Claims

1. A multi-layered piezoelectric ceramic-containing structure comprising:
   - a metal substrate;
   - a metallic adhesive layer on a surface of the metal substrate;
   - a non-metallic thermal barrier layer on the metallic adhesive layer; and
   - a lead-free piezoelectric ceramic layer sandwiched between a first electrode layer and a second electrode layer, wherein the first electrode layer is on the non-metallic thermal barrier layer,

wherein each of the metallic adhesive layer and the non-metallic thermal barrier layer has a thickness of ≥ 20 μm.

2. The structure according to claim 1, wherein the lead-free piezoelectric ceramic layer is a sodium potassium niobate-based or bismuth sodium titanate-based layer.

3. The structure according to claim 1, wherein the substrate comprises a base metal.

4. The structure according to claim 3, wherein the substrate is steel.

5. The structure according to claim 1, wherein the metallic adhesive layer comprises a metal or metal alloy.

6. The structure according to claim 5, wherein the metallic adhesive layer comprises NiCrAlY alloy.

7. The structure according to claim 1, wherein the non-metallic thermal barrier layer comprises an inorganic oxide.

8. The structure according to claim 7, wherein the non-metallic thermal barrier layer comprises yttria-stabilised zirconia (YSZ).

9. The structure according to claim 1, wherein the lead-free piezoelectric ceramic layer has a thickness of ≥ 20 μm.

10. The structure according to claim 1, wherein the non-metallic thermal barrier layer has a thickness of 100-500 μm.

11. The structure according to claim 1, wherein each of the first electrode layer and the second electrode layer has a thickness of ≥ 2 μm.

12. The structure according to claim 1, wherein the lead-free piezoelectric ceramic layer is formed by thermal spraying.

13. The structure according to claim 1, wherein each of the metallic adhesive layer and the non-metallic thermal barrier layer is formed by thermal spraying.

14. The structure according to claim 1, wherein the lead-free piezoelectric ceramic layer has an effective piezoelectric coefficient (d_{33}) of 50-130 pm/V.

15. A method of forming the multi-layered piezoelectric ceramic-containing structure according to claim 1, the method comprising:

- providing a metal substrate;
- depositing a metallic adhesive layer on a surface of the metal substrate;
- depositing a non-metallic thermal barrier layer on the metallic adhesive layer;
- depositing a first electrode layer on the non-metallic thermal barrier layer;
- depositing a lead-free piezoelectric ceramic layer on the first electrode layer; and
- depositing a second electrode layer on the lead-free piezoelectric ceramic layer.

16. The method according to claim 15, wherein the depositing a metallic adhesive layer, the depositing a non-metallic thermal barrier layer and the depositing a lead-free piezoelectric ceramic layer comprises thermal spraying.

17. The method according to claim 15, wherein the method further comprises heat treating the lead-free piezoelectric ceramic layer at a pre-determined temperature prior to the depositing a second electrode layer.

18. The method according to claim 17, wherein the heat treating comprises heat treating the lead-free piezoelectric ceramic layer with a flame at the pre-determined temperature.

19. A multi-layered piezoelectric ceramic-containing structure comprising:

- a metal substrate;
- a metallic adhesive layer on a surface of the metal substrate;
- a non-metallic thermal barrier layer on the metallic adhesive layer, the non-metallic thermal barrier layer having a thickness of 100-500 μm; and
- a lead-free piezoelectric ceramic layer sandwiched between a first electrode layer and a second electrode layer, wherein the first electrode layer is on the non-metallic thermal barrier layer,

wherein the metallic adhesive layer has a thickness of ≥ 20 μm.