would exist as additional noise and would also disturb ANC operation, resulting in noise mitigation performance degradation.

[0005] A need therefore exists to provide a noise management system for a window that seeks to address at least some of the above problems.

SUMMARY

[0006] According to a first aspect, there is provided a noise management system for a window, the system comprising: an active noise control (ANC) module disposed in or adjacent a ventilation channel of the window and configured to substantially cancel low-frequency noise entering the ventilation channel, the ANC module generating harmonic sounds; and a passive sound absorbing module disposed in or adjacent to the ventilation channel, the passive sound absorbing module comprising a sound absorption coefficient selected to absorb both high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

[0007] The ANC module and passive sound absorbing module in the present system can synergistically interact with each other, and the performance of ANC can be improved with the harmonic sounds from the ANC module being absorbed by the passive sound absorbing module. Advantageously, the overall noise mitigation performance with the combined ANC module and passive sound absorbing module can be superior to the sum of ANC effect and passive absorbing effect, separately.

[0008] The ANC module may comprise at least one multi-cell transparent electroactive film speaker comprising a plurality of electroactive cells, and each cell may be individually operable for generating a sound signal anti-phase to the low-frequency noise.

[0009] Each electroactive cell may comprise a transparent electroactive film, a transparent substrate, a transparent bottom electrode and a transparent top electrode.

[0010] The transparent electroactive film may comprise a transparent piezoelectric polymer or a transparent electroactive polymer.

[0011] The transparent piezoelectric polymer may comprise polyvinylidene fluoride (PVDF) or polyvinylidene fluoride-trifluoroethylene (P(VDF-TrFE)).

[0020] The mechano-electrical conversion elements and electro-thermal conversion elements may form a porous composite having a volume porosity of at least 85%.

[0021] The passive sound absorbing module may be capable of absorbing sounds having a frequency below 1 kHz.

[0022] The passive sound absorbing module may comprise a sound absorbing material having a sound absorption coefficient greater than 0.5 at frequencies above 600 Hz.

[0023] The sound absorbing material may have a sound absorption coefficient greater than 0.8 at a frequency of approximately 1 kHz.

[0024] According to a second aspect, there is provided a window system comprising at least one noise management system as defined in the first aspect.

[0025] The ANC module of the window system may comprise a plurality of multi-cell transparent electroactive film speakers spatially disposed at different locations along the ventilation channel.

[0026] The window of the window system may comprise a lower part having a lower ventilation channel and an upper part having an upper ventilation channel, and an ANC module may be disposed in or adjacent each of the lower and upper ventilation channels, and a passive sound absorbing module may be disposed in or adjacent each of the lower and upper ventilation channels.

[0027] The noise management system may be configured to provide a noise reduction index of at least 15 dB.

[0028] According to a third aspect, there is provided a method of managing noise, comprising: substantially cancelling low-frequency noise entering a ventilation channel of a window using an active noise control (ANC) module disposed in or adjacent the ventilation channel; absorbing high-frequency noise entering the channel using a passive sound absorbing module disposed in or adjacent to the ventilation channel; and absorbing harmonic sounds generated by the ANC module using the passive sound absorbing module, wherein the passive sound absorbing module comprises a sound absorption coefficient selected to absorb both the high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

[0029] The method of managing noise may further comprise detecting the low-frequency noise using a reference microphone before substantially cancelling the low-frequency noise.

[0030] The ANC module may comprise at least one multi-cell transparent electroactive film speaker comprising a plurality of electroactive cells, and substantially cancelling the low-frequency noise may comprise individually operating each cell to generate a sound signal anti-phase to the low-frequency noise based on the detection.

[0031] The method of managing noise may further comprise detecting a remaining noise after the absorption and adjusting the ANC module based on the detected remaining noise.

[0032] Absorbing the harmonic sounds generated by the ANC module using the passive sound absorbing module may comprise absorbing sounds having a sound absorption coefficient greater than 0.8 at a frequency of approximately 1 kHz

[0033] According to a fourth aspect, there is provided a method of installing a noise management system on a window, the method comprising: disposing an active noise control (ANC) module in or adjacent a ventilation channel of the window, wherein the ANC module is configured to substantially cancel low-frequency noise entering the ventilation channel, the ANC module generating harmonic sounds; and disposing a passive sound absorbing module in or adjacent to the ventilation channel, wherein the passive sound absorbing module comprises a sound absorption coefficient selected to absorb both high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

[0034] The ANC module may comprise a plurality of multi-cell transparent electroactive film speakers, and disposing the ANC module may comprise spatially distributing the speakers at different locations along the ventilation channel.

[0035] The window may comprise a lower part having a lower ventilation channel and an upper part having an upper ventilation channel, and an ANC module may be disposed in or adjacent each of the lower and upper ventilation channels, and a passive sound absorbing module may be disposed in or adjacent each of the lower and upper ventilation channels.

CLAIMS

1. A noise management system for a window, the system comprising:

an active noise control (ANC) module disposed in or adjacent to a ventilation channel of the window and configured to substantially cancel low-frequency noise entering the ventilation channel, the ANC module generating harmonic sounds; and

a passive sound absorbing module disposed in or adjacent to the ventilation channel, the passive sound absorbing module comprising a sound absorption coefficient selected to absorb both high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

2. The noise management system as claimed in claim 1, wherein the ANC module comprises at least one multi-cell transparent electroactive film speaker comprising a plurality of electroactive cells, and wherein each cell is individually operable for generating a sound signal anti-phase to the low-frequency noise.

