The effect of nitrogen doping on electrical and optical properties of Cu_2O films prepared by high-rate reactive high-power impulse magnetron sputtering

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1 Introduction

Nowadays, transparent conductive oxides are widely used in many important applications. Whereas n-type transparent conducting oxides are well-researched and are already widely used, there needs to be more p-type counterparts with sufficient performance. Cu_2O-based materials are a good candidate for this as they contain only abundant and non-toxic elements. In this study, we systematically investigated the role of nitrogen incorporated in Cu_2O thin films on optical and electrical properties, namely optical band gap, concentration of charge carriers and their mobility.

The Cu_2O:N films were prepared by reactive high-power impulse magnetron sputtering of Cu circular target (100 mm in diameter) in $Ar+O_2+N_2$ atmosphere. The pulse-averaged target power density varied in the range of ≈ 20-1000 Wcm^{-2}, and the fraction of N_2 in $(Ar+N_2)$ mass flow was 0-90%. The pulse-averaged target power density was set at 20 and 1000 Wcm^{2}, respectively. The oxygen partial pressure remained constant within each series but varied for various pulse-averaged target power densities.

2 Result

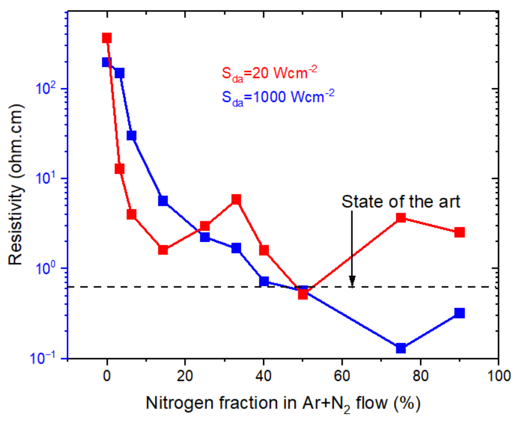

Figure 1: The resistivity of Cu_2O:N films as a function of nitrogen fraction in $Ar+N_2$ mass flow

The resistivity of Cu_2O:N films measured using a four-probe method is shown in Fig.1, where a decreasing trend can be seen with the increasing amount of nitrogen. Other trends for

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the increasing nitrogen flow rate are the increasing concentration of holes and, at the same time, the decreasing mobility of these holes. However, the decreasing mobility of holes makes it more difficult to measure the mobility. And for some layers, a change in conductivity from p-type to n-type cannot be ruled out. The very low resistivity value ≈ 0.1 Ωcm was achieved for the pulse-averaged target power density of 1000 Wcm^{-2} at 75 % nitrogen fraction in $Ar+N_2$ mass flow. To the best of our knowledge, this is the lowest resistivity value of Cu_2O:N thin films according to the current state of the art.

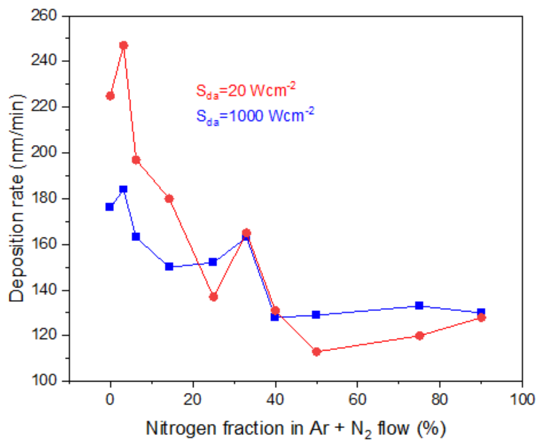

Figure 2: The deposition rate of Cu_2O:N films as a function of nitrogen fraction in $Ar+N_2$ mass flow

In Fig. 2, the deposition rate decreases with increasing nitrogen fraction, and even its minimum value (for 50% of nitrogen in the Ar+N2 mass flow) still exceeds 100 nm/min.

3 Conclusions

We have shown that reactive high-power impulse magnetron sputtering is a promising way for high-rate deposition (> 100 nm/min) of nitrogen-doped Cu_2O films. For the optimized nitrogen concentration, the film exhibits an electrical conductivity three orders of magnitude higher than that of a pure CuO_2 film. Very low resistivity Cu_2O:N films around 0.1 Ωcm was achieved.

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