INTERDIGITATED CELLULAR CUSHIONING

Cross-reference to Related Applications

The present application claims benefit of priority to U.S. Provisional Patent Application No. 61/421,713, entitled "Interdigitated Cellular Cushioning" and filed on December 10, 2010, which is specifically incorporated by reference herein for all that it discloses or teaches. The present application is further related to U.S. Nonprovisional Patent Application No. ~~__/___,___,~~ PCT/US11/64449 entitled "Interdigitated Cellular Cushioning" and filed on December 12, 2011, which is also specifically incorporated by reference herein for all that it discloses or teaches.

~~Technical Field~~

~~The invention relates generally to cushioning and energy absorption systems and methods.~~

Background

Cushioning systems are used in a wide variety of applications including comfort and impact protection of the human body. A cushioning system is placed adjacent a portion of the body (with one or more layers of material between the body and the cushioning system, in some implementations) and provides a barrier between the body and one or more objects impinging on the body. For example, a foam floor mat contains multiple voids filled with air that cushion the body from a hard floor surface. Similarly, chairs, gloves, knee-pads, helmets, etc. may include a cushioning system that provides a barrier between a portion of the body and one or more objects impinging on that portion of the body.

A variety of structures are used for cushioning systems. For example, an array of closed-cell air chambers often constitute various impact protection padding (e.g., pads and helmets). Further examples include open or closed cell foam and elastomeric honeycomb structures. These structures may break down over time and often lack a controlled spring rate or rates over the entire deformation range of the structures.

Claims

WHAT IS CLAIMED IS:

1. An interdigitated cellular cushioning system comprising:

a first sheet of resilient material including a first binding layer and a first array of void cells protruding from the first binding layer, wherein each of the void cells has a wall; and

a second sheet of resilient material including a second binding layer and a second array of void cells protruding from the second binding layer, wherein each of the void cells has a wall, with the walls of the second array of void cells unique from the walls of the first array of void cells, the void cells are configured to monotonically collapse under a load, wherein a peak of each void cell in the first array contacts the second binding layer and a peak of each void cell in the second array contacts the first binding layer, and wherein at least one void cell in the first array is attached to the second binding layer and at least one void cell in the second array is attached to the first binding layer.

2. The interdigitated cellular cushioning system of claim 1, further comprising:

a third sheet of resilient material including a third binding layer and a third array of void cells protruding from the third binding layer; and

a fourth sheet of resilient material including a fourth binding layer and a fourth array of void cells protruding from the fourth binding layer, wherein a peak of each void cell in the third array contacts the fourth binding layer and a peak of each void cell in the fourth array contacts the third binding layer, and wherein at least one void cell in the third array is attached to the fourth binding layer, at least one void cell in the fourth array is attached to the third binding layer, and the second binding layer is attached to the third binding layer.

3. The interdigitated cellular cushioning system of claim 2, wherein the void cells in the first array are aligned with the void cells in the fourth array and the void cells in the second array are aligned with the void cells in the third array.

4. The interdigitated cellular cushioning system of claim 3, wherein the peak of the at least one void cell in the first array, the second binding layer, the third binding layer, and the peak of the at least one void cell in the fourth array are attached together.

5. The interdigitated cellular cushioning system of claim 1, wherein the void cells are hemiellipsoidal.

6. The interdigitated cellular cushioning system of claim 1, wherein each void cell in the first array is attached to the second binding layer and each void cell in the second array is attached to the first binding layer.

7. The interdigitated cellular cushioning system of claim 1, wherein at least one void cell in the first array is welded to the second binding layer and at least one void cell in the second array is welded to the first binding layer.

8. The interdigitated cellular cushioning system of claim 1, wherein the void cells in the first array of void cells are spaced equally from the void cells in the second array of void cells.

9. The interdigitated cellular cushioning system of claim 1, wherein resilient material at a base of at least one void cell is thinner than material at a peak of the void cell.

10. The interdigitated cellular cushioning system of claim 1, wherein each of the void cells are configured to collapse without contacting adjacent void cells.

11. The interdigitated cellular cushioning system of claim 1, wherein at least one of the first binding layer and the second binding layer is configured to conform to a curved surface.

12. The interdigitated cellular cushioning system of claim 1, wherein the first array of void cells are configured to collapse at a different rate than the second array of void cells.

13. The interdigitated cellular cushioning system of claim 1, wherein the void cells are configured to collapse uniformly.

