CONTINUOUS EDGE PROTECTED BARRIER ASSEMBLIES

Technical Field

This disclosure generally relates to films capable of use in a flexible photovoltaic solar module, rolls of films capable of use in a flexible photovoltaic solar module, processes of making the films and rolls of films, and to flexible photovoltaic solar modules including such films.

Background

Emerging solar technologies such as organic photovoltaic devices (OPVs) and thin film solar cells like Copper Indium Gallium di-Selenide (CIGS) require protection from water vapor and need to be durable (*e.g.,* to ultra-violet (UV) light) in outdoor environments. Typically, glass has been used as an encapsulating material for such solar devices because glass is a very good barrier to water vapor, is optically transparent, and is stable to UV light. However, glass is heavy, brittle, difficult to make flexible, and difficult to handle. There has been interest in developing transparent flexible encapsulating materials to replace glass that will not share the drawbacks of glass but have glass-like barrier properties and UV stability, and a number of flexible barrier films have been developed that approach the barrier properties of glass.

Summary

Because solar devices are used outdoors, they are exposed to the elements, including wind, water, and sunlight. Water penetration into solar panels has been a long-standing problem. Solar panels may also be deleteriously affected by wind and sunlight.

Many flexible barrier films are multilayer film laminates. Any multilayer film laminate has the potential for delamination, especially at the edges. Reducing delamination at the edges may improve overall barrier film performance. One way to reduce barrier film delamination is to introduce a protective layer around the perimeter of the barrier film such that the barrier layers and barrier film substrate are insulated from the environment.

The inventors of the present disclosure recognized that it may be desirable to provide barrier film edge protection in a continuous roll format. One reason for this is that roll-to-roll processing can reduce the cost of solar module manufacturing. Consequently, the inventors of the present disclosure discovered a novel process that provides the means to combine discontinuous barrier film sheets with edge protective layers and a weatherable top sheet in a roll-to-roll format. The inventors of the present disclosure also discovered novel films and rolls of films including discontinuous barrier film sheets, edge protective layer(s), and a weatherable top sheet in a roll format.

The present disclosure may provide ~~In some embodiments,~~ a method of forming a continuous multilayer film that~~,~~ comprises: providing discrete segments of multilayer barrier film, wherein adjacent discrete segments of multilayer barrier film

are separated by a gap; and placing a protective layer adjacent to two adjacent discrete segments of multilayer barrier film such that at least a portion of the protective layer spans the gap to form a continuous film capable of use as a barrier film.

In a first aspect, there is provided a method of forming a continuous multilayer film, comprising: providing discrete segments of multilayer barrier film, wherein adjacent discrete segments of multilayer barrier film are separated by a gap; and placing a protective layer adjacent to two adjacent discrete segments of multilayer barrier film such that at least a portion of the protective layer spans the gap to form a continuous film capable of use as a barrier film, wherein the multilayer barrier film has a water vapor transmission rate of less than about 0.05 g/m2/day at 38° C and 100% relative humidity, wherein the multilayer barrier film is transmissive to visible and infrared light, and wherein the protective layer is opaque.

In some embodiments, a film includes a continuous multilayer film, comprising:
a weatherable sheet; segments of a multilayer barrier film; and a protective layer overlapping at least a portion of at least two adjacent segments of the multilayer barrier film; wherein the continuous multilayer film is capable of use as a barrier film in an electronic device.

In some embodiments, a roll of film includes any of the films described herein.

In some embodiments, a photovoltaic cell includes any of the films described herein.

In some embodiments, the protective layer is opaque. In some embodiments, the protective layer includes a protective sheet and an adhesive and is adjacent to the discrete segments of the multilayer barrier film. In some embodiments, the method further comprises placing a weatherable sheet adjacent to the multilayer barrier film. In some embodiments, the film further includes a weatherable sheet. In some embodiments, the weatherable sheet includes a fluoropolymer. In some embodiments the fluoropolymers include ethylene-tetrafluoroethylene copolymers (ETFE), ethylene-chloro-trifluoroethylene copolymers (ECTFE), tetrafluoroethylene-hexafluoropropylene copolymers (FEP), tetrafluoroethylene-perfluorovinylether copolymers (PFA, MFA) tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers (THV), polyvinylidene fluoride homo and copolymers (PVDF), blends thereof, and blends of these and other fluoropolymers. Fluoropolymers typically comprise homo or copolymers of TFE, CTFE, VDF, HFP or other fully fluorinated, partially fluorinated or hydrogenated monomers such as vinyl ethers and alpa-olefins or other halogen containing monomers. In some embodiments, the method further comprises placing a pressure sensitive adhesive on the multilayer barrier film. In some embodiments, the film further includes a pressure sensitive adhesive on the multilayer barrier film. In some embodiments, the pressure sensitive adhesive includes at least one of an acrylate, a silicone, a polyisobutylene, and a urea. In some embodiments, the pressure sensitive adhesive comprises at least one of a UV stabilizer, a hindered amine light stabilizer, an antioxidant, and a thermal stabilizer. In some embodiments, each discrete segment of

