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Babizhayev

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(54) **COATED OPHTHALMIC AND IMPLANTABLE DEVICES AND METHODS FOR PRODUCING SAME**

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(58) **Field of Search** 623/6.56, 6.62

(56) **References Cited**

U.S. PATENT DOCUMENTS

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4,886,505	A	*	12/1989	Haynes et al. 604/265
5,147,125	A	*	9/1992	Austin 359/359
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EP	280 215	8/1988
EP	295 397	12/1988
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WO	WO 93/23092	11/1993

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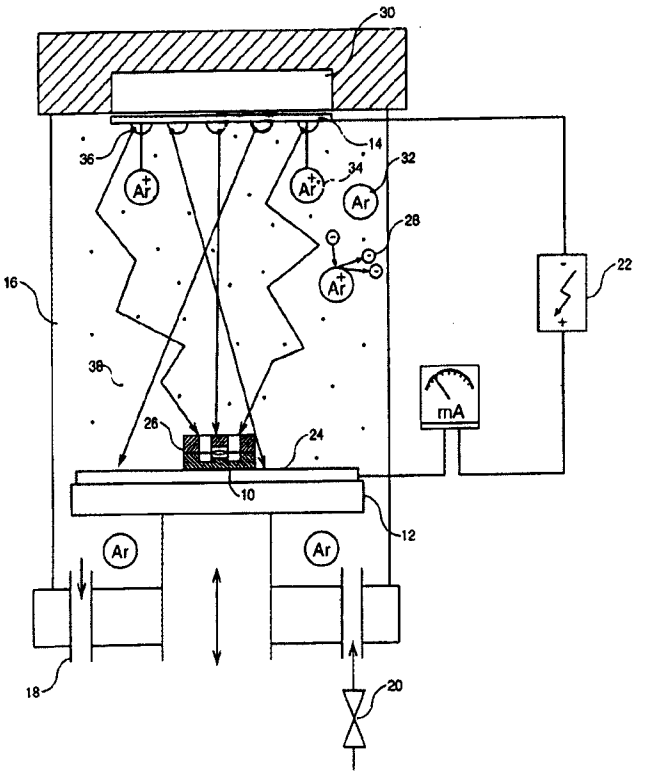
(57) **ABSTRACT**

An implantable device and method for making the device. The device includes a metabolically-active coating on at least a portion of a surface of the device. Preferably, the coating has a thickness of less than about 500 angstroms. The coating improves the bio-compatibility of the device with the human body. The method is particularly applicable to implantable devices for implantation within the human eye, including intraocular lenses.

