Synergistic Organic/Inorganic Implantable Packaging Using Multiple Parylene C and Aluminum Oxide Film

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Recent research on medical implants has asked for more reliable and biocompatible hermetic packaging techniques with integrated circuits (IC). Besides, high-density multi-channel IC interconnects also become a major requirement to realize high-resolution application on electrical stimulation and recording. Previously proposed packaging methods are mostly based on wire bonding technique to bond pads on chip to pads on biocompatible ceramics substrate individually. However, the real medical implant product that are currently in use or under development still lack the high-density packaging techniques which limit the further development of application [1-3].

The development of film package in implantable electronic medical device is one of the major solution. Rodger *et al* [4] introduced a biocompatible interconnect film packaging method based on parylene film, which is already a huge achievement of high-density packaging techniques. Also, Rodger have demonstrated the parylene flex and high-density multi-channel retinal IC chip have a strong bonding to survive during surgical manipulation. Unfortunately, water penetration problem of parylene C film still exists in the *in vivo* corrosive body fluid environment that could not meet the requirement of long-term implantation in humans. Thus, A desired medical implants of lifetime 10 years are mostly depends on the packaging design protection on the device.

Thin film encapsulation has been studied on flexible OLED packaging using incompatible three layers MgF_2/ZnS film, which has a good water vapor and oxygen barrier capability that could substantial improvement in lifetime [5]. In this work, we built an ideal packaging design by introducing multiple biocompatible organic/inorganic film together on PI substrate. The water penetration route of multiple film will significantly enhanced due to the multiple films design. The fabrication and functional validation of the well designed multiple film are based on PI substrate of 1 μm organic parylene C (PA) and 50 nm inorganic aluminum oxide (Al_2O_3) film, which are five layers PA/Al_2O_3/PA/Al_2O_3/PA design structure (Fig. 1). PA and Al_2O_3 film are deposited using advanced chemical vapor deposition (CVD) and atomic layer deposition (ALD) technology, respectively. Specifically, the films packaging sample and the He leakage test sample are shown on fig.2a and fig.2b, respectively. The He leakage test pressure is 1×10^{-10} Pa·m^3/s, meeting FDA 10 year *in vivo* implantation standard. Furthermore, the *in vivo* biological compatibility results of cell relative growth rate (RGR) also demonstrate highly biocompatible level (0 level) in cell L929 (Fig. 3).

In conclusion, the state-of-the-art multiple organic/inorganic film packaging has been successfully demonstrated as a useful package design. Thus, synergistic organic/inorganic packaging by "multiple PA and Al_2O_3 film" provides a promising film package design that ensures highly biocompatible and long-term implantable for medical implants market. Next, we will use this film packaging design in our 1024 high-density retinal product to achieve long time reliable implantation *in vivo*.

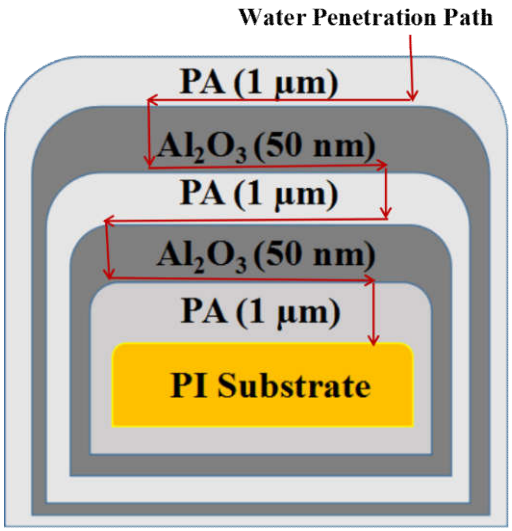

Fig. 1. Schematic diagram of five layers PA/Al_2O_3/PA/Al_2O_3/PA design structure on PI substrate, and water penetration path between PA and Al_2O_3 film (Red Color).

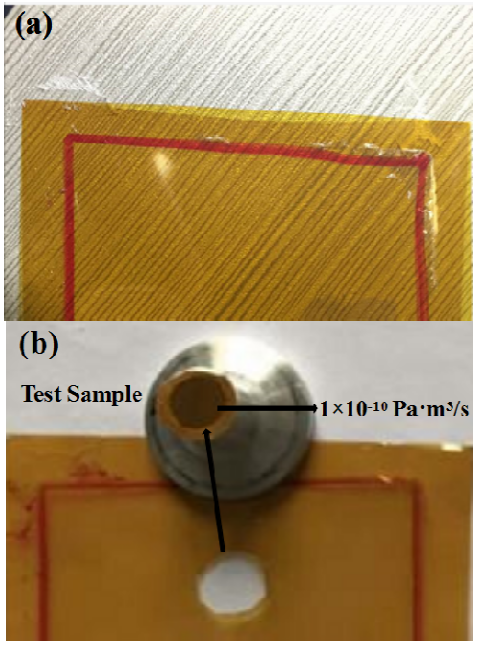

Fig. 2. (a) The film packaging sample; (b) The He leakage test sample.

Group	Absorbance Values (Blank Control)	Absorbance Values (Negative Control)	Absorbance Values (Positive Control)	Absorbance Values (Sample)
1	0.249	0.275	0.054	0.256
2	0.256	0.243	0.052	0.223
3	0.268	0.29	0.061	0.298
4	0.23	0.269	0.059	0.24
5	0.261	0.278	0.057	0.264
6	0.247	0.275	0.062	0.266
Average Absorbance Values	0.251833	0.271667	0.0575	0.257833
RGR		1.078757	0.228326	1.023827
Biocompatible Level		0	4	0

Table 1. Biocompatible level of the film packaging sample.

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