

Research Article

Novel design of low voltage DC source for bio nano diagnostic applications

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Abstract

This paper aims designing prototype power supply for Nano biomedical applications in existing hospital industry. So far only the power supplies are designed using more number of passive components such as resistors, capacitors and inductors. But we have introduced a novel technique using silver nano particles to impregnate on the collagen sheet, deposited on electrode by electrodepositioning method, it produces constant DC power supply voltage of 12 volts or 9 volts for biomedical diagnostic applications. Fourier Transform Infrared Spectroscopy spectrum of chitosan-hydroxyapatite composite film shows the characteristic peaks of chitosan and hydroxyapatite. The free ammonia groups are shown at 1637 cm^{-1} . The $-\text{CH}_2-\text{CH}_2-$ vibration were observed at 2920 cm^{-1} .

Keywords: Electrodes, Silver Nano Particles, Stirrer, Voltage Regulator, Electrodepositioning Technique.

1. Introduction

Recently, thin film sheets are produced by vapour deposition and self assembly techniques. But we introduced a novel method by using nano particles deposited using electrodepositioning method mixed with the collagen thin film sheet^{1,2}. In this research paper we introduced a novel technique for thin film fabrication, impregnated with silver nano particles by electro deposition technique using constant voltage 12V DC or 9V DC. Due to low cost fabrication technique, many commercial integrated circuits (IC) such as regulated power supplies (RPS) are available for the past two decades. The power supply designed by us includes fairly simple, fixed voltage types of high quality precision regulators. These IC regulators have much improved performances as compared to those made from the discrete components. They have a number of unique built-in features such as current limiting, self protected against over temperature remote control operation over a wide range of input voltages and feedback current limiting. We used the IC regulators available in the market that produces fixed positive output voltages making them useful in a wide range of bio medical applications.

2. Experimental Set Up

0.25g of chitosan was dissolved in 50ml of 0.1N hydrochloric acid and then 0.25g of hydroxyapatite was dissolved in 50ml of 0.01N hydrochloric acid.

2.1 Procedure

By using the combination of electrochemical and electrophoretic technique, we prepared the hydroxyapatite-chitosan film. "The migration of charged particles under the influence of electric field" was the basic principle for an electrodeposition of film. It consists of two electrodes such as anode and cathode. The cathode consists of Small Square of stainless steel plate for electrodeposition of film. The dissolved chitosan in hydrochloric acid contain the pH near three. After filtering undisclosed material, the pH of the chitosan solution was adjusted to seven using sodium hydroxide (1M). For electro deposition, cathode and anode electrodes were immersed in a suspension containing chitosan solution. Deposition was performed by connecting both the cathode and anode to a alternative current power supply and applying a voltage of 12V side by side added hydroxyapatite solution and maintain the pH of 7 using 0.1N sodium hydroxide. Chitosan contain free amino group which was migrated towards the cathode. When hydroxyapatite suspended in the chitosan became entrapped and deposited on the steel plate which was placed on the cathode. After deposition the electrodes were disconnected from the power supply, removed from the suspension, rinsed with distilled water and dried at room temperature. Then the film was examined by Fourier transform infrared spectroscopy (FT-IR).

2.2 Power supply design and fabrication

Fig. 1 7812 and 7809 regulated power supply

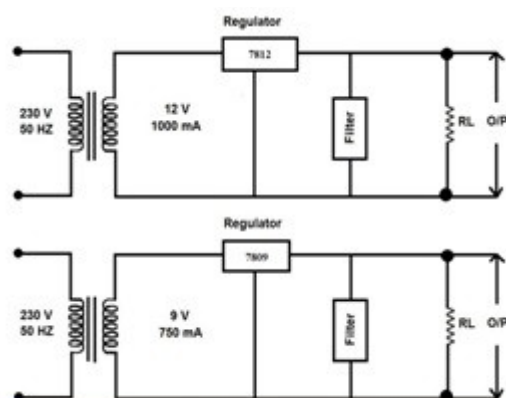
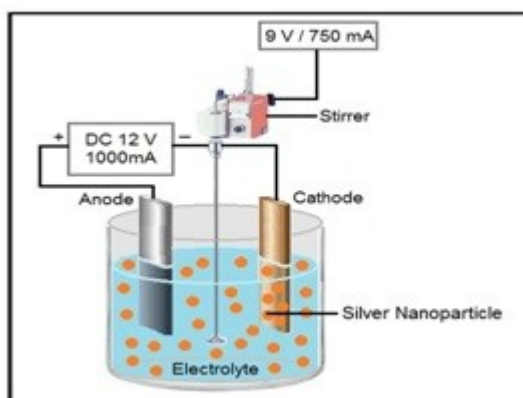


