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Commentary

Micro Electro Mechanical Systems (MEMS) in Geological Applications

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DESCRIPTION

Micro devices or systems that integrate microstructures, micro-transducers, and micro-actuators with signal processing and control circuits are known as Micro Electro Mechanical Systems (MEMS). The Integrated Circuits (IC) with critical dimensions in the micrometer to millimeter range are the source of their fabrication technology. MEMS sensors are devices made by micro fabrication technology that detect physical or chemical quantities utilizing silicon, quartz, metal, or other semiconductor materials. MEMS sensors have the built-in advantages of being small, light, integrable, and able to be mass produced, making them less expensive than conventional sensors. As a result, they have been widely used in a number of new domains during the past thirty years and are now taking the place of traditional sensors in low to medium-end application fields. High-precision MEMS sensors, such as MEMS seismic sensors for oil exploration, have become common in the geophysical and resource search fields over the past ten years. However, the requirements for geophysical and exploration application do not yet have a systematic analysis and summary.

A sequence of vibrations known as earthquake are caused by the abrupt rupture and rebound of rocks where elastic strain has been gradually building up. In order to determine an earthquake's location, depth, magnitude, and seismic intensity, seismic sensors are employed to monitor them. The information gathered can be used to minimize the effects of natural disasters and comprehend how geological disasters develop. In order to reduce the number of fatalities and injuries, short-term earthquake forecasting can also be used to take advantage of the interval between the faster P-wave and the more destructive surface wave. Strong-motion and weak-motion seismometers are two types of seismic sensors that can distinguish between measurable seismic intensity. Weak-motion seismometers, such as the commercial macroscopic devices CMG-3T from Guralp and Trillium 120 from Nano metrics, typically have self-noise levels less than 1 ng/Hz. The model STS 2.5 from Kinemetrics is one example of a high-end seismometer with an even lower noise floor than the Earth's New Low Noise Model (NLNM). The noise floor of strong-motion seismometers, on the other hand, is typically higher than 1 g/Hz. Examples of these seismometers include several high-resolution force-balance accelerometers, such as the models CMG-5U from Guralp and Epi-sensor from Kinemetrics. Tilt-meters or angular accelerometers are needed to measure the tilt angle and then compensate to reduce sensitivity error because atmosphere and other effects induced tilt cannot be distinguished by a single seismic sensor due to the equivalence principle of inertial acceleration and gravitational acceleration. Since earthquake signals typically range in frequency from 8.3 mHz (120 s) to 50 Hz, seismometers and angular accelerometers must have the bandwidth to accommodate this range.

In addition to being a necessary process for oil and gas development, seismic exploration is also widely applied in geological surveys and earth's crust research. Geophones and seismometers clearly differed before MEMS technology was applied to seismology. Traditional geophones are passive, coil-magnet-based devices that react to ground motion above their natural frequency, which is between 1 and 60 Hz. Seismometers, as opposed to geophones, are better suited for detecting extremely slow and minor ground motions, typically between 0.01 to 50 Hz, which encompasses the frequency range below their natural frequency. The distinction between geophones and seismometers has become less evident as a result of the development of MEMS-based geophones, which are essentially highly sensitive MEMS accelerometers that can operate across a wide frequency range from DC to 500 Hz.

Magnetic exploration has gradually advanced, necessitating high-performance magnetic sensors, due to advancements in maritime survey, resource exploitation, and magnetic sensor technologies. Magnetic sensors can be classified as fluxgate, induction, SQUID, proton, atomic, and MEMS magnetometers, which include micro fluxgate, Hall, magneto-resistance, and resonant magnetometers, based on their operating principles. For resource exploration and geophysical applications, magnetometers must have a measuring range of between 10 pT and 100 T. The applications for MEMS sensors in geological fields are numerous.

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