MULTIFUNCTIONAL AMORPHOUS METAL OXIDE THIN FILMS – STRUCTURE TRANSFORMATION FOR VARIOUS FUNCTIONS

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Metal oxides are well-known high-*k* dielectric materials since the early solid state electronics age. However, they were rarely used in modern IC chips except as charge storage layers in MOS capacitors. Recently, due to the performance and reliability issues of the nm thick SiO_2 in the gate dielectric application, metal oxide high-*k* dielectrics become popular alternatives. For the most advanced MOSFET, the sub nm EOT metal oxide is the preferred choice for the gate dielectric for its low leakage current and high reliability. Separately, metal oxides, such as IGZO or ZnO, are popular semiconductor materials in thin film transistors (TFTs) because of its high field effect mobility, e.g., 10 to 100 times that of the a-Si:H TFT. For above applications, the crystalline structure is preferable. For example, for the same metal oxide dielectric, the *k* value of the crystalline film can be several times higher than that of the amorphous film. TFTs made of the crystalline ZnO semiconductor film have much higher mobilities than those made of the amorphous ZnO semiconductor film. However, for practical applications, only amorphous films are used in products considering the repeatability, reliability, and manufacturability factors.

In this paper, the author will discuss the versatility of the amorphous metal oxide high-k thin film through transformation of the structure in simple process steps. For example, the sputter deposited zirconium doped hafnium oxide (ZrHfO) high-*k* dielectric can be made into the sub 1 nm EOT gate dielectric on Si wafer. By inserting a very thin metal, semiconductor, or dielectric layer in the ZrHfO film during the sputtering process and subsequently annealed with a RTP step, a nanocrystal-embedded dielectric structure is formed, which is a nonvolatile memory device. Each nanocrystal can store a single electron. Even holes can be stored in this kind of device once the proper nanocrystal material is chosen. Furthermore, nano resistors can be formed in the high-k film after a dielectric breakdown step. In the low voltage operation range, the new structure performs like a diode except the current increases linearly not exponentially with the applied voltage. The nano resistor structure can emit light under the high voltage stress condition, which is called the solid state incandescent LED (SSI-LED). The light emission phenomenon can last for more than 20,000 hours in air without failure. Among many possible applications, the SSI-LED can be used to fabricate the on-chip optical interconnect.

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