Figure.1 shows a standard configuration of a fixed positive voltage IC regulator of 7800 series. It has three terminals labelled as input, output and ground. The IC7812 is +12 Volt regulator and IC7809 is +9volt regulator. The filter consists of two capacitors namely C_1 and C_2 . The capacitor(C_1) with $0.33\mu\text{F}$ is required if power supply filter is located 3inches from the IC regulator and the capacitor(C_2) with $0.01\mu\text{F}$ acts basically as line filter to improve transient response. Figure 2 shows the circuit indicating the use of 7805 as an adjustable voltage regulator the output voltage is given by the following equation

$$V_{\text{out}} = V_{\text{fixed}} + \left(\frac{V_{\text{fixed}}}{R_1} + I_q \right) R_2$$

For the above equation 7805IC regulator, when the $V_{\text{fixed}} = 5\text{V}$, Let R_1 and $R_2 = 1\text{k}\Omega$ and $I_q = 2\text{mA}$, then its output voltage is $V_{\text{out}} = 15\text{Volts}$. The input voltage for the IC regulator must be at least 2volt and above the output voltage. This is required in order to maintain regulation. The input voltage should not be more than 35 or 45Volts depending upon the requirement. The circuit inside all the IC regulators have internal thermal overload protection and short circuit current limiting features. Thermal overload in a IC regulator occurs whenever the internal power dissipation becomes excessive and the temperature of the device exceeds a certain value.

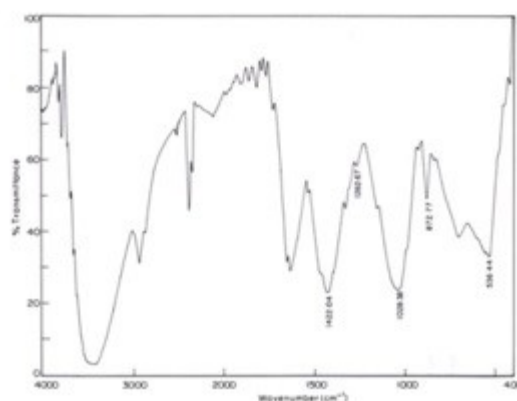
Fig. 2 Prototype power supply with detachable electrodes.



The prototype power supply with anode and cathode terminals attached with DC power supply of 12 V, 1A with Stirrer. Stirrer is attached with 9V/750 mA power supply. The stirrer speed can be varied from low rpm to high rpm [up to 1200 rpm]. The anode and cathode terminals are immersed in electrolyte with silver nano particle. Due to electro deposition method the silver nano particles are deposited on the cathode terminal. The chitosan with silver nano particle in the form of paste is deposited on the cathode and the the paste is later made as a thin film using self assembly method.

3. Testing and Results

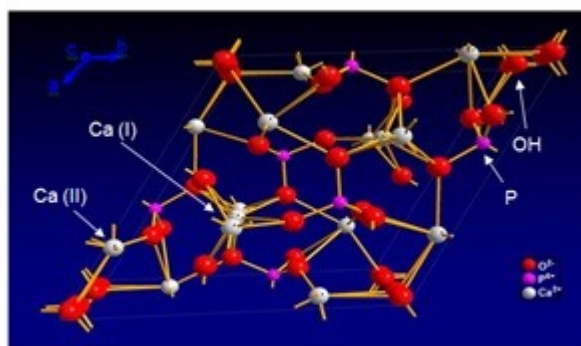
Fig.3 FTR spectrum of chitosan-hydroxyapatite.



Fourier Transform Infrared Spectroscopy spectrum of chitosan-hydroxyapatite composite film shows the characteristic peaks of chitosan and hydroxyapatite. The free ammonia groups are shown at 1637 cm^{-1} . The $\text{CH}_2\text{-CH}_2$ Vibration were observed at 2920 cm^{-1} , the vibration modes of V_1, V_3 and V_4 of phosphate ion absorbed from the spectrum, well dissolved bands at 602,580 and 536 represent V_4 vibration modes.

Chitosan is a linear polysaccharide composed of randomly distributed β -(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). It is made by treating shrimp and other crustacean shells with the alkali sodium hydroxide.

