PARTICLE CALORIMETER WITH NORMAL METAL BASE LAYER

CROSS REFERENCE PATENTS

Incorporated herein by reference are U.S. Pat. Nos. 4,869,558, 5,090,819, and 4,943,559.

FIELD OF INVENTION

The present invention relates to micro calorimeters used as x-ray spectrometers. A normal metal base layer collects energy produced by an x-ray interacting with an absorber, with the heat generated by the x-ray raising the base layer temperature which is held near absolute zero temperature. A normal metal-insulator-superconductor (NIS) tunnel junction(s) detects current changes corresponding to the energy of the incident x-ray.

BACKGROUND OF THE INVENTION

GLOSSARY

Photon—a quantum of electromagnetic radiation, equal to Planck's constant multiplied by the frequency in hertz.

Normal Metal—Any metal not in a superconducting state, e.g. silver, gold, copper.

Quasi Particle—fundamental energy excitation of a superconductor similar to an electron

Microbolometer—device for measuring very small energy levels of microwave and infrared energy.

Tunnel junction—an electron device that allows quantum mechanical tunneling of electrons through an insulating barrier whose thickness is a few nanometers.

Particle—any object which has a quanta of energy that can be absorbed by the calorimeter. examples are: optical, ultra violet, x-ray, and gamma ray photons; proton, neutron and alpha particles; ions, and neutral atoms; molecules; and phonons.

Phonon—a quantum of vibrational energy of atoms in a solid, equal to Plank's constant multiplied by the frequency in hertz.

Semimetal—metal such as bismuth with very low conduction-electron density.

Superconductor—certain metals, alloys, and compounds in which the resistance drops essentially to zero below a critical temperature near absolute zero.

Radiation detectors are crucial components of many commercial and scientific measurement apparatuses. Because of the wide use of radiation detectors, there has been much development of these kinds of detectors to measure the many different types of radiation and to measure them more accurately. Although the invention discussed here can be used as a general purpose radiation detector, we will initially describe the detection of X-rays since this is the most immediate application of the present invention. Our x-ray detector gives more accurate energy resolution and higher speed than other competing technologies.

Every element in nature emits X-rays with a characteristic or a set of characteristic energies. When an X-ray is detected and its energy accurately determined, then one can simply infer from the energy the constituent element it came from. Typically one measures an unknown sample with many different constituent elements. The x-rays and their energies collected from the unknown sample is then displayed according to energy in an x-ray spectrum, from which the constituent elements can be deduced. This basic idea is behind a large class of analytical measurement instruments that serves a wide variety of industries ranging from mining (ore composition) to semiconductor fabrication (composition and contaminant determination).

Energy resolution of the x-ray detector is a major specification for these type of x-ray radiation detectors. The better the resolution for the detection of x-rays, the more reliably one can "tag" that particular x-ray with an element. Because of other imperfections and background x-ray signals that are always present in a measurement system, improved x-ray energy resolution also allows one to better determine how much (the percentage) of a given element is present in an unknown sample.

It is always useful to take an x-ray spectrum with as many x-ray events (or counts) as possible. This makes the "signal" of the x-rays as large as possible as compared with the background "noise" that is always present in a real measurement. The capability to take a spectrum with more counts are generally given through two other important specifications. One is the area of the x-ray detector. Since the detector always has to be located at a finite distance away from the sample, it can intercept only a fraction of x-rays that are emitted from the sample. Increasing the area of the detector is thus desirable as it subsequently increases the number of x-rays that can be detected. The last important specification is the maximum permissible count rate of the x-ray detector. One typically operates these instruments by taking an x-ray spectrum such that it gives a fixed number of total counts. The spectrum is then accumulated over a time from typically several minutes to hours. A faster count rate allows the x-rays to be collected over a smaller time period. Improvements in speed can be very important for real applications. For example, a factor of 100 increase in maximum count rate reduces a measurement time of 10 hours to one that only takes six minutes. This large decrease in measurement time is obviously very important for scientific and commercial applications.

Commercial instruments today are primarily based on two detector technologies. The most widely used is called an Energy Dispersive Spectrometer (EDS) which uses a crystal of silicon cooled to 77 Kelvin. At low temperature the electrons in the silicon are frozen into their atomic positions and no electrical current flows. However, when an x-ray interacts with the silicon it breaks the atomic bond of an electron and allows it to freely flow through the crystal. An amplifier then measures the electrical current from these electrons moving through the crystal, with the magnitude of the current being proportional to the energy of the x-ray that interacted with the crystal. (The higher the x-ray energy, the more electrons are freed from their positions, giving more electrical current.) This technology is now quite mature and has leveled out to a resolution of about 130 eV (electron volts), and maximum count rate of about 3 thousand/second, and a collection area of 2–4 mm^2.

CHART I

SUMMARY OF ENERGY DISPERSIVE SPECTROMETER (EDS)

Method of Operation	X-ray hits a sensor and creates an electric current
Resolution	130 eV for 5000 eV X-ray
Sampling Speed	3,000–10,000 counts per second
Collection Area	2–4 mm^2
Operating Temperature	Usually 77k, liquid nitrogen

Wavelength Dispersive Spectrometers (WDS) constitute a second type of detector technology which diffract x-rays from a crystal at angles that depend on the x-ray energy. These detectors have a good energy resolution of approxi-