quantification of trace elements in a variety of materials. Although some other new analytical techniques have been developed and utilized in minerals research, SIMS is probably the best technique for quantification of submicroscopic gold in sulphide minerals in refractory gold ores. The SIMS in-depth concentration profiling is used to discriminate colloidal gold (0.02-0.1 μm) and solid solution gold. SIMS mapping is often used to show the location and distribution of submicroscopic gold in host minerals.

A large amount of D-SIMS data acquired by the authors and other researchers showed that pyrite and arsenopyrite are the most common host minerals for sub-microscopic gold, with a maximum reported concentration of 1.7% in arsenopyrite. The concentration of sub-microscopic gold in pyrite and arsenopyrite is often related to their morphological types, and tends to concentrate in fine-grained sulphide particles. The order of concentration of submicroscopic gold in pyrite and arsenopyrite is usually: fine-grained>porous>coarse-grained.

ToF-SIMS is a surface analysis technique and is unique in that it measures the outermost atomic layers of any material. In this regard, the technique is particularly suited for determining surface chemistry of mineral particles from a variety of mineral-related applications. The ToF-SIMS technique utilizes an energetic primary ion beam to sputter (remove) and ionize small amounts of the sample surface including material adsorbed onto the sample surface. The strengths of the ToF-SIMS technique are that: (1) non-destructive and comprehensive surface analysis capable of detecting and quantifying inorganic and organic species; (2) minimum detection limits in the low ppm and sub-ppm range; (3) imaging capabilities with spatial resolution down to 0.3μm; and (4) elemental depth profiling. ToF-SIMS is most commonly used to quantify the preg-robbing capability of carbonaceous material in the Carlin-type gold deposits and other gold ores

containing organic carbon. It is also used as a diagnostic tool to measure mineral surface chemical variability in plant and bench top flotation separation processes during ore processing.