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High Mobility and Stability Indium Oxide Thin-film Transistor with Praseodymium and Hetero-valence Tungsten Doping

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Oxide thin-film transistors have been widely studied for more than one decade. Due to high electron mobility, high transparency, high uniformity, and low processing temperature[1-4], they have become the most competitive candidate for next generation flat panel display. So far, many indium oxide based channel layer materials have been developed, such as In_2O_3[5], InGaO, InSiO, InZnO[6, 7], InWO [8], InGaZnO [9-11], InZnSnO, InZnWO. Nevertheless, there is a serious issue limiting further commercialization applications of oxide thin-film transistors that serious threshold voltage shift (ΔV_{th}) is observed when the thin-film transistors experience a negative gate bias stress, which cannot be fully recovered even after removing the stress for days.

According to previous research results, we find that lanthanide-doped indium oxide thin-film transistors show high bias stress stability but with low mobility. Lanthanide-doping is a tradeoff of mobility and stability. Therefore, to optimize the mobility and stability of indium oxide thin-film transistors, tungsten (W) was doped as well as praseodymium (Pr) to fabricate InPrWO thin-film transistor. W has different valence with Pr and In, thus more carriers are supported by W increasing mobility. This experiment explored the possibility of hetero-valence doping to optimize the performance of mobility and stability in indium oxide thin-film devices.

As a result, the InPrWO of 0.2 M with 1 mol% W has the highest mobility of 5.4 cm^2/Vs (annealing at 350 ℃). In this study, the interface between InPrWO and Al_2O_3 films was investigated by micro-wave photoconductivity decay (μ-PCD) which measures the microwave reflectivity of the photo-carrier trapping and recombination to evaluate defect state density of thin film or interface[11]. the InPrWO of 0.2 M with 1 mol% W shows highest peak signal, D value and lowest τ2 value, which refers to best bulk and interface performance. All InPrWO thin-film were amorphous measured by XRD, preventing carriers scattering from grain boundary. Under negative bias stress for an hour, InPrWO thin-film transistor showed good stability of only -1.2V shift. Above all, the InPrWO thin-films in this experiment have great application prospects for modifying the performance of high mobility and high stability thin-film transistor.

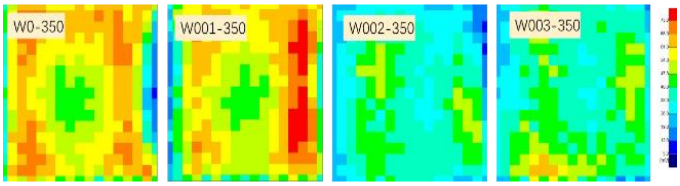

Fig. 1. μ-PCD mapping of InPrWO thin-film with different W concentration (annealing at 350℃).

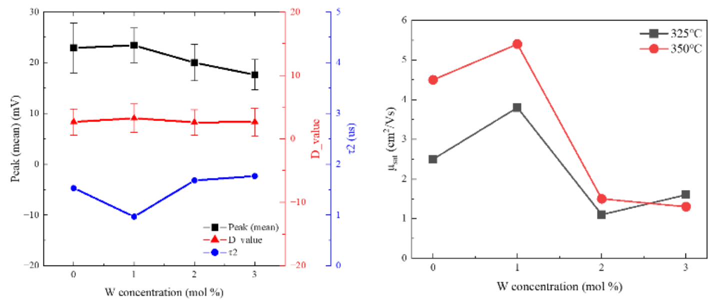

Fig. 2. (left) μ-PCD measurement of InPrWO thin-films with different W concentration (annealing at 350 ℃). (right) Saturation mobility of InPrWO thin-films with different W concentration at 325/350℃.

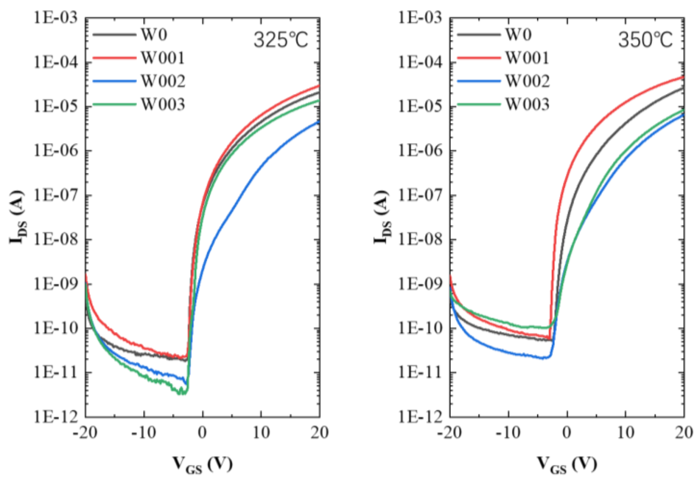

Fig. 3. Transfer characteristics of InPrWO thin-film transistors with different W concentration at 325 /350℃.

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