26 Claims, 3 Drawing Sheets



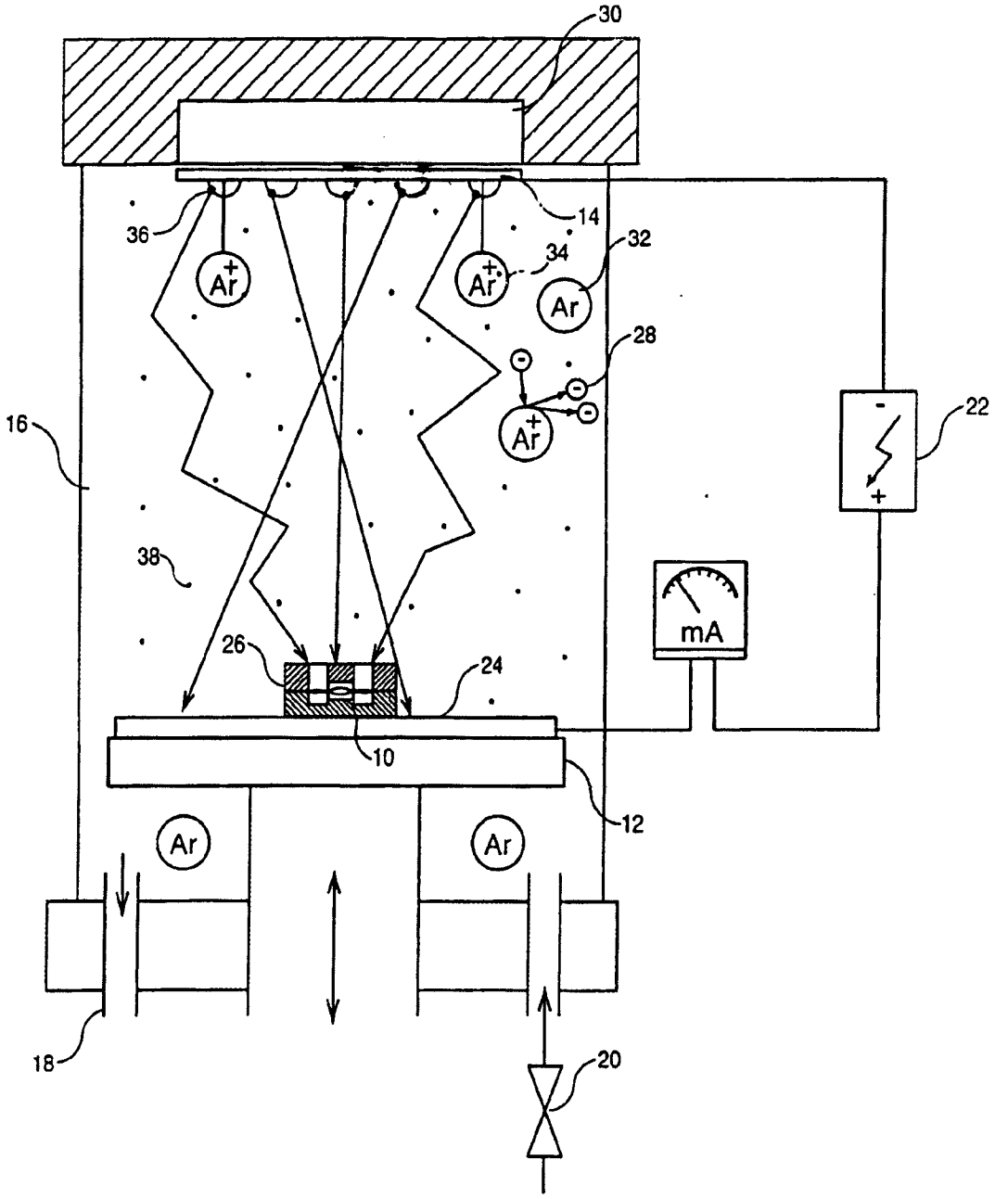


FIG. 1

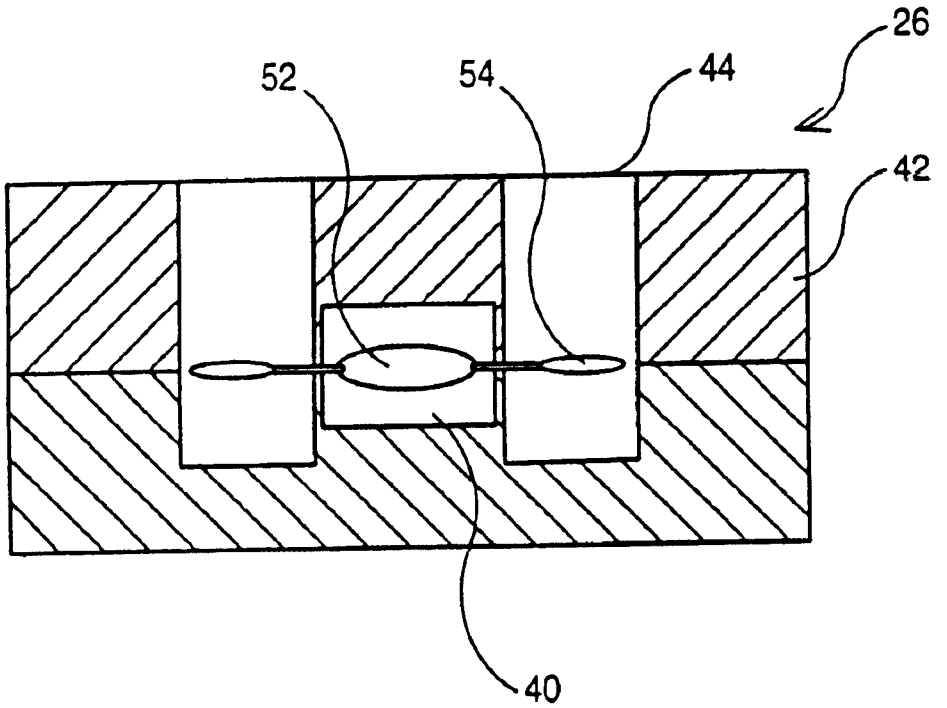


FIG. 2

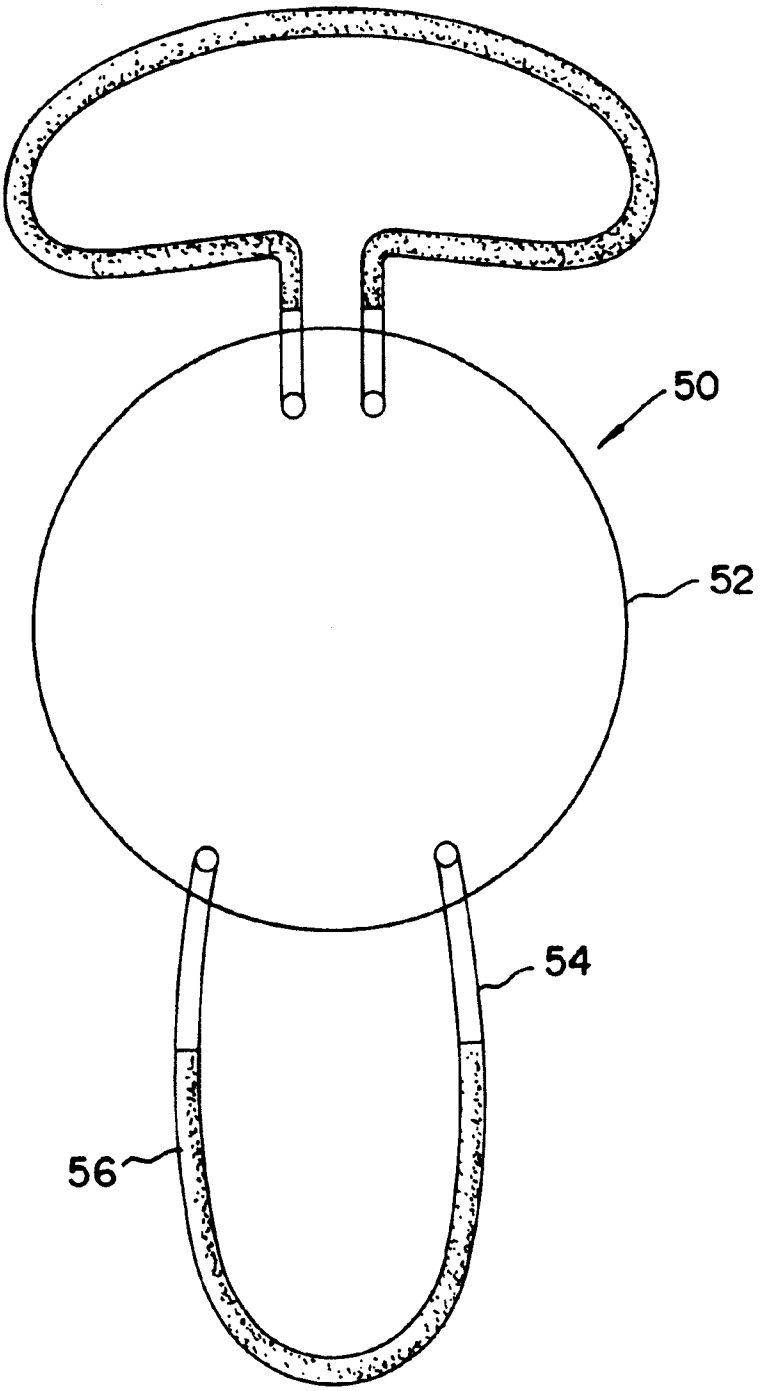


FIG. 3

COATED OPHTHALMIC AND IMPLANTABLE DEVICES AND METHODS FOR PRODUCING SAME

This application is a U.S. National Stage of International application PCT/IB98/01490, filed Sep. 24, 1998 and published on Apr. 8, 1999 in the English Language.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to devices that are adapted for implantation within the human body and methods for making such devices. More particularly, the present invention relates to a method for coating such devices and the devices coated thereby, wherein the coating increases the bio-compatibility and the medical usefulness of the device.

2. Description of Related Art

Artificial implantable devices, such as prosthetic devices or artificial eye lenses, have been implanted in humans for many years. For example, an artificial lens can be implanted in the posterior or anterior chamber of the human eye to restore vision of patients, as is done following cataract extraction. The function of the artificial lens, like the natural crystalline lens, is to maintain transparency and refract incidental light to focus the light on the retina for visual acuity.

Implantable artificial lenses, referred to as intraocular lenses (<<IOLs>>), have been made using many different designs. A common form of intraocular lens includes a central circular lens, frequently with flexible haptic loops radiating from the circumference of the lens to center the lens and maintain the position of the lens within the eye chamber.

