Medical Applications of Radioactive Isotopes through Electroplating / Electrodeposition Techniques

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Electroplating has found application in solidifying radioactive isotopes on the surface of supporting materials such as stents and patches, and therefore becomes useful in topical applications of radioactive isotopes in radiation therapy. This manuscript offers a brief review of the past developments and puts forward some ideas about future developments in this field.

Keywords: *electroplating, electrodeposition, stent, radioactive patch, cancer, radiation therapy*

Introduction

Electroplating as a traditional technique has been developing very rapidly in recent years. The 21st century's most rapidly developing fields are new materials, new energy sources, life science and information science. Electroplating has something to do with all of them. To materials science, we see the relation between electrodeposition and nanotechnology. To information science, we see the application of electrodeposition techniques in chip manufacturing. To new energy sources, we see the application of electrodeposition in fuel cell research and development. And to life science, we see the application of radioactive isotopes for radiation therapy through electrodeposition techniques, which will be the focus of this paper. What follows is an incomplete summary of the current state of the art about the combination of electrodeposition and medical application of radioactive isotopes.

Radioactive stents

The most popular ways to prepare radioactive surfaces are ion implantation, activation in a reactor or cyclotron and surface modification such as electroplating.[1]

^{188}Re on Wallstent® and Ultraflex® stents

In 1998, Häfeli, *et al*. prepared a stent for the prevention of restenosis with an electroplating technique[2] and in 2000 and 2002, filed patents on using electroplating to prepare radioactive medical devices/stents.[3,4] Later on, Häfeli, *et al*. developed an automated process to prepare radioactive stents with rhenium-188 for lung cancer treatment.[5-8] With the automated electroplater, it took less than 30 min to prepare a radioactive stent with the prescribed radioactivity. The two kinds of stents tested were Wallstent® and Ultraflex® stents. This process system was used to electrodeposit ^{188}Re directly onto the surfaces of stents. The final electroplated layers were examined by SEM and showed strong adhesion to the stent.

^{103}Pd radioactive stent

Radioactive ^{103}Pd stents with radioactivity up to 2000 μCi (microcuries) were prepared by electrodeposition by Xu, *et al*. The stent thus prepared had no edge effect, and the distribution of radioactivity on the stent surface was uniform.[9] The dose distribution in the radial direction for the radioactive ^{103}Pd stent was studied using the Monte Carlo simulation technique.[10]

^{90}Y stents and patches

Liang, *et al*. did research on the separation of ^{90}Y from ^{90}Sr using electrodeposition.[11] In their research, the cathode was stainless steel. The radioactive cathode could then be made into stents or medical patches and the 72-hr leaching rate for the stents and patches was less than 1% after heat treatment. No details were given about how to control precisely the radioactivity on the stents or patches because the focus of their research was on the separation of ^{90}Y from ^{90}Sr solution.

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^{32}P- Radioactive Stent Prepared with multilayer plating

Zhang, *et al*. developed a new method of preparing ^{32}P radioactive stents to reduce restenosis after PTCA (Percutaneous Transluminal Coronary Angioplasty).[12] The process included four steps:

1. Electroplate nickel onto the stent surface to catalyze the subsequent chemical plating step
2. Chemical plate the Ni-P(^{32}P) film
3. Gold electroplate and
4. Heat treat at 620 to 640°C.

Step (2) is the most important, since it is the step in which the radioactive source is applied to the stent surface.

Radioactive patches

The preparation of radiaoactive patches by electroplating has been given less attention in the literature than have stents. Yet theoretically, all stent electroplating techniques mentioned above should be applicable to radioactive patch preparation with minimal modification. The following discussion considers some examples of the research on radioactive patches prepared using different techniques.

Patches made from paper and bandages

Jeong, *et al*. developed a method for preparing ^{188}Re-attached nitrocellulose paper to provide homogeneous β irradiation to skin cancer.[13] Radioactive bandages have been prepared by different research groups for treating superficial tumors.[14-17]

Patches made from bombardment

A topical application to treat skin cancer with a ^{166}Ho patch has been reported.[18,19] The ^{166}Ho radioactive patch was produced by bombarding a ^{165}Ho incorporated patch in a nuclear reactor. However, this method is not available to a general hospital unless a nearby nuclear reactor is in service to produce the ^{166}Ho patch.

Discussions and ideas about future developments.

There is a gap between the research and development of radioactive stents and patches. Considering that nearly all of the stent electroplating techniques can be used to prepare radioactive patches with minimal modifications, there are many advantages in using electroplating, such as automated controlled processing, precisely-controlled radioactivity,[7] ease in carrying out experiments, etc. In addition, there are many inherent advantages in having a metal patch as a radioactive isotope carrier, given the strength and ductility of the material. It is unfortunate to see the existence of this gap between research and application.

With a metal patch, it is possible to electroplate one side with radioactive isotopes while keeping the other side unplated. By exposing the side containing the radioactive isotope to the region under treatment (such as skin cancer), the metal patch itself provides some shielding to the environment. For an electroplated radioactive patch, the strong adhesion of the radioactive layer to the patch body and the strength of the patch itself are factors which help to minimize potential radioactive environmental contamination.

Obata, *et al*. obtained therapeutic ^{64}Cu by first electroplating nickel on a gold disk and then bombarding the electroplated layer with 12 MeV protons at a current of 50 ± 3 μA in a cyclotron.[20] Considering the therapeutic effect of ^{64}Cu and its intermediate half-life (12.7 hr), it is quite realistic that radioactive stents and/or patches with ^{64}Cu as the radioactive source can be prepared by first electroplating nickel on metal patches or stents, followed by bombardment of the electroplated devices in a cyclotron.

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