14. A method of absorbing kinetic energy comprising:

monotonically collapsing a first sheet of resilient material including a first binding layer and a first array of void cells protruding from the first binding layer, wherein each of the void cells has a wall;

monotonically collapsing a second array of void cells protruding from a second binding layer of a second sheet of resilient material, wherein each of the void cells has a wall, with the walls of the second array of void cells unique from the walls of the first array of void cells, without collapsing the second binding layer, wherein a peak of each void cell in the first array contacts the second binding layer and a peak of each void cell in the second array contacts the first binding layer, and wherein at least one void cell

in the first array is attached to the second binding layer and at least one void cell in the second array is attached to the first binding layer.

15. The method of claim 14, further comprising:

monotonically collapsing a third sheet of resilient material including a third binding layer and a third array of void cells protruding from the third binding layer; and

monotonically collapsing a fourth sheet of resilient material including a fourth binding layer and a fourth array of void cells protruding from the fourth binding layer, wherein a peak of each void cell in the third array contacts the fourth binding layer and a peak of each void cell in the fourth array contacts the third binding layer, and wherein at least one void cell in the third array is attached to the fourth binding layer, at least one void cell in the fourth array is attached to the third binding layer, and the second binding layer is attached to the third binding layer.

16. A method of manufacturing an interdigitated cellular cushioning system comprising:

molding a first sheet of resilient material into a first binding layer with a first array of void cells protruding from the first binding layer;

molding a second sheet of resilient material into a second binding layer with a second array of void cells protruding from the second binding layer;

molding a third sheet of resilient material into a third binding layer with a third array of void cells protruding from the third binding layer;

molding a fourth sheet of resilient material into a fourth binding layer with a fourth array of void cells protruding from the fourth binding layer; and

welding a peak of a void cell in the first array to the second binding layer, the third binding layer, and a peak of a void cell in the fourth array.

17. The method of claim 16, further comprising:

welding a peak of a void cell in the first array to the second binding layer and a peak of a void cell in the second array to the first binding layer; and

welding a ~~peaks~~ peak of a void cell in the third array to the fourth binding layer and a peak of a void cell in the fourth array to the third binding layer.

18. The method of claim 16, further comprising:

arranging peaks of each void cell in the first array in contact with the second binding layer and peaks of each void cell in the second array in contact with the first binding layer; and

arranging peaks of each void cell in the third array in contact with the fourth binding layer and peaks of each void cell in the fourth array in contact with the third binding layer.

19. The method of claim 16, further comprising:

aligning the void cells in the first array with the void cells in the fourth array and the void cells in the second array with the void cells in the third array.

20. An interdigitated cellular cushioning system comprising:

a first sheet of resilient material including a first binding layer and a first array of hemiellipsoidal void cells each having a wall protruding from the first binding layer; and

a second sheet of resilient material including a second binding layer and a second array of hemiellipsoidal void cells each having a wall protruding from the second binding layer, the walls of the second array of hemiellipsoidal void cells being unique from the walls of the first array of hemiellipsoidal void cells, wherein the void cells have thinner resilient material at a base of each of the void cells than at a peak of each of the void cells, wherein the void cells are configured to monotonically collapse under a load, wherein a peak of each void cell in the first array contacts the second binding layer and a peak of each void cell in the second array contacts the first binding layer, wherein at least one void cell in the first array is attached to the second binding layer and at least one void cell in the second array is attached to the first binding layer, and wherein the void cells in the first array of void cells are spaced equally from the void cells in the second array of void cells.

21. The interdigitated cellular cushioning system of claim 20, further comprising:

a third sheet of resilient material including a third binding layer and a third array of hemiellipsoidal void cells protruding from the third binding layer; and

a fourth sheet of resilient material including a fourth binding layer and a fourth array of hemiellipsoidal void cells protruding from the fourth binding layer, wherein a peak of each void cell in the third array contacts the fourth binding layer and a peak of each void cell in the fourth array contacts the third binding layer, wherein at least one void cell in the third array is attached to the fourth binding layer, at least one void cell in the fourth array is attached to the third binding layer, and the second binding layer is

attached to the third binding layer~~, and wherein the void cells in the first array of void cells are spaced equally from the void cells in the second array of void cells~~.

22. The interdigitated cellular cushioning system of claim 1, wherein the first array of void cells is contiguous with the first binding layer and the second array of void cells is contiguous with the second binding layer.

23. The method of claim 14, wherein the first array of void cells is contiguous with the first binding layer and the second array of void cells is contiguous with the second binding layer.

24. The interdigitated cellular cushioning system of claim 20, wherein the first array of void cells is contiguous with the first binding layer and the second array of void cells is contiguous with the second binding layer.