The lens and haptic loops have been made from a number of different materials. Presently, polymethylmethacrylate (PMMA) is the most common material used for the lens portion of the IOL. Haptic loops have been made from a variety of materials, including plastics or metals. The haptic loops must be flexible and retain a spring-like quality to properly hold the lens in place without causing discomfort, such as from rubbing or tension on the ocular tissues. However, metal-loop lenses and poorly polished lenses can lead to chafting of the iris and related complications.

The tissues of the anterior segment of the eye and the corneal endothelium are bathed in an aqueous humor containing hydrogen peroxide (H_2O_2), lipid hydroperoxides and other reactive oxygen species. Natural crystalline lenses are anteriorly covered by a single layer of cuboidal epithelial cells which are highly metabolically active, and natural crystalline lenses that are healthy can tolerate substantial concentrations of such peroxides and lipid hydroperoxides without apparent damage. This ability of the natural lens is attributed to an active glutathione redox cycle. Typical concentrations of hydrogen peroxide in the aqueous humor of a healthy eye are on the order of 20 to 30 μM (micromoles per liter).

However, the average concentration of peroxides in cataract patients is elevated, typically to about 40 μM. Higher concentrations, such as 50 μM or higher, have been shown to cause significant corneal swelling and a decrease in the glutathione concentration. Concentrations of 50 μM or higher have also been shown to cause damage to DNA, including single strand breaks.

In addition to the foregoing complications, these oxygen derivatives and peroxide compounds are believed to contribute to pathological processes in ageing and systematic diseases, such as diabetes, artherosclerosis, chronic renal failure, inflammation and retinal degenerative diseases. IOLs that are implanted within the eye, for example after cataract extraction, do not have the ability to reduce or stabilize the concentration of these detrimental peroxide compounds. Therefore, the foregoing problems persist when the natural lens is replaced with an IOL. There is also evidence that PMMA lenses cause granulocytes to release significant amounts of oxygen radicals.

As it is discussed above, the anterior cuboidal epithelial cells of the natural crystalline lens which provide the anti-oxidant protection of the natural lens are usually removed during cataract extraction. However, the equatorial residual epithelial cells of the crystalline lens can spread to the posterior capsule, grow, and cause secondary opacification of the IOL after implantation. Further, a PMMA lens can cause a foreign body reaction accompanied by the formation of giant cells and macrophages on the IOL and acute chronic inflammation of the eye. The interaction between the ocular tissue and the artificial IOL can also be responsible for complications such as post operative inflammation, cell and pigment deposits on the lens, capsule opacification and macular oedema, a swelling of the macula of the retina.

U.S. Pat. No. 5,376,116 by Poler is directed to an intraocular lens device for impeding secondary growth within an eye, such as the growth of epithelial cells. It is disclosed that epithelial cell and protein strand development can be impeded by providing one or more metals and/or a basic salt in the environment or in the construction of the intraocular lens. It is believed that the metal and/or basic salt provide an electrolytic action within the capsule and that cell growth is thereby reduced. The changed pH, temperature and chemical balance that result allegedly reduce or eliminate-the ability of epithelial cells to multiply. When metal coatings are used, complicated schemes are used to produce patterns of at least two different metals on the lens surface. The device may be plated using known techniques and the thickness of the adhered coating is about 316 to 633 nm, as determined by interferometry.

U.S. Pat. No. 4,718,905 by Freeman is directed to a haptic element for an intraocular lens. The longevity of the haptic is enhanced by a bio-compatible and inert ion coating of the polypropylene haptic on the surfaces making tissue contact. The preferred coating elements are nitrogen, carbon, silicon and aluminum and the protective ion coating is applied by ion beam implantation.

Ion beam implantation has significant disadvantages. The implanted ions create a net positive surface charge which can facilitate the formation of free radicals. Further, the ions penetrate the surface of the device to a depth of up to 2 μm. This creates a new structure with decreased flexibility, stability and smoothness. Further, the process occurs at elevated temperatures which can damage the device. The process is also a <<line of sight>> process which is not readily adaptable to high volume production of devices.

It would be useful to provide a biologically compatible implantable device, such as an intraocular lens that mimics the capacity of the crystalline lens to withstand oxidative stresses and provide a reduction of peroxide compounds in ocular humors, thus preventing cellular disfunction and pathologies resulting from oxidative attack. It would be useful if such a device could be fabricated without sacrificing the desirable physical properties of the device, such as flexibility and smoothness.

In addition to the need for improved IOL devices, there is a need for improved bio-compatibility for other devices.