multilayer barrier film has a first side edge and a second side edge, and the method further comprises placing a protective layer adjacent to at least one of the first and second side edges of the discrete segments of multilayer barrier film to form a continuously edge protected barrier film wherein all edges of the discrete segments of multilayer barrier film are insulated from the environment. In some embodiments, the multilayer barrier film has a first major surface and a second major surface and the protective layer is adjacent to the first major surface, and the method further comprises placing a substrate adjacent to the second major surface of the multilayer barrier film. In some embodiments, the substrate comprises at least one of polyethylene terephthalate, polyethylene naphthalate, polyetheretherketone, polyaryletherketone, polyacrylate, polyetherimide, polyarylsulfone, polyethersulfone, polyamideimide, or polyimide. In some embodiments, the multilayer barrier film has a first major surface and a second major surface and the protective layer is adjacent to the first major surface, and the method further comprises placing an electronic device adjacent to the second major surface of the multilayer barrier film. In some embodiments, the method further comprises affixing the barrier film and electronic device construction adjacent to a roof. In some embodiments, the multilayer barrier film includes a polymer layer and an

inorganic barrier layer. In some embodiments, the inorganic barrier layer is an oxide layer. In some embodiments, the multilayer barrier film includes at least two oxide layers. In some embodiments, the multilayer barrier film includes at least two polymers layers. In some embodiments, the protective layer is at least one of an ink layer, a metal foil layer, and an inorganic barrier layer. In some embodiments, the method further comprises forming a roll of the continuous multilayer film. In some embodiments, the roll includes a plurality of discrete sheets of barrier film. In some embodiments, the protective layer includes multiple segments each of which has a first terminal edge and a second terminal edge, and the method further comprises placing a segment of protective layer adjacent to two adjacent discrete segments of multilayer barrier film such that the first and second terminal edges of the segment of protective layer span the gap to form a continuous film capable of use as a barrier film.

In a second aspect, there is provided a continuous multilayer film, comprising: a weatherable sheet; segments of a multilayer barrier film; and a protective layer overlapping at least a portion of at least two adjacent segments of the multilayer barrier film; wherein the continuous multilayer film is capable of use as a barrier film in an electronic device, wherein the multilayer barrier film has a water vapor transmission rate of less than about 0.05 g/m2/day at 38° C and 100% relative humidity, wherein the multilayer barrier film is transmissive to visible and infrared light, and wherein the protective layer is opaque.

The present disclosure allows for the combination of any of the disclosed elements or processes.

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 schematic view of one exemplary process according to the present disclosure.

Fig. 2 is a schematic perspective view of an article made according to the process of Fig. 1.

Fig. 3 is a cross-sectional schematic drawing of an article in accordance with the teachings herein.

Fig. 4 is a schematic perspective view of an alternative article in accordance with the teachings herein.

Fig. 5 is a cross-sectional schematic drawing of an alternative article in accordance with the teachings herein.

Detailed Description

Edge delamination is a concern for multilayer articles. Edge delamination can cause separation of the layers. Delamination can be controlled by the assessment, control, and modification of three inputs. The first input is the exposure to light at the interface(s) between the layers of the multilayer barrier film, including visible light and, in some embodiments, UV light. Water exposure is the second

input. The third input is stress on the interface. Minimization and control of these three inputs reduces spontaneous delamination, defined herein as a peel of less than 20 grams/inch as measured according to ASTM D3330 -"Standard Test Method of Peel Adhesion of Pressure-Sensitive Tape."

The development of methods to prevent separation/delamination of the flexible barrier films in, for example, a photovoltaic device are especially valuable to the photovoltaic industry. The longer the photovoltaic module outputs power, the more valuable the photovoltaic module. In some embodiments,