Figure.4. Crystalline structure of hydroxyapatite



3.1 Hydroxyapatite

The term "apatite" applies to a group of compounds (not only at calcium phosphates) with a general formula in the form $\text{M}_{10}(\text{XO}_4)_6\text{Z}_2$, where M^{2+} is a metal and species XO_4^{3-} and Z^- are anions. The particular name of each apatite depends on the elements or radicals M, X and Z. In these terms, hydroxyapatite (HAp) has the molecular structure of apatite, where M is calcium (Ca^{2+}), X is phosphorus (P^{5+}) and Z is the hydroxyl radical (OH^-). This is known as stoichiometric hydroxyapatite and its atomic ratio Ca/P is 1.67. Its chemical formula is $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$, with 39% by weight of Ca,

18.5% P and 3.38% of OH. Hydroxyapatite crystallizes in a hexagonal system, although with some exception in a monoclinic system. The system belongs to the hexagonal space group P6₃/m, with hexagonal rotational symmetry and a reflection plane and with cell parameters of $a=b=9.418 \text{ \AA}$ and $c=6.884 \text{ \AA}$. Figure 1 shows the unit cell of hydroxyapatite. HAP structure is formed by a tetrahedral arrangement of phosphate (PO_4), which constitute the "skeleton" of the unit cell. Two of the oxygens are aligned with the c axis and the other two are in a horizontal plane. Within the unit cell, phosphates are divided into two layers, with heights of 1/4 and 3/4, respectively, resulting in the formation of two types of channels along the c axis, denoted by A and B (figure.4).

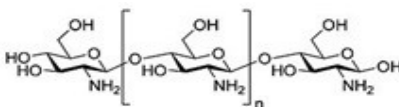


Figure.5. Chitosan powder from sea foods



The first patent on producing chitosan was taken out in the 1920's, since then there have been taken out several hundred patents on production and even more on application. Although there have been used extensive resources on both research and development of processes and application, it's only the last two decades chitosan has been an industrial available product in large scale quantities.

3.2 A polysaccharide

Chitosan is made by alkaline N-deacetylation of chitin, (Fig. 5). The term chitosan does not refer to a uniquely defined compound, it merely refers to a family of copolymers with various fractions of acetylated units. It consists of two types of monomers; chitin-monomers and chitosan-monomers. Chitin is a linear polysaccharide consisting of (1-4)-linked 2-acetamido-2-deoxy- β -D-glucopyranose. Chitosan is a linear polysaccharide consisting of (1-4)-linked 2-amino-2-deoxy- β -D-glucopyranose. Commercial, chitin and chitosan consists of both types of monomers. Chitosan is found in nature, to a lesser extent than chitin, in the cell walls of fungi. Chitin is believed to be the second most abundant biomaterial after cellulose. The annual biosynthesis of chitin has been estimated to 10^9 to 10^{11} tons. Chitin is widely distributed in the nature. Among several sources the exoskeleton of crustaceans consist of 15-20 % chitin of dry weight. Chitin found in nature is a renewable Bio-resource. Chitin is similar to cellulose both in chemical structure and in biological function as a structural polymer. The crystalline structure of chitin has been shown to be similar to cellulose in the arrangements of inter- and intrachain hydrogen bonding. It has been proposed to define chitosan and chitin as soluble or insoluble in 0.1 M acetic acid, respectively or by degree of deacetylation, >20 % of deacetylation is proposed defined as chitosan.

3.3 Cationic Nature

The main interest in chitosan derives from its cationic nature in acidic solutions, which provides unique properties relative to other polysaccharides which are usually neutral or negatively charged. The cationic nature allows chitosan to be used in among other applications waste-water treatment. Positively charged chitosans reacts with organic solids and cell surfaces which are usually negatively charged. Another useful property is that it is possible to control the solubility and the charge density by varying the mole fraction of N-acetylated units. Regarding potential applications of chitosan in water-solutions, control of the solubility of the chitosans is of primary importance. In general, the solubility of heteroglucans are influenced by the polarity and size of the monomers, distribution of the monomers along the chain, the flexibility of the chain, branching, charge density and molecular weight of the polymer.

