ELECTRICAL MULTILAYER LAMINATION TRANSFER FILMS

BACKGROUND

Many common electrical devices can be fabricated in a continuous manner on a flexible substrate. Continuous film-based methods have been demonstrated for complete or partial fabrication of capacitors, resistors, thin film batteries, organic photovoltaics (OPVs), organic light emitting diodes (OLEDs), and other components. However, there are fewer continuous techniques available for producing fully integrated multilayer electrical films, especially those with a large number of layers and electrodes, for example over 100 layers. Also, many thin film electrical devices are produced through multiple vapor deposition and patterning steps. Accordingly, a need exists for complex electrical devices and methods to fabricate them.

SUMMARY

The present disclosure relates to multilayer lamination transfer films, methods of forming these lamination transfer films and methods of using these lamination transfer films. These lamination transfer films utilize electrical protolayers that can be electrically coupled after a high temperature step that removes sacrificial material and densifies thermally stable material.

There is provided a transfer film that includes a plurality of co-extensive electrical protolayers forming an electrical protolayer stack. At least selected or each electrical protolayer independently comprises at least 25 wt% sacrificial material and a thermally stable material and a uniform thickness of less than 25 micrometers. In one aspect, there is provided a transfer film comprising: a plurality of co-extensive electrical protolayers forming an electrical protolayer stack, at least selected or each electrical protolayer independently comprising at least 25 wt% sacrificial material and a thermally stable material and having a uniform thickness of less than 25 micrometers.

There is provided a transfer film that includes a plurality of co-extensive electrical protolayers forming an electrical protolayer stack. At least selected or each protolayer independently exhibits a complex viscosity of between 10^3 and 10^4 Poise at a shear rate of 100/s when heated to a temperature between its T_g and T_{dec}.

There is provided a transfer film that includes a plurality of interdigitated electrical protolayers forming an electrical protolayer stack. At least selected or each electrical

protolayer independently comprises at least 25 wt% sacrificial material and a thermally stable material and a uniform thickness of less than 25 micrometers.

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There is provided a method that includes laminating a transfer film, described herein, to a receptor substrate and baking out sacrificial material to form an electrical stack.

There is provided a method that includes depositing a plurality of interdigitated electrical protolayers to form an electrical protolayer stack. Each protolayer independently has sacrificial material and a thermally stable material and a uniform thickness of less than 25 micrometers. In another aspect, there is provided a method of forming a transfer film, comprising: forming a plurality of electrical protolayers to form an electrical protolayer stack, each protolayer independently comprising a sacrificial material and a thermally stable material and having a uniform thickness of less than 25 micrometers.

There is provided a method that includes co-extruding a plurality of interdigitated electrical protolayers to form an electrical protolayer stack. Each protolayer independently includes a sacrificial material and a thermally stable material.

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These and various other features and advantages will be apparent from a reading of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure may be more completely understood in consideration of the following detailed description of various embodiments of the disclosure in connection with the accompanying drawings, in which:

FIG. 1 is a schematic process flow diagram of an illustrative method of forming the transfer film and the electrical stack;

FIG. 2 is a schematic diagram of a three layer electrical stack with a negative and positive electrode formed by lamination transfer and baking out;

FIG. 3 is a cross-sectional schematic diagram of a multilayer interdigitated electrode film with buried electrodes and vertical bus bars; and

What is claimed is:

1. A transfer film comprising:

a plurality of co-extensive electrical protolayers forming an electrical protolayer stack, at least selected or each electrical protolayer independently comprising at least 25 wt% sacrificial material and a thermally stable material and having a uniform thickness of less than 25 micrometers.

2. A transfer film according to claim 1, wherein the plurality of co-extensive electrical protolayers are interdigitated.

3. A transfer film according to claim 1, wherein at least selected electrical protolayers are electrically conductive.

4. The transfer film according to claim 1, wherein each or at least selected electrical protolayers comprise less than 75 wt% inorganic nanomaterials.

5. A transfer film according to claim 1 further comprising a polymeric support layer having a releasable surface, the releasable surface contacting the electrical protolayer stack.

6. A transfer film according to claim 1, wherein the electrical protolayer stack comprises an electrode protolayer comprising electrically conductive material and a dielectric protolayer comprising electrically insulating material.

7. A transfer film according to claim 1, wherein the electrical protolayer stack comprises a negative electrode protolayer comprising negative electrode material, a positive electrode protolayer comprising positive electrode material and an electrolyte protolayer comprising electrolyte material and the electrolyte protolayer is disposed between the negative electrode protolayer and the positive electrode protolayer.

8 A transfer film according to claim 1, wherein the electrical protolayer stack comprises a plurality of electrochromic protolayers comprising electrochromic material and an optional electrolyte protolayer comprising an electrolyte material.

9. The transfer film according to claim 8, wherein the electrochromic material comprises at least one of, tungsten oxide, iridium oxide, nickel oxide, hydrous nickel oxide, molybdenum oxide, vanadium oxide, niobium oxide, titanium oxide, transition metal oxides of manganese, cobalt, rhodium, and ruthenium, Prussian Blue and metal phthalocyanines.

10. The transfer film according to claim 8, wherein the electrochromic material comprises at least one $PW_{12}O_{40}^{3-}$, $SiW_{12}O_{40}^{4-}$, $W_{10}O_{32}^{3-}$, $[Eu\text{-}(H_2O)P_5W_{30}O_{11}]^{12-}$, WO_3, IrO_2, $Ir(OH)_3$, MoO_3, V_2O_5, Nb_2O_5, TiO_2, $(Fe(III)_4[Fe(II)(CN)_6]_3$, and $KFe(III)Fe(II)(CN)_6$).

11. A transfer film according to claim 1, wherein at least selected electrical protolayers comprise inorganic nanomaterial having an average size of less than 1000 nm.

12. A transfer film according to claim 1, wherein sacrificial material comprises an organic polymer material.

13. A transfer film according to claim 1, wherein the sacrificial material is present in each electrical protolayer in a range from 25 to 95 wt%.

14. A transfer film according to claim 1, wherein the electrical protolayer stack comprises at least 10 electrical protolayers.

15. A transfer film according to claim 1, wherein at least selected electrical protolayers comprise inorganic nanoparticles and an organometallic polymer or coordination compound.

16. A method of forming a transfer film, comprising:

forming a plurality of electrical protolayers to form an electrical protolayer stack, each protolayer independently comprising a sacrificial material and a thermally stable material and having a uniform thickness of less than 25 micrometers.

17. A method according to claim 16, wherein the electrical protolayers are interdigitated.

18. A method according to claim 16, wherein forming a plurality of electrical protolayers comprises coextruding the plurality of electrical protolayers.

19. A method according to claim 16, wherein each electrical protolayer of the electrical protolayer stack independently exhibits a complex viscosity of between 10^3 and 10^4 Poise at a shear rate of 100/s when heated to a temperature between its T_g and T_{dec}.