

Iron effect on the oxidation, colour and antibacterial activity of zinc nanostructures for active food packaging produced by magnetron sputtering

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Introduction

Zinc oxide nanoparticles are known as an antibacterial agent with a great variety of applications in the industrial field, especially in food packaging. Recently, it has been demonstrated that the mixed oxides from Zinc (Zn) and Iron (Fe) can be used as a pigment and humidity sensor [1-3]. Based on these applications, the objective of this investigation was produced Zn and Zn-Fe bimetallic nanostructures on Poly-lactic acid (PLA) films using two different magnetron sputtering techniques. The effect of Fe content on the colour and antibacterial properties of the films when exposed at different ranges of humidity was especially evaluated.

Experimental details

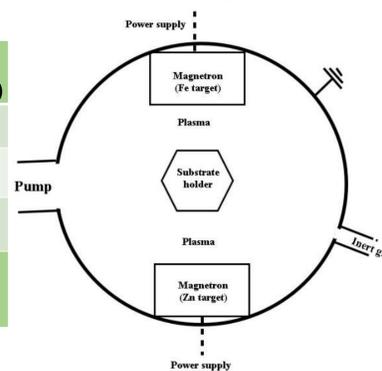
Process		J_{Zn} (mA/cm ²)	J_{Fe} (mA/cm ²)	Zn layer time (min)	Fe layer time (min)	N. of layers	Thickness (nm)	Rate (nm/s)	Zn (at. %)	Fe (at. %)	O (at. %)
Classical**	L4	0.5	--	14.5		1	109	0.13	72	-	38
Cluster***	M28	1.9	3.2	0.5	10	24	238	0.016	65	8	27
Classical**	L18	1	2.5	15*	10	1	207	0.09	60	9	31

* Zn and Fe simultaneously deposited

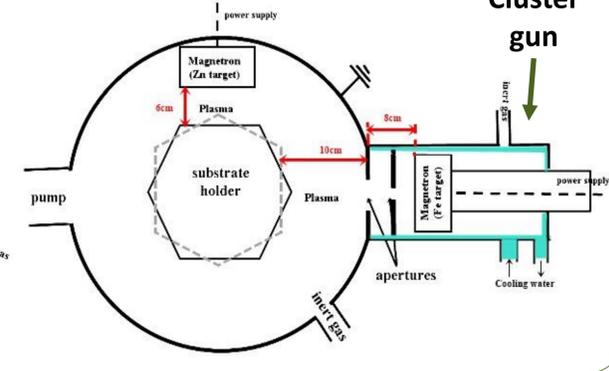
** Working pressure (WP)=4.9E-2mbar and $\Phi Ar=80sccm$

*** WP (Main chamber)=3.6E-3 mbar and WP(cluster gun)=7.7E-1 mbar $\Phi Ar=80sccm$

Classical Magnetron

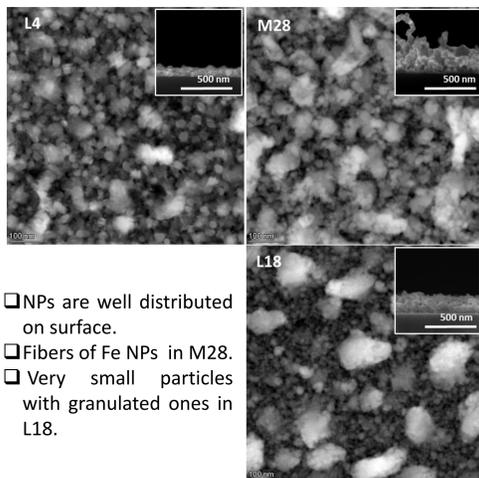


Cluster gun

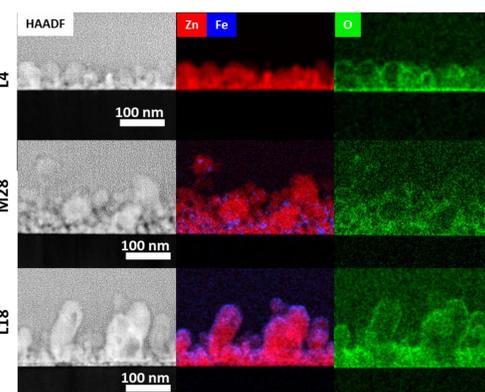


Results

Morphology (STEM)

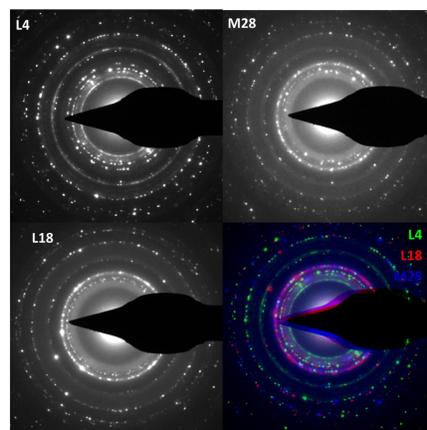


- NPs are well distributed on surface.
- Fibers of Fe NPs in M28.
- Very small particles with granulated ones in L18.

