

CLAIMS

What is claimed is:

1. A fluid jet dispenser comprising:

a support frame having a fluid passageway;

a fluid chamber for containing a pressurized fluid and coupled to the fluid passageway;

a piston;

a nozzle; and

a dispensing head comprising:

at least two d_{31} -mode multilayer piezoelectric actuators, each comprising multiple electrode layers and multiple piezoelectric layers, wherein the multiple piezoelectric layers comprise d_{31} -mode piezoelectric layers with polarization substantially perpendicular to a utilized displacement direction of the piezoelectric actuator upon charging of the piezoelectric actuator; and

an electrical driver electrically coupled to the at least two d_{31} -mode multilayer piezoelectric actuators and configured to deliver anti-phase driving pulses to the at least two d_{31} -mode multilayer piezoelectric actuators to charge and discharge the at least two d_{31} -mode multilayer piezoelectric actuators to drive them backward and forward in anti-phase mechanical displacement in the utilized displacement direction,

wherein the piston is coupled to the at least two d_{31} -mode multilayer piezoelectric actuators configured to dispense the pressurized fluid through the nozzle in response to the anti-phase mechanical displacement thereof.

2. The fluid jet dispenser, in accordance with Claim 1, further comprising a displacement magnifying element coupled between the at least two d_{31} -mode multilayer piezoelectric actuators and the piston and configured to move the piston relative to the nozzle between an open position to let the pressurized fluid flow from the nozzle and a closed position to establish a fluid seal between the fluid passageway and the nozzle.

3. The fluid jet dispenser, in accordance with Claim 1, wherein the at least two d_{31} -mode multilayer piezoelectric actuators comprise multiple piezoelectric ceramic layers and multiple metal layers comprising a ceramic composition having a sintering temperature of 950°C or below.

4. The fluid jet dispenser, in accordance with Claim 3, wherein the multiple metal layers comprise one or more metals selected from the group comprising silver, a nickel alloy, a copper alloy, or a silver-palladium alloy having a low palladium concentration of ≤ 10 wt %.

5. The fluid dispenser, in accordance with Claim 1, wherein each of the multiple piezoelectric ceramic layers has a perovskite phase which is substantially away from a morphotropic phase boundary of the piezoelectric ceramic composition of the multiple piezoelectric layers.

6. The fluid jet dispenser, in accordance with Claim 1, wherein the anti-phase mechanical displacement of the at least two d_{31} -mode multilayer piezoelectric actuators is configured to induce a push-pull force on the piston.

7. The fluid jet dispenser, in accordance with Claim 1, wherein the electrical driver comprises at least two electrical driver circuits, each of the at least two electrical driver circuits coupled to one of the at least two d_{31} -mode multilayer piezoelectric actuators, and wherein each of the at least two electrical driver circuits is configured to supply one of the anti-phase driving pulses to one of the at least two d_{31} -mode multilayer piezoelectric actuators to generate the anti-phase mechanical displacement of the one of the at least two d_{31} -mode multilayer piezoelectric actuators.

8. The fluid jet dispenser, in accordance with Claim 1, wherein the electrical driver comprises:

a reserve capacitor;

a high voltage supply, coupled to the reserve capacitor and configured to charge the reserve capacitor;

a push-pull switch coupled to the reserve capacitor, electrical ground and the at least two d_{31} -mode multilayer piezoelectric actuators, the push-pull switch configured to charge and discharge the at least two d_{31} -mode multilayer piezoelectric actuators by alternately coupling each of the at least two d_{31} -mode multilayer piezoelectric actuators to the reserve capacitor for charging or the electrical ground for discharging; and

a signal controller unit configured to provide control signals to the push-pull switch to charge and discharge the at least two d_{31} -mode multilayer piezoelectric actuators.

9. The fluid jet dispenser, in accordance with Claim 8, wherein the reserve capacitor is configured to be pre-charged by the high voltage supply to provide a huge transient current to charge the at least two d_{31} -mode multilayer piezoelectric actuators rapidly when coupled to the at least two d_{31} -mode multilayer piezoelectric actuators by the push-pull switch.

