New trends in silicon thin films and applications

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Silicon thin films have been studied over thirty years and remarkable progress has been achieved both on the materials knowledge and development, and in their applications. From the material point of view, research was first focused on hydrogenated amorphous silicon (a-Si:H), which now serves as a reference and prototype material. The material with optimised electronic properties is generally produced by the glow discharge decomposition of silane in a Plasma Enhanced Chemical Vapour Deposition (PECVD) deposition system. Among the various advantages of this material are the low temperature processing (typically T<300°C), and the possibility to use a wide variety of substrates including cheap and large area substrates like glass. Many applications are today available to the largest audience, such as large area photovoltaic solar panels and active matrix flat panel displays, where picture elements are controlled by a-Si:H thin film transistors.

In the last decade, great effort was focused to overcome the limits of a-Si:H such as low carrier mobility and metastability effects (1), which are directly linked to its amorphous structure. In particular, the exploration of deposition conditions like the increase of power density and pressure, the strong dilution of silane in hydrogen or helium revealed that materials with a degree of cristallinity can also be produced by low temperature PECVD systems. This allowed to identify materials with different structures like hydrogenated microcrystalline silicon (μc-Si:H), a material made of crystalline grains of typical size up to a few tens of nanometers, but also materials with a more relaxed amorphous tissue compared to the early a-Si:H and that can contain nanometer size crystalline inclusions such as polymorphous silicon (pm-Si:H) (2,3). Improved material properties and stability have been reported for this last material compared to a-Si:H (4,5). During the same period, new fields have been opened for the use of silicon thin films. In particular, interesting applications combine silicon thin films and crystalline silicon and take advantage of the complementary material properties and technologies. An example in the field of photovoltaïcs is given by the so-called "HIT" structures (6), where thin a-Si:H layers deposited on both sides of a crystalline wafer are used as the emitter and back contacts of solar cells. The a-Si:H/c-Si heterostructures provide low surface recombination and solar cell efficiencies above 20% have been reported. Another example is given in the field of visible cameras, where the active devices made of PIN a-Si:H diodes can be deposited and patterned directly onto crystalline CMOS wafers (7).

In this paper, we first give a short review of the evolution of silicon thin film materials from a-Si:H to pm-Si:H, and detail some striking features of this last material. Then, we focus on the visible matrix sensors for cameras combining CMOS substrates with above IC processed detectors made of thin films of polymorphous silicon, as shown in Fig.1. We detail the properties of these detectors, emphasizing the advantages of this technology and the use of pm-Si:H instead of a-Si:H.

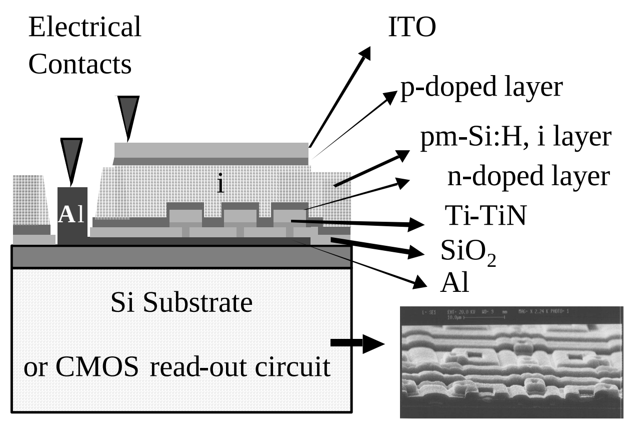

Figure 1: sketch of a pm-Si:H thin film detector processed on a crystalline silicon substrate

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