Description

Background

[0001] The field of this disclosure relates to thin film deposition systems and methods for coating flexible substrates.

[0002] Atomic layer deposition ("ALD"), formerly known as atomic layer epitaxy ("ALE"), is a thin film deposition process that is known for use in manufacturing electroluminescent (EL) display panels, in semiconductor integrated circuit manufacturing, and for other purposes. See U.S. Patent No. 4,058,430 of Suntola et al., and U.S. Patent Application Publication Nos. US 2004/0208994 A1 of Härkönen et al., US 2004/0124131 A1 of Aitchison et al., and US 2005/0011555 A1 of Maula- et al.,. ALD offers several benefits over other thin film deposition methods, such as physical vapor deposition ("PVD") (e.g., evaporation or sputtering) and chemical vapor deposition ("CVD"), as described in Atomic Layer Epitaxy (T. Suntola and M. Simpson, eds., Blackie and Son Ltd., Glasgow, 1990).

[0003] In contrast to CVD, in which the flows of precursors are static (i.e., flow rates are steady during processing) and the substrate is exposed to multiple precursors simultaneously present in the reaction chamber, the precursor flows in ALD processing are dynamic and sequential, so that the substrate is exposed to only one precursor at a time. Successful ALD growth has conventionally required the sequential introduction of two or more different precursor vapors into a reaction space around a substrate. ALD is usually performed at elevated temperatures and low pressures. For example, the reaction space may be heated to between 200°C. and 600°C and operated at a pressure of between 0.1 mbar and 50 mbar. In a typical ALD reactor, the reaction space is bounded by a reaction chamber sized to accommodate one or more substrates. One or more precursor material delivery systems (also known as "precursor sources") are typically provided for feeding precursor materials into the reaction chamber.

[0004] After the substrates are loaded into the reaction chamber and heated to a desired processing temperature, a first precursor vapor is directed over the substrates. Some of the precursor vapor chemisorbs or adsorbs on the surface of the substrates to make a monolayer film. In pure ALD, the molecules of precursor vapor will not attach to other like molecules and the process is therefore self-limiting. Next, the reaction space is purged to remove excess of the first vapor and any volatile reaction products. Purging is typically accomplished by flushing the reaction space with an inert purge gas that is non-reactive with the first precursor. After purging, a second precursor vapor is introduced. Molecules of the second precursor vapor chemisorb or otherwise react with the chemisorbed or adsorbed first precursor molecules to form a thin film product of the first and second precursors. To complete the ALD cycle, the reaction space is again purged with an inert purge gas to remove any excess of the second vapor as well as any volatile reaction products. The steps of first precursor pulse, purge, second precursor pulse, and purge are typically repeated hundreds or thousands of times until the desired thickness of the film is achieved.

[0005] The required temperatures, pressures, and reaction chamber conditions have conventionally limited the ALD technique to deposition on substrates of relatively small size. For example, known uses of ALD include EL display panels and semiconductor wafers.

[0006] [0006.1] US 6,888,172 B2 discloses an apparatus and method for forming a transparent dielectric metal oxide moisture barrier over each of a plurality of discrete OLED devices previously formed on the surface of a flexible substrate. Multiple oxidizing gas stations and metal-organic gas stations are spaced apart in alternating succession along a transport path of the substrate. At each oxidizing gas station oxygenated surface sites are formed and, when the OLED device is advanced to the next metal-organic gas station in the path, a metal-organic gas reacts with the oxygenated surface sites to form an atomic layer of a metal oxide over the OLED device. Disposed between each of the oxidizing gas stations and metal-organic gas stations are purging stations that direct an inert gas to impinge upon the substrate so as to prevent mixing of the two processing gasses that may seep from the processing gas stations. The substrate is advanced past multiple sets of the gas stations and purging stations to form successive atomic layers, one layer for each set of adjacent oxidizing gas station, purge station, and metal-organic gas station.

Summary

[0007] In accordance with one embodiment, a system for depositing a thin film on a flexible substrate includes an isolation zone interposed between first and second precursor zones. When in use, reactive first and second precursor gases are introduced into the respective first and second precursor zones, and an inert gas is introduced into the isolation zone. A series of flow-restricting passageways from the isolation zone to the first and second precursor zones are spaced apart along the precursor zones. The passageways may include elongated tunnels and/or flexible wipers to restrict the flow of gases between the isolation zone and the precursor zones. When in use, a flexible substrate is threaded through the passageways so that it traverses back and forth between the first and second precursor zones multiple times and each time through the isolation zone. A substrate transport mechanism of the system includes a plurality of first turning guides, such as rollers, spaced apart along the first precursor zone and a plurality of second turning guides spaced apart along the second precursor zone. At least some of the first turning guides are adapted to support the substrate during a change in a direction of travel of the substrate toward the second precursor zone,