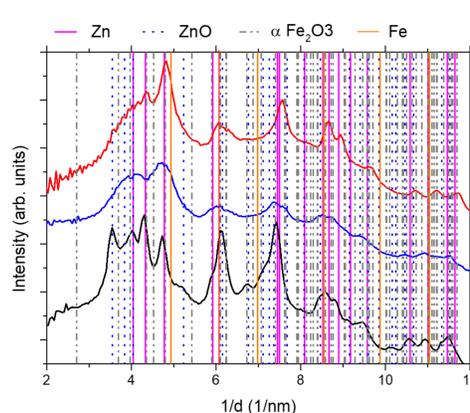


- Different Fe distribution depending on the production method.
- Presence of a passivated surface and column boundaries.

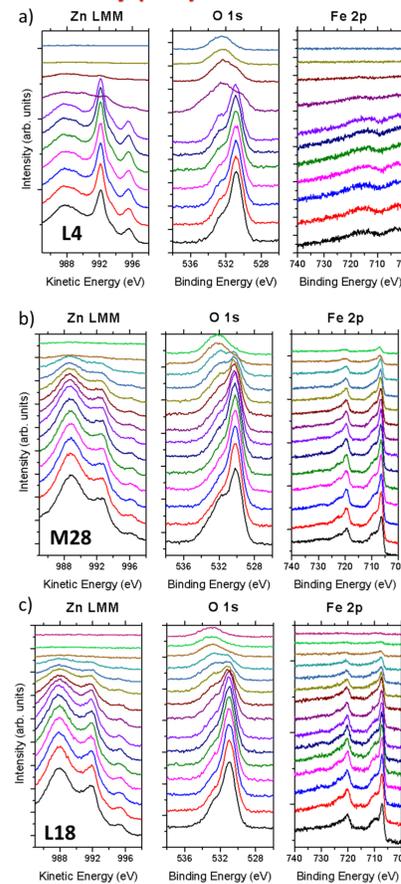
Structure (SAED)



- SAED data shows a polycrystalline nature of all the films.
- A mixture of Zn and ZnO phases, both hexagonal.
- Presence of more diffused rings in the ZnFe films.

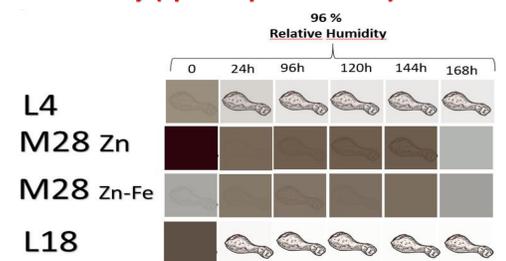


Chemistry (XPS)



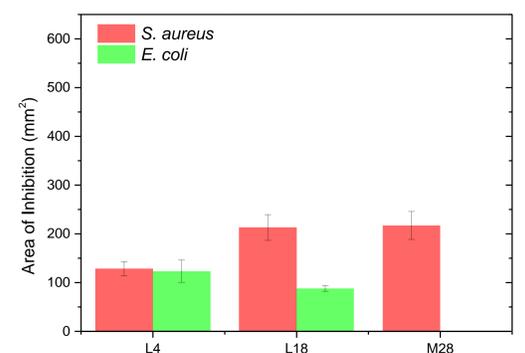
- The XPs shows that films are composed by a mixture of metallic and oxidized Zn and Fe.
- Pure Zn sample (L4) shows also a combination of Zn/ZnO.

Colour study (spectrophotometer)



- The opacity of Zn and Zn-Fe NPs from the classical chamber decreased after 24h from 100% to 24%.
- In both films of M28, the opacity stayed stable until the sixth day, it started decreasing to 80%.

Antibacterial activity (Zone of inhibition)



- For *S. aureus*, both Zn-Fe samples show a higher inhibition than pure Zinc NPs.
- The inhibition activity of M28 against *E. coli* is non-existent
- The inhibition area for both bacteria are similar for pure zinc sample, while it is higher for *S. aureus* and lower for *E. coli* in L18 and diminished in M28.

Conclusion

- SEM showed different morphologies on surface and the size of particles.
- STEM showed a passivated surface and column boundaries., which is confirmed by the XPS (Presence of Zn and Fe in metallic and oxidized states)
- The exposure of deposited NPs at high humidity, showed a chromatic affect during the oxidation of the Zinc - Iron NPs, changing from sample to another.
- Antibacterial tests presented activities against *E. coli* and *S. aureus*, showing better response for *S. aureus*.

Acknowledgements

The authors also thank the financial support by Portuguese Foundation for Science and Technology (FCT) in the framework of the project NANOXPAC co-financed via FEDER (PT2020) POCI-01-0145-FEDER-030789.



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