Application of Solution Method to Prepare High Performance Multicomponent Oxide Thin Films

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Metal oxides are considered one of the ideal options for gate dielectric materials because of their high transmittance, good uniformity, and excellent electrical stability[1]. So metal oxide films are used to make microelectronic devices[2]. The fabrication of metal oxide films initially relies on vacuum-based methods (e.g. sputtering and chemical vapor deposition), which require long-term treatment in high vacuum environments to successfully deposit the films. However, vacuum deposition is difficult to satisfy the request for low cost and large-scale production. This severely limits their potential in practical applications[3]. With the rapid development of film deposition technology, the recent use of solution-based processes alleviates the shortcomings of the high cost of the vacuum method which is not suitable for industrial development. Therefore, the preparation of metal oxide films with excellent properties by solution method at low temperature has attracted extensive attention of researchers[4-5]. Solution-based manufacturing significantly reduces manufacturing costs by eliminating vacuum deposition processes and replacing them with printable precursor materials. And compared with the traditional method, solution processing is easier to operate and regulate the chemical composition, contributing to the high quality of thin films[6].

According to previous research results, we find that the single-metal or binary-metal oxide films working as the dielectric layer did make great progress in leakage current density or permittivity, such as Al₂O₃, ZrO₂, HfO₂, Y₂O₃, HfLaO, but these systems focus on making a breakthrough in one aspect. Therefore, to optimize different properties of the dielectric layers simultaneously, we combined multi-component metal oxides. This experiment explored the possibility of other metal oxide combinations to optimize the performance of dielectric layers in thin-film devices.

As a result, the aluminum-magnesium-yttrium-zirconium-oxide (AMYZO) group of 0.6 M has the lowest leakage current density of 5.03 × 10⁻⁸ A/cm² @ 1.0 MV/cm. The hafnium-magnesium-yttrium-zirconium-oxide (HMYZO) group of 0.8 M has a maximum capacitance density of 208 nF/cm². The aluminum-hafnium-magnesium-yttrium-oxide (AHMYO) group component with the best optical properties has an average transmittance of 95%. Compared with the oxide films prepared by the solution method, the multiple oxide films in this experiment have made some breakthroughs in leakage current and capacitance density. Above all, the films in this experiment have great application prospects for making transparent new electronic devices with good transmittance, low leakage current, and high capacitance density.

Fig. 1. Transmittance of films in condition of (a)0.6 M; (b)0.8 M; (c)1.0 M in the 300 nm-800 nm wavelength range

Fig. 2. The relationship between leakage current density and field intensity of MIM devices in condition of (a)0.6 M; (b) 0.8 M; (c)1.0 M; (d)Measurement of electrode radius
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