by exploiting e.g., through-holes interconnecting the plural layers. When the piezo actuator **21** is bowed, the center area of the piezo actuator **21** is deformed to a lesser extent than the other area, in order to prevent the piezo actuator **21** from becoming damaged at this time.

[**0052**] The piezo actuator **21** in its entirety may be covered by e.g. a polymer material, in order that the user will not become aware of the electrode mounted to the piezo actuator **21**. It is also possible to use a casing in which to accommodate the piezo actuator **21**. Any suitable type of the casing may be used, provided that such casing allows the center area of the piezo actuator **21** to be deformed.

[**0053**] Since the force of bowing of the piezo actuator **21** is directly proportionate to the voltage, and the piezoelectric element of the multi-layered structure is exploited, the piezo actuator **21** of the present embodiment is able to present tactile feedback by vibrations large enough to be recognized by the user.

[**0054**] FIG. **4** shows an example of a particular structure of the operating unit **20** constituting the system shown in FIG. **1**. In FIG. **4**, a control apparatus **200** for playing a game, provided with a piezo actuator **204**, is shown. The piezo actuator **204** is constructed similarly to the piezo actuator **21** described above.

[**0055**] A casing **203**, included in the control apparatus **200** for playing a game, has an inner structure and a spacing for holding the piezo actuator **204** therein and for allowing the piezo actuator **204** held therein to be bowed in an up-and-down direction when the piezo actuator **204** presents an upturned or downturned dome shape. A stopper **201** plays the part of preventing excessive bowing of the piezo actuator **204** when the user is running the program of the control apparatus **200** for playing a game. A cover **202** is provided for convenience in user's operations and for preventing the user from directly contacting the piezo actuator **204**. For the cover **202**, a cap formed e.g. of rubber may be used. The component forming the cover **202** is preferably such a component that does not appreciably attenuate the vibrations generated by the piezo actuator **204**.

[**0056**] The piezo actuator **204** is mounted to the casing with its peripheral part to permit its center portion to be displaced in the up-and-down direction responsive to driving signals.

[**0057**] The piezo actuator **204** is bonded or mounted with an adhesive. Or, it may be simply retained by any proper mechanical structure. For example, the piezo actuator **204** may be immovably fitted in a groove formed in a wall section of the casing **203**. The principal condition, imposed in this structure, is that it is possible to prevent the piezo actuator **204** from becoming excessively bowed on user actuation, as the bowing in the up-and-down direction of the piezo actuator **204** is allowed. It may be said that the stopper **201** is provided in this particular embodiment for preventing this excessive bowing.

[**0058**] Turning to the structure of the control apparatus **200**, such a structure prohibiting such excessive bowing or bowing in a direction different than the direction perpendicular to the actuator surface is desirable. It is also more desirable that the piezo actuator **204** is mounted to the control apparatus **200** in such a manner that, when the user acts on the control apparatus **200**, the force will be acting only in a direction perpendicular or substantially perpendicular to the surface of the piezo actuator **204**.

[**0059**] The interfacing element **22**, such as a switch or a button, may be provided within the casing **203**, or to a lower portion of the casing **203**, so that these elements may be controlled to be on or off when the user has pressed the control apparatus **200**.

[**0060**] The user's inputting operation may also be measured using the piezo element itself. For example, when the control apparatus **200** is acted on by the user, the piezo element, enclosed within the control apparatus **200**, is bowed to generate a signal. The input applied to the control apparatus **200** by the user may be detected with this signal. Of course, this same piezo element may be used to provide tactile feedback.

[**0061**] FIG. **5** shows an example of an operating unit **300** of a simplified structure having the built-in piezo actuator. In the example of FIG. **5**, a piezo actuator **302** of a circular profile, such as is shown in FIGS. **3**A to **3**C, is mounted on a button having a corresponding circular profile (interfacing element **22**). The piezo actuator **302** is covered up by a cover **303**.

[**0062**] FIG. **6** shows an example of an apparatus in which the piezo actuator embodying the present invention is built in a control apparatus **400** for playing a game. In this example, as in the example shown in FIG. **5**, a piezo actuator **302***a* is mounted to an operating part **301***a* of a joystick, provided to the control apparatus **400** for playing a game. A cover member **303***a*, formed e.g. of rubber, is further mounted to the piezo actuator **302***a*.

[**0063**] The present invention is not limited to the above embodiments explained with reference to the drawings and, as will be apparent to those skilled in the art, various changes, substitutions or equivalents may be attempted without departing from the scope of the invention as defined in the appended claims.

## INDUSTRIAL UTILIZABILITY

[**0064**] The tactile feedback according to the present invention is not limited to the above-described embodiments. For example, the present invention may be applied to other usages, such as mobile or portable devices in need of mechanical switches or controllers, such as remote controllers for PDA, mobile phone, wearable computers, or personal music playing apparatus. In particular, the tactile feedback according to the present invention is suited for use in a controller for playing a game which is capable of providing tactile feedback.

What is claimed is:

**1**. A tactile feedback apparatus comprising

an interfacing element acted on by a user;

a piezo actuator arranged on said interfacing element for presenting tactile feedback to a user acting on said interfacing element; and

a controller for driving controlling said piezo actuator;

said piezo actuator being of a circular-shaped multi-layered structure and having a shape changed to an upturned dome shape or to a downturned dome shape on application of voltages of opposite polarities to a