MICROCALORIMETER X-RAY DETECTORS WITH X-RAY LENS

This invention relates to microcalorimeter detectors used as x-ray spectrometers and, more specifically, to a microcalorimeter detector in an electron microscope having improved x-ray collection efficiency.

BACKGROUND OF THE INVENTION

Every element in nature emits x-rays when excited, such as when bombarded by high energy electrons. The emitted x-rays have a set of characteristic energies. When an x-ray is detected and its energy accurately determined, one can infer from the energy the constituent element from which it originated. For example, if x-ray measurement is taken on an unknown sample having many different constituent elements, the x-rays collected from the unknown sample can be tabulated according to energy in an x-ray spectrum. Analysis of the spectrum enables the deduction of the constituent elements and analysis of intensity indicates concentration. This is the basic approach for a class of analytical measurement instruments serving a wide variety of industries ranging from mining (ore composition) to semiconductor fabrication (composition and contaminant determination).

Commercial instruments today are primarily based on one of two detector technologies. The most widely used technology is Energy Dispersive Spectroscopy (EDS) which uses a crystal of silicon cooled to 77 degrees Kelvin as the detecting element. In the EDS technique, the x-rays strike the silicon creating mobile electrons which move under the influence of an applied electric potential. An amplifier is used to measure the electrical current of these electrons, the magnitude of the current being proportional to the energy of the x-ray that interacted with the crystal. Because silicon detectors typically have collection areas that are greater than 9 mm^2, and can be placed within one to two centimeters of the sample, good collection efficiency is possible. However, because of the statistical noise inherent in the detection process, a limiting energy resolution of only about 100 electron volts (eV) is obtainable.

Wavelength Dispersive Spectrometers (WDS) constitute the second commonly used type of detector technology. In WDS, x-rays from the sample under test are defracted by an analyzer crystal at angles that depend on the x-ray energy. WDS detectors have good energy resolution, approximately ten to twenty eV, but they have a small collection angle. Two additional difficulties with WDS are that the analyzing crystal must be mechanically rotated for each energy to be measured, and that the collection efficiency changes as this rotation occurs. Thus the WDS technique is difficult for spectroscopy.

The type of detector used in the invention is the x-ray microcalorimeter. This device is based on calorimetry: when the x-ray is absorbed, its energy is converted into heat and the subsequent temperature rise is proportional to the x-ray energy. Because the actual x-ray energy is quite small, the heat capacity of the detector must also be small so that a relatively large temperature rise is observed. This is accomplished by operating the device at very low temperatures where materials have lower heat capacities, and by minimizing the size of the detector. Microcalorimeter x-ray detectors have obtained energy resolution as good as 8 eV and have the potential to achieve 0.5 eV. It is easier to obtain good energy resolution when the detectors are made with small absorbing area. Present detectors, which have areas of 0.1 to 0.25 mm^2, are typically placed from approximately 2–3 cm from the sample and thus have collection efficiencies that are significantly smaller than EDS systems. This is an important disadvantage, causing long x-ray collection times.

In designing a microcalorimeter spectrometer system, the inventors herein recognized that the significant advantage of the microcalorimeter, i.e., a large improvement in resolution over other detectors is facilitated by a small detector size. Small detectors, however, have the disadvantages of poor collection efficiency and long collection times. The invention herein describes the solution to these problems which the inventors have devised.

Accordingly, an object of this invention is to improve the collection efficiency of microcalorimeters, thereby reducing the collection time of x-ray samples.

Another object of the present invention is to provide a microcalorimeter with an increased effective collection area that is substantially independent of x-ray energy over a broad energy range.

Another object of the invention is to provide a microcalorimeter with an increased effective collection area that is substantially independent of alignment between the microcalorimeter and the x-ray source, as may be necessary in systems in which the sample is scanned, such as in a scanning electron microscope.

These and other features and objects of the invention and the manner of attaining them will become apparent and the invention itself will best be understood through the following description of embodiments with the accompanying drawing.

SUMMARY OF THE INVENTION

The objects of the invention are achieved by a system which utilizes a broadband polycapillary x-ray lens positioned between a microcalorimeter and an x-ray source at the two respective focal points of the lens. Recent developments in polycapillary lenses allow x-rays to be collected over an approximately 22 degree opening angle, and then focused to a spot size of about 100 micrometers. Even though microcalorimeters are of small area, they have absorber sizes. greater than 100 micrometers, and therefore the system has a very high collection efficiency. Polycapillary optics are now available with the proper focusing capabilities and can readily be mounted on existing microcalorimeter x-ray detector systems. Because the lens focuses x-rays over a broad energy range, from 200 eV to over 10 keV, the lens is compatible with spectroscopic applications for materials analysis and the collection angle is large enough for practical measurements in materials analysis. An advantage of the invention is that the increase in effective collection area of the microcalorimeter corresponds to a reduction in the time period needed for x-ray collection. The invention also allows placement of the microcalorimeter detector farther from the x-ray source than current designs, which is advantageous for interfacing the detector to a scanning electron microscope or a transmission electron microscope. Another advantage of the present invention is that the effective collection area is improved for a broad energy range of x-rays, thus providing compatibility with spectroscopic applications for material analysis.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a prior-art EDS detector used in an electron microscope that is positioned relative to an electron beam and a sample.