

[0146] The resistive (in-phase) and capacitive (out-of phase) components of the impedance may be measured simultaneously using conventional impedance analyzing circuitry, preferably using a voltage waveform having a frequency at which both components have a significant effect on the impedance and/or a voltage waveform having a plurality of frequencies comprising at least one frequency where the resistance is a significant component of the impedance and at least one frequency where the capacitance is a significant component of the impedance. Alternatively, the resistive and capacitive components may be measured separately, preferably at frequencies that maximize the effect of the component being measured. For example, at high frequencies the effect of surface capacitance is minimized and the impedance is primarily due to solution resistance. In one embodiment of the invention, the solution resistance is measured by applying a voltage waveform having a frequency greater than 2000 Hz, more preferably between 2,000 and 100,000 Hz, most preferably around 20,000 Hz.

[0147] Sample matrix identification can be very important since certain biochemical assays may have varied steps or different post-processing requirements (e.g., the blood samples may be treated different than plasma samples). Tables 3 and 4 list resistance and capacitance values acquired for five different matrices by applying low voltage AC excitation to electrodes within an experimental cartridge. The electrode array comprised screen printed carbon ink electrodes, the exposed surface of which were defined by a patterned dielectric layer printed over the carbon ink. The impedance measurements were taken at 25 degrees C. using an excitation voltage equal to 0.010 V rms at the frequencies indicated in the tables. For capacitance measurements, since it is desirable to use a frequency where all (or nearly all) of the voltage drop occurs across the capacitive element, a frequency of 200 Hz was utilized as this was found to result in greater than 95% of the voltage drop to occur across the double layer capacitance; i.e., the solution losses were almost negligible. Resistance and capacitance were calculated using a series RC model.

[0148] As can be seen in Tables 3 and 4, the capacitance varied little between the different sample matrices, however, the resistances showed much greater variation among the matrices.

TABLE 3

| Sample Discrimination Using Capacitance Measurements (phase angles 76 to 82 degrees). | |
|--|---------------------------|
| Matrix | Capacitance, uF at 200 Hz |
| assay buffer | 0.023 |
| saline | 0.021 |
| serum | 0.019 |
| plasma | 0.018 |
| blood | 0.020 |

[0149]

TABLE 4

| Sample Discrimination Using Resistance Measurements (includes 700 ohms of lead resistance; phase angles 12 to 16 degrees) | |
|---|----------------------------------|
| Matrix | Resistance, ohms at 20,000 Hz |
| assay buffer | 2516 |
| saline | 3722 |
| serum | 3996 |
| plasma | 4158 |
| blood | 7039 |

[0150] In certain preferred embodiments the electrochemical current measured during the induction of ECL, may be used to detect the presence of trapped air over an electrode since trapped air may cause a significant decrease in the electrochemical current (e.g., current from TPA oxidation during ECL). FIG. 5 depicts an image of ECL emitted from an electrode array. One of the electrodes has a small dark spot 500 due the presence of a small air bubble on the electrode surface. Even such a small bubble gave a detectable change in the electrochemical current measured at that electrode during the ECL experiment; the current in the presence of the air bubble (178 uA) was significantly different (by 5%) than the average of the current at the other electrodes (187 uA). Other factors besides trapped air, e.g., errors in the printing of the electrodes, may change the effective area of an electrode and thus the measured current. The measurement of current during ECL can be used to check for these factors as well as for bubbles and can be used to trigger error flags if the current values fall out of an acceptable range or, alternatively, to allow for normalization of the reported ECL signal to compensate for the actual electrode area.

[0151] The bubble detection methods described above can also be employed to detect the presence of fluids, the presence of bubbles in fluids and/or identify classes of samples in compartments in an assay cartridge outside the detection flow cells. For example, certain preferred embodiments of assay cartridges comprise fluid inlet and/or outlet lines for introducing and removing fluids from the cartridge flow cells, wherein these inlet and/or outlet lines comprise fluid detection electrodes for detecting the presence of fluid, the presence of air bubbles in fluids and/or for identifying samples. These fluid detection electrodes may have independent electrode leads and contacts. So as to reduce the number of electrical contacts to the cartridge, these fluid detection electrodes, preferably, comprise exposed surfaces of the leads to assay electrodes (e.g., assay electrodes in the assay cartridge flow cells). In this arrangement, it is further preferred that the exposed leads in a given fluid volume (e.g., an inlet line or outlet line) do not comprise leads from two electrodes that will be fired together in an assay measurement (e.g., used as a working electrode counter electrode pair in an ECL measurement). In this fashion it is ensured that the assay measurements are not affected by low resistance current paths between exposed leads.

[0152] With reference to the simplified embodiment depicted in FIG. 4, use of the impedance sensors 425 for detection of fluid presence and/or discrimination within the