Process for producing flexible organic-inorganic laminates

Description

The present invention is in the field of processes for producing flexible organic-inorganic laminates as well as barrier films comprising flexible organic-inorganic laminates by atomic layer deposition.

Electronic devices need efficient encapsulation and passivation due to their high sensitivity to moisture and oxygen. Typically, inorganic materials such as oxides, nitrides, carbides or glass are used as barrier material as they show excellent moisture and oxygen barrier properties. However, inorganic materials strongly limit the form factor of electronic devices due to their rigidity. Furthermore, the fragility of e.g. large glass sheets makes production processes difficult and expensive. Electronic devices containing materials such as glass are prone to breakage upon mechanical stress.

WO 2009 / 002 892 A1 discloses coatings having inorganic layers and flexibilizing polymeric layers. However, the barrier properties are still insufficient for some applications.

It was an objective of the embodiments disclosed herein to provide a process for producing films with high water and oxygen barrier properties. At the same time it was aimed at providing a process for producing films which retain their barrier properties under high mechanical stress. A further objective was to provide a process for producing films with high stability against degradation in a humid atmosphere at elevated temperatures.

In an aspect, the objectives were achieved by a process for producing a laminate comprising

(a) depositing an inorganic layer by an atomic layer deposition process, and
(b) depositing an organic layer comprising selenium by a molecular layer deposition process.

In another aspect, the present disclosure further relates to a laminate comprising

(a) an inorganic layer and
(b) a selenium-comprising organic layer.

In another aspect, the present disclosure further relates to a barrier film comprising the laminate according to the present invention.

In another aspect, the present disclosure further relates to the use of the barrier film according to the present invention for encapsulation, packaging, or passivation.

In another aspect, the present disclosure further relates to an electronic device comprising the barrier film according to the present invention.

Preferred embodiments of the present disclosure can be found in the description and the claims. Combinations of different embodiments fall within the scope of the current disclosure.

A laminate in the context of the present invention is a product in which at least two layers of a different chemical composition are in close contact to each other. Unless indicated otherwise, there is generally no particular restriction to the size, the composition of each layer, or the strength with which the layers are held together.

Inorganic in the context of the present invention refers to materials which contain at least 1 wt.-% of at least one metal or semimetal, preferably at least 2 wt.-%, more preferably at least 5 wt.-%, in particular at least 10 wt.-%. Organic in the context of the present invention refers to materials which contain more than 99 wt.-% of nonmetals, preferably more than 99.5 wt.-%, in particular completely or essentially completely. It is even more preferable that the nonmetals are C, H, O, N, S, Se and/or P.

Atomic layer deposition (ALD) is a technique in which a series of self-limiting surface reactions are conducted which builds up conformal coatings of precise thickness depending on the number of self-limiting reactions performed. Typically the surface reaction takes place upon adsorption of a precursor from the gaseous state to the substrate. When all surface sites of the substrate are occupied, no further precursor adsorbs to the substrate making the reaction self-limiting. After removal of excess precursor the deposited layer is treated either chemically or physically which allows the subsequent deposition of further precursor. A sequence comprising such deposition and treatment is usually referred to as a cycle in the ALD process. The ALD process is described in detail by George (Chemical Reviews 110 (2010), 111-131). If organic molecules are deposited in an ALD process, such a process is sometimes referred to as molecular layer deposition process (MLD).

The process according to the present invention comprises depositing an inorganic layer by an atomic layer deposition process. The inorganic layer is deposited by any number of atomic layer deposition cycles, for example 1 to 1000, preferably 2 to 200, more preferably 4 to 60, in particular 5 to 30.

A cycle in an ALD process to form an inorganic layer typically comprises bringing a metal- or semimetal-containing compound or mixtures thereof into the gaseous state and depositing it from the gaseous state onto a substrate. In the following the term "metal or semimetal or mixtures thereof" is abbreviated by "(semi)metal". Bringing the (semi)metal-containing compound to the gaseous state can be achieved by heating it to elevated temperatures. In any case a temperature below the decomposition temperature of the (semi)metal-containing compound has to be chosen. Preferably, the heating temperature ranges from slightly above room temperature to 300 °C, more preferably from 30 °C to 250 °C, even more preferably from 40 °C to 200 °C, in particular from 50 °C to 150 °C. Alternatively, an inert gas such as nitrogen or argon can be purged through the (semi)metal-containing compound. In this way the inert gas is saturated with