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Zinc nitride material for the development of novel electronic sensors and flexible electronics

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Zinc nitride (Zn_3N_2) is a material with an antibixbyite structure in its crystal form and a band gap energy of 1.23 eV. It is deposited by radio frequency magnetron sputtering and molecular beam epitaxy (MBE) at low temperatures (T < 500 K) using reactive N_2 plasma and tends to form polycrystalline films. Despite its low temperature growth, it presents high mobilities (100 cm^2/V·s, in sputtering samples, and 350 cm^2/V·s, in MBE samples) and low resistivities (10^{-2}-10^{-3} Ω.cm). Those are attractive features for applications in flexible electronics for which common substrates do not often tolerate high temperature growth. An intrinsic property of the material is its metastability in ambient conditions. The as-grown material has a black appearance but, through the reaction with the water molecules in air, it oxidizes completely to produce a translucent whitish film of ZnO. As a result of the transformation, the material becomes electrically insulating. Through our extensive work on the material characteristics, a good correlation between the transformation span and the storage conditions was found. Thus, at a constant temperature, the lifetime of the nitride layer reduces as the relative humidity increases. The irreversible characteristic of the nitride degradation makes our devices suitable for potential applications in industry. In particular, the thickness of the Zn_3N_2 layer can be tuned to adapt the device lifetime to the degradation time of a perishable product in transit during long-distance transportation or long-time storage. These products suffer sudden changes on the ambient conditions that could spoil them or diminish their quality. The device is fabricated on polyethylene substrates and can be read out either optically or electronically. In order to further develop the technology, we investigated material passivation using a ZnO layer on top of the nitride. The results indicate that the cap layer improves the stability of the electrical characteristics, enabling the fabrication of thin film transistors, which deliver good output characteristics and field effect mobilities close to those achieved in amorphous Si technology.

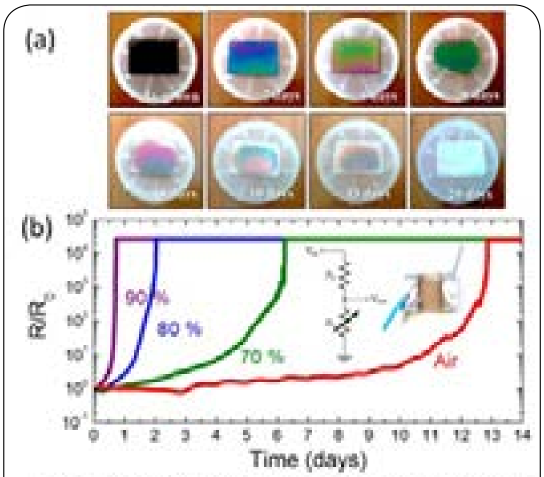

Figure 1: (a) Transformation of the zinc nitride film into zinc oxide. The as-grown film is black and opaque but becomes transparent due to the oxidation in air. (b) Normalized resistance as a function of time for different RH values.

Recent Publications

1. Gómez-Castaño M, Redondo-Cubero A, Vázquez L, Pau JL (2016) Analysis of Zinc Nitride Resistive Indicators under Different Relative Humidity Conditions. ACS Appl. Mater. Interfaces 8:29163-29168.

2. Redondo-Cubero A, Gómez-Castaño M, García Núñez C, Domínguez M, Vázquez L, Pau JL, Zinc Nitride Thin Films: Basic Properties and Applications. Oxide-based Materials and Devices VIII, San Francisco, CA, USA, 29 Jan - 1 Feb 2017, 101051B.
3. Domínguez MA, Pau JL, Gómez-Castaño M, Luna-López JA, Rosales P (2016) High mobility thin film transistors based on zinc nitride deposited at room temperature. Thin Solid Films 619:261-264.
4. García Núñez C, Pau JL, Ruíz E, Piqueras J (2012) Thin film transistors based on zinc nitride as a channel layer for optoelectronic devices. Appl. Phys. Lett. 101:253501.
5. García Núñez C, Pau JL, Hernández MJ, Cervera M, Piqueras J (2011) On the true optical properties of zinc nitride. Appl. Phys. Lett. 99:232112.

Biography

Jose Luis Pau is an Associate Professor of the Applied Physics Department at Universidad Autónoma de Madrid, Spain. Currently, he is involved in the development of electronic devices based on novel materials, semiconductor nanostructures and bidimensional materials. The device technology developed at his group also exploits the properties of surface plasmons and polaritons in metal nanostructures and thin films to enhance device performance. Optoelectronic devices and (bio)sensors are the main targets as part of advanced technologies for future communications, food quality sensors and biomedical systems.

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