CLAIMS

1. An evaporative cooling system comprising:

a porous ceramic body comprising

a plurality of dry channels configured to inhibit transfer of water vapor into the dry channels and comprising a roughened layer with a features size less than 1000 nm and a hydrophobic chemical modification disposed on the roughened layer; and

a plurality of wet channels configured to allow transfer of water vapor.

2. The evaporative cooling system of claim 1, wherein the plurality of dry channels and the plurality of wet channels have a configuration selected from the group consisting of parallel-flow, counter-flow, and cross-flow.

3. The evaporative cooling system of claim 1, wherein the evaporative cooling system is an indirect evaporative cooling system.

4. The evaporative cooling system of claim 3, wherein the indirect evaporative cooling system is selected from the group consisting of a regenerative indirect evaporative cooling system, a dew-point indirect evaporative cooling system, and a Maisotsenko indirect evaporative cooling system.

5. The evaporative cooling system of claim 1, wherein the porous ceramic body is selected from a group consisting of oxides, composites, clay bodies, stoneware, earthenware, porcelain, bone china, and combinations thereof.

6. The evaporative cooling system of claim 5, wherein the oxide is selected from a group consisting of alumina, silica, titania, beryllia, ceria, zirconia, manganese oxide, iron oxide and combinations thereof.

7. The evaporative cooling system of claim 5, wherein the composite is selected from a group consisting of particle-reinforced composites, fiber-reinforced composites, combinations of oxides and non-oxides, and combinations thereof.

8. The evaporative cooling system of claim 1, wherein the porous ceramic body has a pore size between 10 nm and 1000 nm.

9. The evaporative cooling system of claim 1, wherein the porous ceramic body has a pore size between 1 μm and 1000 μm.

10. The evaporative cooling system of claim 1, wherein the porous ceramic body has a pore volume of 1 to 80 percent.

11. The evaporative cooling system of claim 1, wherein in the roughness of the roughened layer is between 0.1 nm and 1000 nm.

12. The evaporative cooling system of claim 1, wherein the roughness of the roughened layer is between 0.1 nm and 100 nm.

13. The evaporative cooling system of claim 1, wherein the roughness of the roughened layer is between 100 and 1000 nm.

14. The evaporative cooling system of claim 1, wherein the roughened layer is selected from the group consisting of alumina, silica, titania, beryllia, ceria, zirconia, cupric oxide, cuprous oxide, barium oxide, germanium oxide, yttria, strontium oxide, hafnium oxide, magnesium oxide, niobium oxide, tin oxide, tantalum oxide, tungsten oxide, aluminum oxyhydroxide, and combinations thereof.

15. The evaporative cooling system of claim 1, wherein the roughened layer comprises a sol-gel coating.

16. The evaporative cooling system of claim 1, wherein the roughened layer comprises a dispersion of metal oxide particles.

17. The evaporative cooling system of claim 16, wherein the metal oxide particles have a diameter of 2 nm to 20 μm.

18. The evaporative cooling system of claim 16, wherein the metal oxide particles have a diameter of 2 nm to 10 nm.

19. The evaporative cooling system of claim 16, wherein the metal oxide particles have a diameter of 10 nm to 50 nm.

20. The evaporative cooling system of claim 16, wherein the metal oxide particles have a diameter of 50 nm to 200 nm.

21. The evaporative cooling system of claim 16, wherein the metal oxide particles are polydisperse.

22. The evaporative cooling system of claim 16, wherein the metal oxide particles are selected from the group consisting of alumina, silica, titania, beryllia, ceria, zirconia, cupric oxide, cuprous oxide, barium oxide, germanium oxide, yttria, strontium oxide, hafnium oxide, magnesium oxide, niobium oxide, tin oxide, tantalum oxide, tungsten oxide, and combinations thereof.

23. The evaporative cooling system of claim 1, wherein the roughened layer has a thickness of 100 nm to 5 mm.

24. The evaporative cooling system of claim 1, where in the roughened layer has a penetration depth of 200 nm to 5 mm.

25. The evaporative cooling system of claim 1, wherein the roughened layer comprises an overlayer with a thickness of 100 nm to 500 μm.

26. The evaporative cooling system of claim 1, wherein the hydrophobic chemical modification is selected from the group consisting of organic silane or thiol molecules terminated with either methyl groups, aryl groups, branched alkyl chains, linear alkyl chains, perfluorinated chains, or hydrophobic polymers, siloxanes, alkyl-phosphates, alkyl phosphoric acid esters, alkane-phosphonic acids, alkane-phosphonic esters, alkane-hydroxamic acids, alkane-carboxylic acids, and combinations thereof.

27. The evaporative cooling system of claim 1, wherein the hydrophobic chemical modification is selected from the group consisting of fatty acids, natural waxes, synthetic waxes, and combinations thereof.

28. The evaporative cooling system of claim 1, wherein the hydrophobic chemical modification is covalently attached to the roughened layer.

29. The evaporative cooling system of claim 1, wherein the hydrophobic chemical modification is adsorbed to the roughened layer.