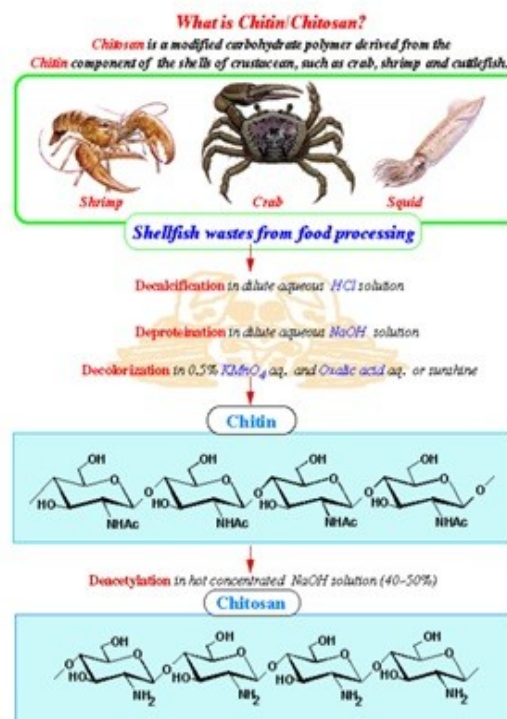
3.4 Product characterization

Both chitin and chitosan are naturally biodegradable and nontoxic products. Chitosan can be described in general by the following parameters: Degree of deacetylation in %, Dry matter in %, Ash in %, Protein in %, Viscosity in Centipoise, Intrinsic viscosity in ml/g, Molecular weight in g/mol: average MW of 4.5×10^4 g/mol and a numerical MW of 1.7×10^4 g/mol, Turbidity in NTU units. All these parameters can be adjusted to the application chitosan is being used for. The main parameters that influence on the product properties is as mentioned above, the degree of deacetylation and viscosity. The deacetylation is very important to get a soluble product. But it's not only the degree of deacetylation that influence on the solubility. The distributions of the acetyl groups are also important. Viscosity can be adjusted to each application, by controlling our process parameters. The range of viscosity is from 10 to 5000 cp (Figure.6 & 7).

4. Applications

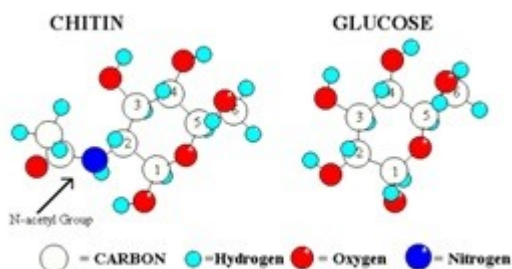
Chitosan is unique, with a polyamin character which makes it soluble (at acid pH), positively charged, different viscosity and easily modified chemically. These properties confer upon chitosan potential applications in: Bio-medicine, Biotechnology, Agriculture, Cosmetics, Shampoo, Toothpaste, Contact lenses, Clarification, Recovery of proteins, Emulsions, Coatings, Pollution treatment, Adhesives, Industry.

Fig. 6. Structural formula of chitin and chitosan.



4.1 Chitin

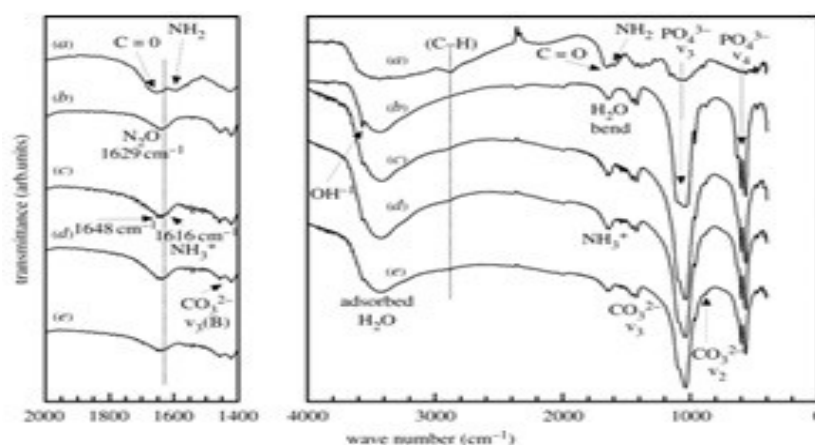
Fig.7 Molecular structure of Chitin and Glucose



Chitosan has a number of commercial and possible biomedical uses. It can be used in agriculture as a seed treatment and bio pesticide, helping plants to fight off fungal infections. In winemaking it can be used as a fining agent, also helping to prevent spoilage. In industry, it can be used in a self-healing polyurethane paint coating. In medicine, it may be useful in bandages to reduce bleeding and as an antibacterial agent; it can also be used to help deliver drugs through the skin.

The FTIR spectra of HA and 20CS-80HA powders are given in Fig. 8. In the FTIR of 500±C-sintered pure HA (Fig. 8(a)), the absorption bands around 1037, 963 and 603, 565 cm^{-1} are ascribed to the stretching vibration and bending vibration of PO_4 respectively¹⁰. The double peaks at 1416, 1464 cm^{-1} and absorption peak of 873 cm^{-1} were the typical absorption peaks of CO_3 , indicating that HA contained CO_3 .¹¹ The absorption peaks of 3426 and 1635 cm^{-1} were caused by absorbed water and stretching vibration of the O-H group.

