Chapter 12
Discrete Portable Measuring Device for Monitoring Noninvasive Intraocular Pressure with a Nano–Structured Sensing Contact Lens Prototype

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ABSTRACT

A new portable measuring device for monitoring intraocular pressure with a non-invasive system using a prototype of contact lens has been developed. The contact lens is based on a new organic flexible highly piezo-resistive film sensor that is glued to the central hole of a lens. The measuring system is wire connected to the contact lens and incorporates user interface methods and a Bluetooth link for bi-directional wireless data transfer.

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*The key design aspects of such architecture are discussed in this paper. The system is designed with an architecture that can be integrated in the future in order to be placed in the contact lens. The discrete system is used to validate the electronic measurement operation and the contact lens sensor (CLS). The measurement instrument can calibrate the differences of the nominal value of the sensor and measure resistances variations that are related to pressure variations. The measuring system and the contact lens sensor were tested with an eye phantom and with enucleated pig eyes by applying pressure changes between 7 to 32 mmHg recording the electrical changes with the portable device.*

**INTRODUCTION**

Glaucoma is the second cause of irreversible blindness worldwide (Resnikoff et al., 2004). Its prevalence varies between 1 and 3% depending on population studied and the diagnostic criteria (Raychaudhuri et al., 2005; Sung et al., 2006). Moreover, glaucomatous optic neuropathy leads to certain characteristic changes in the optic nerve head together with a visual field loss that is usually associated with an increase in the intraocular pressure (IOP) with values superior to basal ones, 21 mmHg (Sung et al., 2006). One of the most important parameters in glaucoma diagnosis is the IOP measurement and for the treatment of this disease the decrease of this IOP value is needed, to prevent the optic nerve damage (Asrani et al., 2000; Konstas, Mantziris, & Stewart, 1997; Rota-Bartelink, Pitt, & Story, 1996). Hughes et al. (2003) showed that punctual IOP measurements are not valid for glaucoma diagnosis demonstrating with a 24 h clinical monitoring that this value changes in an incident rate of 79.3% patients with glaucoma.

At the moment the only reliable method known to determine the IOP tensional curve is to perform continuous punctual measurements during 24 hours (Konstas, Mylopoulos, & Karabatsas, 2004). Due to the complexity of this method, the patient is forced to be admitted in a hospital during a day. Several attempts to enable a non-invasive IOP control with continuous monitoring have been done, however none of the developed devices have been integrated into clinical practice mainly due to technical problems and lack of long-term measurements stability (Flower, Maumenee, & Michelson, 1982; Greene & Gilman, 1974; Maurice, 1958; Svedbergh, Bäcklund, Hök, & Rosengren, 1992; Wolbarsht, Wortman, Schwartz, & Cook, 1980). Leonardi et al. has developed a marketable prototype based on a hydrophilic CLS, (Leonardi, Leuenberger, Bertrand, Bertsch, & Renaud, 2004; Leonardi, Pitchon, Bertsch, Renaud, & Mermoud, 2009) which measures deformations of the eyeball (changes in cornea curvature) due to IOP variations. This device is embedded in a soft contact lens with a platinum-titanium strain gauge. The IOP changes of this device are transmitted to a Pt-based sensor through the deformation of the soft contact lens.

The discovery of ultra high piezo-resistive properties in flexible conducting all-organic bi-layer (BL) films (Laukhina et al., 2010) has enabled the design and fabrication of novel pressure sensor devices (Laukhina, Mas-Torrent, Rovira, Veciana, & Laukhin, 2006). Such BL films consist of a polycarbonate film covered on one of its sides with a thin layer of nanostructured crystals of an organic molecular conductor; like the bis(ethylenedithio)tetrathiafulvalene (ET) charge-transfer salt β-(ET)2I3. The ultra high piezo-resistivity of such BL films is originated by the softness of the nanocrystals of the conducting salt (Kondo et al., 2006), embedded on the top of the polymeric matrix, that are deformed under small strains changing their conducting properties. Other advantages of using BL films as piezoresistive materials is that they enable to develop strain sensitive active elements that are flexible and transparent and which can be easily glued over a hole of any configuration for fabricating...
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