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ELECTROCHEMICAL SENSOR TRANSDUCERS

The basic design of the transducer, shown in Figure 1 (US Patent # 6,576,103). The transducer is contained in a channel, (1), filled with a specially prepared electrolytic solution. It consists of four fine platinum mesh electrodes, namely, two anodes, (2), and two cathodes, (3), separated by thin, microporous polymer spacers (4). A housing (5) tightly holds the assembly together. To measure the motion of the fluid, it must be converted into an electrical signal. One way of achieving this is by using the convective diffusion of the ions in the electrolyte.

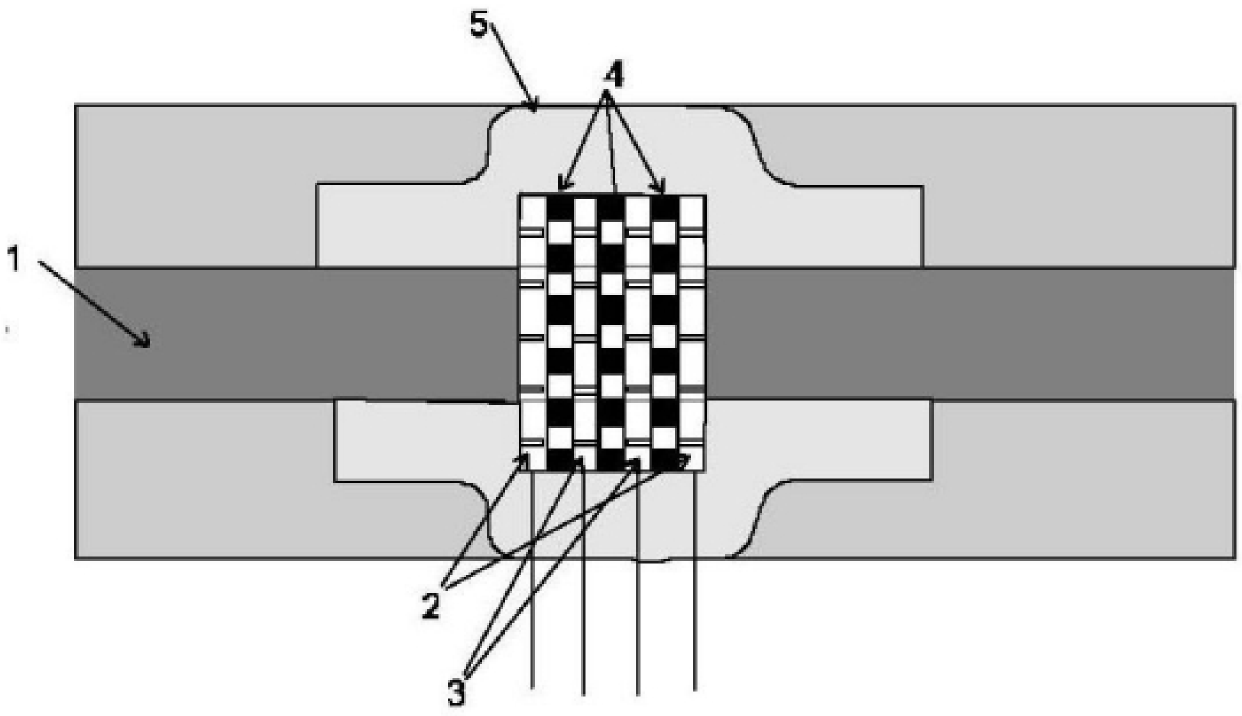

FIGURE 1: TRANSDUCER

1 - Electrolyte channel
2 - Platinum mesh anodes
3 - Platinum mesh cathodes
4 - Microporous spacers
5 - Housing

When a small dc offset is applied between the anodes and cathodes, the flow of ions of each type is given by the following expression:

Equation 1:

$$\mathbf{j}_a = -D \cdot \nabla c_a + q_a \cdot c_a \cdot \mu \cdot \mathbf{E},$$

where D = diffusion coefficient, μ = mobility, c_a = concentration of active ions, **E** = the electrical field vector. Since the electrolyte is a good conductor, the electric potential drops rapidly in the vicinity of the electrodes, and there is no electric field, **E**, in the bulk of the fluid. The second term in Eq. 1 can therefore be ignored. Thus, the application of a bias voltage results *only* in a concentration gradient. This is in contrast both to conductors, in which the current is driven by the external electric field, and to semiconductors, in which both the field and the concentration gradient determine the currents.

An external acceleration, **a**, along the channel creates a pressure differential, **ΔP**, across the transducer, which forces the liquid in motion with a velocity, **v**. This flow of electrolyte entrains ions and causes an additional charge transfer between the electrodes:

Equation 2:

$$\mathbf{j}'_a = \mathbf{v} \cdot c_a \cdot$$

The total current from active ions, in the presence of acceleration, will thus be:

Equation 3:

$$\mathbf{j}_\mathbf{a} = -D \cdot \nabla c_a + \mathbf{v} \cdot c_a$$

The transducer thus generates an electrical signal in response to an input motion. The symmetric geometry of the cell ensures its linear behavior over a wide range of input signals.

With a highly concentrated electrolyte, the electric field is non-zero only in a narrow boundary layer adjacent to the electrodes. In this case, the electric current in the absence of electrolyte flow is fully determined by the diffusion. If such a transducer cell is incorporated into a motion sensor, the latter can be used, for example, to respond to linear motion (or to angular motion in a different sensor design).

Electrochemical transducers are characterized by a very high conversion coefficient of mechanical motion into electrical signal. That is why the electronics noise plays a noticeably smaller role in the total signal-to-noise ratio than in the traditional electromechanical seismic motion sensors. Also this results is a very low power consumption, which can be several times smaller than in any other active seismometers.

Electrochemical sensor noise is determined by the damping factor, and has a constant spectral density over its passband and beyond:

Equation 4:

$$\langle a^2 \rangle_\omega = \frac{2R_h kT}{(\rho \cdot L + m/S)^2}$$

where R_h= cell's hydraulic impedance; ρ = electrolyte density; L = electrolyte dimension along the sensitivity axis, m – total inertial mass; S – transducer characteristic cross-section. Electrochemical sensor noise may be controlled largely by varying the four parameters: R_h; L; m; S. Out of these four, L is the least practically useable parameter since increasing it results in significantly larger seismometers. Reduction of R_h requires significantly larger use of very expensive platinum mesh and a more sophisticated transducer cell design and thus is justified only in the top-of-the-line, very low noise, very broad band seismometers. Changing sensor's inertial mass is the most straightforward and practical way of controlling noise.

In order to increase the dynamic range of motion sensors and stabilize their parameters it is necessary to use a force-balancing feedback. In this respect electrochemical motion sensors are no different than their electromechanical counterparts: both types employ electromagnetic feedback (moving voice coil and a strong permanent magnet). However, electrochemical motion sensor design is significantly simpler since it does not require high precision mechanical parts and is extremely rugged. In addition, in an electrochemical sensor the inertial mass position have no effect of the output signal and thus it needs not to be tracked and/or adjusted. Neither are mass arresters required. Furthermore, such sensor remains fully operable at significant installation tilts (over ±10°). The latter feature along with above mentioned minute power consumption makes these seismometers ideally suited for field, borehole and especially ocean-bottom seismic applications.