Figure.8. FTIR of (a) chitosan, (b) control nHA, (c) HS20, (d)HS40and(e)HS70hybrid HA–chitosan nanoparticles¹¹



The FTIR analysis of 500±C-sintered 20CS-80HA showed that the strong peaks at 564, 604, 1044 and 3415 cm^{-1} caused by $\text{PO}_3/4$ and OH vibration still existed, but the peaks of $\text{CO}_2/3$ disappeared (Fig. 3(b)). From the FTIR spectra of 20CS-80HA dried at 130±C, it can be seen that the typical peaks of $\text{PO}_4/3$ (1034, 603 and 561 cm^{-1}) still existed but the intensity was sharply reduced compared with pure HA. And the intensity of the peak at 3466 cm^{-1} increased evidently, indicating that OH content increased, which is ascribed to the existence of chitosan. The FTIR spectrum of 130±C-dried 20CS-80HA is similar with that of pure chitosan, which indicates that chitosan in the CS-HA composites was not decomposed at 130±C. Whereas, as shown in Fig. 3(b), there are many absorption peaks between 544{604 cm^{-1} and 982{1121 cm^{-1} for 500±C-sintered 20CS-80HA powders, which indicates that the decomposition of chitosan occurred(Figure.8).

5. Conclusion

The cost of the 12V & 9V power supply is Rs 350 and Rs 300 respectively and the stirrer cost is Rs 300.2. The electrodes anode and cathode can be attached and detached. This is to facilitate the choice of two different electrodes for research and development. Hydroxy apatite was prepared using stainless steel as cathode. The hydroxy apatite has shown characteristic phosphate vibration bands of synthetic hydroxy apatite. XRD pattern of the hydroxyl apatite is comparable that of synthetic hydroxy apatite and the SEM picture has shown rectangular shape hydroxyl apatite crystal on the surface of chitosan film. The TGA studies have shown that 30% of the hydroxy apatite was deposited in the composite film. It is concluded that hydroxyapatite crystals can be synthesized on the surface of chitosan using electrode position technique. These types low voltage power supplies are very useful for nano-biomedical applications for diagnostics.

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References

1. N.Raj, R. K. Sharma, and et.al., "A Low Power OTA for Biomedical Applications" Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Bioengineering (JSAB), December Edition, 2010
2. P.M.Furth and et.al., "Linearised differentialtransconductor in subthreshold CMOS," *Electron. Lett.* 1995;31 (7): 547-554,.
3. P.M.Furth and A.G.Andreou, "Linearised differential trans conductor in sub threshold CMOS," *Electron. Lett.*, vol. 31, no.7, pp. 547-554, 1995.
4. X. Zhang & E. El-Masry, "A regulated body-driven CMOS currentmirror for low-voltage applications," *IEEE Trans. on Circuits & Systems II: Analog and Digital Signal Processing*, 51 (10), 571-574.
5. Ferreira,T.Pimenta, and et.al., "An ultra-low voltage ultra-low-power CMOS miller OTA with rail-to-rail input/output swing", *IEEE TCAS II*, 2007; 54 (10): 843–847.
6. B. J. Blalock, P.E. Allen and et.al., "Designing 1-VOp-Ams Using Standard Digital CMOS technology," *IEEE Trans.on Circuits and Systems – II: Analog and Digital Signal Processing*, 1998; 45 (7): 769-780
7. R. Sarpeshkar and et.al., A low-power widelinear-range transconductance amplifier, *Analog Integrated Circuits Signal Processing*, 1997 vol. 13, pp. 123–151.
8. N. Raj, R. Gupta, V. Chopra, "A Low-voltage high performance OTA in 0.18 micron with High Linearity," in proc. Of Recent Trends in Networks and Communications, *NeCoM 2010*, vol. 90, part-5, pg.712-721.
9. B. L. Hart and R. W. J. Barker, "D. C. Matching Errors in the Wilson Current Source," *Electronics Letters*, vol. 12, no. 15, pp.389–390.
10. B. Minch, "Low-Voltage Wilson Current Mirrors in CMOS," in IEEE ISCAS, New Orleans, LA, USA, 2007, pp. 2220 – 2223.
11. R. Kumar and et.al., Chitosan-mediated crystallization and assembly of hydroxyapatite nanoparticles into hybrid nano structured films, *J. R. Soc. Interface*; 2008, 5: 427–439.