distance between the first and second electrodes, the capacitance between the first and second electrodes increases and the signal in the amplifier increases. Thus, in operation, the current measured with the amplifier can be set at zero (or another baseline value) when the capacitive device is in a rest state and any change in current flow and the related capacitance can be measured by the amplifier within a given sensitivity range. As a result, the capacitive devices of the present invention are capable of detecting differences in an applied force over a continuous range of applied force including zero force.

[0031] Also, as mentioned above, the changes in capacitance may be indicative of other information related to the applied force. For example, information related to the application of force applied to the capacitive device over a predetermined time period may be used to determine characteristics of the force such as, for example, whether the applied force was an impact force, the acceleration by which the force was applied, or the magnitude of the force, etc., depending on the capabilities of the system in which the capacitive device is incorporated.

[0032] One preferred embodiment of a capacitive device of the present invention may be well suited for use with a computer monitor. Such an embodiment may have first electrodes that include spring-tempered phosphor bronze in a flattened sheet stock having a thickness of about 0.2 mm. The first electrodes may be cut into a rectangular shape having dimensions of about 3.05 mm by 5.84 mm using a high precision method such as electric discharge machining. A dimple may be formed in the electrode using a specially designed dye that creates a dimple of about 0.2 mm in height. The first electrodes may be lapped to ensure proper thickness of the electrodes using, for example, a 30 micron diamond film for about 10 strokes. An example of a diamond film suitable for lapping is an imperial diamond film, for example, made by 3M Company. The first electrodes may then be rinsed with water and/or sonicated in an acetone base and then dried.

[0033] The substrate of the capacitive device may be a printed circuit board (PCB) having a thickness of about 0.79 mm with four ounce copper and plated with white tin (for example, PCB supplied by OnTime Circuits, Inc., Hoffman Estates, Ill.). Before use, the PCB may be lapped, for example, on a 30 micron diamond film until flat and the entire tin layer is removed. PCBs lapped with this method have been measured to be flat within about +/−1 micron. In many applications, this degree of lapping may not be required to obtain the desired results. The lapped PCBs may be rinsed with water and/or sonicated in acetone and then dried.

[0034] The connecting material may include a solder base, such as an F541 series product supplied by Heraeus, Inc., West Conshohocken, Pa. The solder balls used in this paste are type 4 (−400/+500 mesh) and made of 63SN/37PB alloy. Preferably, the flux used in this solder paste is about 10% volume or less of the paste.

[0035] The structured elements used in the connecting material may have a variety of different shapes and sizes. For example, the structured elements may be spherical shaped or pyramid shaped. Preferably, the structured elements have a predictable landing position such that a predetermined maximum dimension of the structured element will define the spacing between two objects.

[0036] One example of a structured element having particular relevance for a capacitive device using the electrodes and printed circuit boards discussed above are spherical shape Zeeospheres™ made by 3M. The structured elements preferably have a predetermined maximum dimension of about 20 to 80 microns, and most preferably about 25 microns. The structured elements are also present in the connecting material in an amount to yield about 1 to 10% volume, with about 2% volume being most preferred. Mixing of the structured elements in the connecting material can be performed in one particular embodiment as follows:

[0037] 0.096 grams G-400 Zeeospheres™ are added to a 2 dram vial.

[0038] 10 drops (~0.15 gram) Indium Flux No. 4 (Indium Corporation of American, Utica, N.Y.) are added to the vial. Extra flux is added as required to aid in dispersion of the Zeeospheres™ in the solder paste.

[0039] The vial is capped and shaken, and then placed in a sonicator bath for a predetermined time period (typically about five minutes) in order to disperse the spheres. Sonification typically results in an increased viscosity of the Zeeospheres™/flux premix.

[0040] About 19.2 grams of F541SN63-90M4 solder paste (supplied by Heracus, Inc., West Conshohocken, Pa.) is then added to the Zeeospheres™/flux premix.

[0041] The paste/Zeeospheres™/flux mixture is then mixed until homogenous.

[0042] The vial is capped and stored in a cool environment, such as a refrigerator, when not in use.

[0043] Other connecting materials may be composed using alternative materials having different properties than those recited in the above example.

[0044] As discussed above, the second and third electrodes of the capacitive device may simply be traces formed on a printed circuit board. However, in some embodiments the second and third electrodes may be separate pieces of material that are mounted to the printed circuit board and separately electrically connected.

[0045] Assembly of the capacitive device according to a method of the invention may include several steps. Generally, a method of manufacturing a capacitive device capable of detecting differences in an applied force over a continuous range of applied force including zero force may require a device that includes opposing first and second electrodes spaced apart a predetermined distance when in a rest state. The device includes a capacitance controlled by the relative spacing between the first and second electrodes. The method may include the steps of spacing apart the first and second electrodes the predetermined distance using structured elements that have a predetermined maximum dimension. As a result of this predetermined spacing, an applied force causes a change in the distance between the first and second electrodes and a related change in the capacitance that can be measured to determine information related to the applied force.

[0046] A method of assembling or manufacturing a capacitive device of the present invention may include the