30. The evaporative cooling system of claim 1, wherein the hydrophobic chemical modification has a thickness of 2 nm to 1 μm.

31. The evaporative cooling system of claim 1, wherein the evaporative cooling system is integrated into an exterior wall of a building.

32. The evaporative cooling system of claim 1, wherein the evaporative cooling system is integrated into a roof of a building.

33. The evaporative cooling system of claim 1, wherein the evaporative cooling system is integrated into an interior of a building.

34. The evaporative cooling system of claim 1, wherein the evaporative cooling system is a stand-alone unit.

35. The evaporative cooling system of claim 1, wherein the evaporative cooling system cools an interior space.

36. The evaporative cooling system of claim 1, wherein the evaporative cooling system cools an exterior space.

37. The evaporative cooling system of claim 1, further comprising a water reservoir.

38. The evaporative cooling system of claim 1, further comprising a pump.

39. The evaporative cooling system of claim 1, further comprising a fan configured to draw air through the porous ceramic body.

40. The evaporative cooling system of claim 1, wherein the evaporative cooling system further comprises a water system selected from the group consisting of misters, ultrasonic misters, atomizing spray nozzles, spray nozzles and combinations thereof.

41. A method of making an evaporative cooling system comprising:

providing a porous ceramic body,

forming a roughened layer with a feature size less than 1000 nm within a first region of the porous ceramic body, and

chemically modifying the roughened layer within the first region with a hydrophobic chemical modification.

42. The method of claim 41, further comprising forming the roughened barrier layer within a second region of the porous ceramic body.

43. The method of claim 41, wherein said providing the porous ceramic body comprises forming the ceramic according to a method selected from the group consisting of extrusion, co-extrusion, pressing, casting, foams, additive manufacturing, and multi-material additive manufacturing.

44. The method of claim 43, wherein said co-extrusion further comprises

depositing a first formulation of the porous ceramic body and components of the roughened layer from a first extrusion head in a first region,

depositing a second formulation of the porous ceramic from a second extrusion head in a second region.

45. The method of claim 43, wherein said co-extrusion further comprises depositing a formulation of the porous ceramic body and components of the roughened layer from an extrusion head, wherein the formulation has a composition that varies temporally during said depositing.

46. The method of claim 41, wherein the roughened layer is selected from the group consisting of alumina, silica, titania, beryllia, ceria, zirconia, cupric oxide, cuprous oxide, barium oxide, germanium oxide, yttria, strontium oxide, hafnium oxide, magnesium oxide, niobium oxide, tin oxide, tantalum oxide, tungsten oxide, aluminum oxyhydroxide, and combinations thereof.

47. The method of claim 41, wherein said forming the roughened layer comprises:

dissolving a sol-gel precursor in an organic solvent,

initiating a hydrolysis reaction to form a network gel,

applying the network gel to the porous ceramic body, and

heating the porous ceramic body.

48. The method of claim 47, wherein said forming the roughened layer further comprises providing metal oxide particles.

49. The method of claim 48, further comprising providing the metal oxide particles in the sol-gel precursor before dissolving the sol-gel precursor in the organic solvent.

50. The method of claim 48, further comprising providing the metal oxide particles in the sol-gel precursor after dissolving the sol-gel precursor in the organic solvent.

51. The method of claim 48, further comprising providing the metal oxide particles during the hydrolysis reaction.

52. The method of claim 47, further comprising densifying the network gel by a hydrothermal reaction and recrystallizing the network gel.

53. The method of claim 47, wherein said forming the roughened layer comprises

applying a dispersion of metal oxide particles to the porous ceramic body.

54. The method of claim 53, wherein said applying a dispersion of metal oxide particles comprises a method selected from the group consisting of wash-coating, spray coating, dip coating, or painting.

55. The method of claim 41, wherein said chemically modifying the roughened layer comprises covalently attaching a molecule to the roughened layer.

56. The method of claim 57, wherein the molecule is selected from the group consisting of alkyl chains, perfluorinated chains, siloxanes, alkyl-phosphates, alkyl-phosphates, alkyl phosphoric acid esters, alkane-phosphonic acids/esters, alkane-hydroxamic acids, alkane-carboxylic acids, thiols, and combinations thereof.

57. The method of claim 41, wherein said chemically modifying the roughened layer comprises adsorbing a molecule to the roughened layer.

58. The method of claim 57, wherein the molecule is selected from the group consisting of fatty acids, natural waxes, synthetic waxes, and combinations thereof.

59. The evaporative cooling system of claim 1, wherein the plurality of dry channels are configured to reduce pore surface energy in the dry channels and wherein the roughened layer is disposed on a surface of a plurality of pores in the dry channel.

60. The method of claim 41, wherein the roughened layer is formed of a surfaces of a plurality of pores within the first region of the porous ceramic body and wherein forming the roughened layer and chemically modifying the roughened layer reduces the surface energy in the first region.

61. The method of claim 41, wherein the porous ceramic body has a pore volume of 1 to 80 percent.