3. The noise management system as claimed in claim 2, wherein each electroactive cell comprises a transparent electroactive film, a transparent substrate, a transparent bottom electrode and a transparent top electrode.

4. The noise management system as claimed in claim 3, wherein the transparent electroactive film comprises a transparent piezoelectric polymer or a transparent electroactive polymer.

5. The noise management system as claimed in claim 3 or 4, wherein at least one of the transparent top and bottom electrodes comprises a coating of a transparent conductive material selected from a group consisting of indium tin oxide (ITO), carbon nano-tube, carbon nano-bud, graphene, metal nano-wires, and poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS).

6. The noise management system as claimed in any one of the preceding claims, wherein the passive noise absorbing module comprises mechano-electrical conversion elements and/or electro-thermal conversion elements.

7. The noise management system as claimed in claim 6, wherein the mechano-electrical conversion elements comprise a piezoelectric polymer, a charge electret polymer, piezoelectric ceramic particles, or a combination thereof.

8. The noise management system as claimed in claim 7, wherein the piezoelectric polymer comprises one selected from a group consisting of polyvinylidene fluoride (PVDF), polyvinylidene fluoride–trifluoroethylene (P(VDF-TrFE)), polyvinylidene fluoride-co-hexafluoropropylene (P(VDF-HFP)), and wherein the charge electret polymer comprises one selected from a group consisting of polypropylene, polyethylene terephthalate, polytetrafluoroethylene, polyimide, polymethylmethacrylate, or ethylene vinyl acetate cyclic olefin.

9. The noise management system as claimed in any one of claims 6 to 8, wherein the electro-thermal conversion elements comprise a conductive material or a lossy material.

10. The noise management system as claimed in claim 9, wherein the conductive material comprises one selected from a group consisting of carbon nanotubes (CNT), graphene, carbon black, and conductive metal particles.

11. The noise management system as claimed in claim 9, wherein the lossy material comprises one selected from a group consisting of aluminum nitrate nonahydrate ($Al(NO_3)_3 9H_2O$), aluminum chloride hexahydrate ($AlCl_3 6H_2O$), tetra-n-butylammonium chloride (TBAC), and ammonium acetate (NH_4OAc).

12. The noise management system as claimed in any one of claims 6 to 11, wherein the mechano-electrical conversion elements and electro-thermal conversion elements form a porous composite having a volume porosity of at least 85%.

13. The noise management as claimed in any one of the preceding claims, wherein the ANC module and the passive sound absorbing module have a synergistic interaction and the harmonic sounds generated by the ANC module are absorbed by the passive sound absorbing module, such that a total noise mitigation effect is larger than a sum of noise mitigation effects produced by said modules separately.

14. A window system comprising at least one noise management system as claimed in any one of the preceding claims.

15. A method of managing noise, comprising:

substantially cancelling low-frequency noise entering a ventilation channel of a window using an active noise control (ANC) module disposed in or adjacent to the ventilation channel;

absorbing high-frequency noise entering the channel using a passive sound absorbing module disposed in or adjacent to the ventilation channel; and

absorbing harmonic sounds generated by the ANC module using the passive sound absorbing module,

wherein the passive sound absorbing module comprises a sound absorption coefficient selected to absorb both the high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

16. The method as claimed in claim 15, further comprises detecting the low-frequency noise using a reference microphone before substantially cancelling the low-frequency noise.

17. The method as claimed in claim 16, wherein the ANC module comprises at least one multi-cell transparent electroactive film speaker comprising a plurality of electroactive cells, and wherein substantially cancelling the low-frequency noise comprises individually operating each cell to generate a sound signal anti-phase to the low-frequency noise based on the detection.

18. The method as claimed in any one of claims 15 to 17, further comprising detecting a remaining noise after the absorption and adjusting the ANC module based on the detected remaining noise.

19. The method as claimed in any one of claims 15 to 18, wherein absorbing the harmonic sounds generated by the ANC module using the passive sound absorbing module comprises absorbing sounds having a frequency below 1 kHz.

20. The method as claimed in any one of claims 15 to 19, wherein the ANC module and the passive sound absorbing module have a synergistic interaction and the harmonic sounds generated by the ANC module are absorbed by the passive sound absorbing module, such that a total noise mitigation effect is larger than a sum of noise mitigation effects produced by said modules separately.

21. A method of installing a noise management system on a window, the method comprising:

disposing an active noise control (ANC) module in or adjacent to a ventilation channel of the window, wherein the ANC module is configured to substantially cancel low-frequency noise entering the ventilation channel, the ANC module generating harmonic sounds; and

disposing a passive sound absorbing module in or adjacent to the ventilation channel, wherein the passive sound absorbing module comprises a sound absorption coefficient selected to absorb both high-frequency noise entering the channel and the harmonic sounds generated by the ANC module.

22. The method as claimed in claim 21, wherein the ANC module comprises a plurality of multi-cell transparent electroactive film speakers, and wherein disposing the ANC module comprises spatially distributing the speakers at different locations along the ventilation channel.

23. The method as claimed in claim 21 or 22, wherein the ANC module and the passive sound absorbing module have a synergistic interaction and the harmonic sounds generated by the ANC module are absorbed by the passive sound absorbing module, such that a total noise mitigation effect is larger than a sum of noise mitigation effects produced by said modules separately.