10. The fluid jet dispenser, in accordance with Claim 8, wherein the reserve capacitor is configured to store an electrical output of the high voltage supply for pre-charging thereof, and wherein the reserve capacitor consists of one or more of an electrolyte capacitor, a ceramic capacitor, a tantalum capacitor, and a polymer capacitor.

11. The fluid jet dispenser, in accordance with Claim 8, wherein the push-pull switch comprises a push-up circuitry configured to be switched on to electrically connect one or more of the at least two d_{31} -mode multilayer piezoelectric actuators to the reserve capacitor for charging, and a pull-down circuitry configured to be switched on to electrically connect one or more of the at least two d_{31} -mode multilayer piezoelectric actuators to the electrical ground for discharging, wherein the switching states of the push-up circuitry and the pull-down circuitry are configured to be complementary to each other.

12. The fluid jet dispenser in accordance with Claim 11, wherein the push-up circuitry and the pull-down circuitry each comprise a pair of transistors in a cascading arrangement.

13. The fluid jet dispenser, in accordance with Claim 8, wherein the push-up circuitry and the pull-down circuitry each comprises multiple transistors in parallel connection, all the parallelly-connected transistors coupled to the at least two d_{31} -mode multilayer piezoelectric actuators at drain terminals of the parallelly-connected transistors.

14. The fluid jet dispenser, in accordance with Claim 8, wherein the high voltage supply comprises a boost converter or a charge pump and is configured to generate a high voltage level output by stepping up from a low voltage level.

15. A fluid dispenser comprising:

at least two d_{31} -mode multilayer piezoelectric actuators, each comprising multiple electrode layers and multiple piezoelectric layers, wherein the multiple piezoelectric layers comprise d_{31} -mode piezoelectric layers with polarization substantially perpendicular to a utilized displacement direction of the piezoelectric actuator upon charging of the piezoelectric actuator; and

an electrical driver electrically coupled to the at least two d_{31} -mode multilayer piezoelectric actuators for charging and discharging the at least two d_{31} -mode multilayer piezoelectric actuators to drive them backward and forward in anti-phase mechanical displacement in the utilized displacement direction,

wherein each of the multiple piezoelectric layers comprises a perovskite phase which is substantially away from a morphotropic phase boundary, and
wherein the piezoelectric ceramic composition includes $0.1\text{Pb}(\text{Ni}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - $0.35\text{Pb}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - $0.15\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - 0.1PbZrO_3 - 0.3PbTiO_3 with 4 mol% excess NiO (0.1PNN - 0.35PZN - 0.15PMN - 0.10PZ - 0.3PT - 0.04NiO).

16. A piezoelectric ceramic actuator comprising:
multiple metal electrode layers; and
multiple piezoelectric ceramic layers, wherein the multiple piezoelectric ceramic layers comprise d_{31} -mode piezoelectric layers, and wherein a polarization of the d_{31} -mode piezoelectric layers is substantially perpendicular to a direction of utilized displacement of the piezoelectric ceramic actuator upon charging of the piezoelectric ceramic actuator, and
wherein the d_{31} -mode piezoelectric layers comprise a ceramic composition having a sintering temperature of $950\text{ }^\circ\text{C}$ or below, and
wherein the multiple metal electrode layers comprise metal selected from the group comprising silver (Ag), a silver palladium alloy (Ag/Pd alloy) having a low palladium concentration of $\leq 10\text{ wt}\%$, nickel, a nickel alloy, copper, or a copper alloy,
wherein the composition of the d_{31} -mode piezoelectric layers has a perovskite phase which is substantially away from a morphotropic phase boundary, and
wherein the ceramic composition of the d_{31} -mode piezoelectric layers further includes $0.1\text{Pb}(\text{Ni}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - $0.35\text{Pb}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - $0.15\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - 0.1PbZrO_3 - 0.3PbTiO_3 with 4 mol% excess NiO (0.1PNN - 0.35PZN - 0.15PMN - 0.10PZ - 0.3PT - 0.04NiO).