

Medical Applications of Radioactive Isotopes through Electroplating / Electrodeposition Techniques

Huixiong John Zhang,* Shan Gao and Lei Sun

Department of Biomedical Engineering

School of Life Science and Technology

University of Electronic Science and Technology of China (UESTC)

Chengdu, P.R. China

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

¹⁸⁸Re on Wallstent® and Ultraflex® stents

In 1998, Häfeli, *et al.* prepared a stent for the prevention of restenosis with an electroplating technique² 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 ¹⁸⁸Re directly onto the surfaces of stents. The final electroplated layers were examined by SEM and showed strong adhesion to the stent.

¹⁰³Pd radioactive stent

Radioactive ¹⁰³Pd stents with radioactivity up to 2000 μ Ci (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 ¹⁰³Pd stent was studied using the Monte Carlo simulation technique.¹⁰

⁹⁰Y stents and patches

Liang, *et al.* did research on the separation of ⁹⁰Y from ⁹⁰Sr 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 ⁹⁰Y from ⁹⁰Sr solution.

* Corresponding author

Huixiong John Zhang

Department of Biomedical Engineering

School of Life Science and Technology

University of Electronic Science and Technology of China (UESTC)

Chengdu, 610054 China.

E-mail: johnzhangwolf@gmail.com

³²P- Radioactive Stent Prepared with multilayer plating

Zhang, *et al.* developed a new method of preparing ³²P 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(³²P) 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 radioactive 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 ¹⁸⁸Re-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 ¹⁶⁶Ho patch has been reported.^{18,19} The ¹⁶⁶Ho radioactive patch was produced by bombarding a ¹⁶⁵Ho 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 ¹⁶⁶Ho 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 ⁶⁴Cu by first electroplating nickel on a gold disk and then bombarding the electroplated layer with 12 MeV protons at a current of $50 \pm 3 \mu\text{A}$ in a cyclotron.²⁰ Considering the therapeutic effect of ⁶⁴Cu and its intermediate half-life (12.7 hr), it is quite realistic that radioactive stents and/or patches with ⁶⁴Cu 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.

Acknowledgement

We wish to thank Dr. Junfeng Yu from the Shanghai Institute of Applied Physics, Chinese Academy of Science for providing helpful suggestions.

References

1. X. Zhang & W. Li, *Nuclear Techniques* (in Chinese), **24** (11), 946 (2001).
2. U.O. Häfeli, M.C. Warburton & U. Landau, *Biomaterials*, **19** (10), 925 (1998).
3. U. Häfeli, U. Landau & M.C. Warburton, U.S. Patent No. 6,413,271 (2002).
4. U. Häfeli, U. Landau & M. Warburton, U.S. Patent No. 6,077,413 (2000).
5. H. Zhang & U. Häfeli, *Plating & Surface Finishing*, **92** (3), 40 (2005).
6. H. Zhang & U. Häfeli, *J. Medical Engineering & Technology*, **28** (5), 197 (2004).
7. U.O. Häfeli, *et al.*, *Applied Radiation & Isotopes*, **61** (6), 1313 (2004).
8. H. Zhang & U. Häfeli, *J. Applied Surface Finishing*, **3** (1), 31 (2008).
9. S. Xu, *et al.*, P.R.C. Patent No. CN1341405 (2002).
10. Z. Xu, L. Zhang & S. Fan, *Chinese J. Interventional Cardiology* (in Chinese), **11** (3), (2003).
11. J. Liang, X. Hou & Q. Ouyang, *Journal of Isotopes* (in Chinese), **20** (3), 159 (2007).
12. X. Zhang, *et al.*, *Nuclear Techniques* (in Chinese), **25** (1), 78 (2002).
13. J.M. Jeong, *et al.*, *Applied Radiation & Isotopes*, **58** (5), 551 (2003).
14. A. Mukherjee, *et al.*, *Nuclear Medicine Communications*, **23** (3), 243 (2002).
15. A. Mukherjee, *et al.*, *Int'l. J. Radiation Biology*, **79** (10), 839 (2003).
16. U. Pandey, *et al.*, *Cancer Biotherapy & Radiopharmaceuticals*, **21** (3), 257 (2006).
17. M. Salgueiro, *et al.*, *Applied Radiation and Isotopes*, **66** (3), 303 (2008).
18. Y.L. Chung, *et al.*, *European J. Nuclear Medicine & Molecular Imaging*, **27** (7), 842 (2000).
19. J.D. Lee, *et al.*, *J. Nuclear Medicine*, **38** (5), 697 (1997).
20. A. Obata, *et al.*, *Nuclear Medicine & Biology*, **30** (5), 535 (2003).

About the Authors



Dr. Huixiong (John) Zhang, PE is an Associate Professor at the School of Life Science and Technology, University of Electronic Science and Technology of China (UESTC), Chengdu, China. He was formerly a Postdoctoral Research Fellow in the Radiation Oncology Department at the Cleveland Clinic Foundation. He holds a B.S. degree from Tianjin Institute of Light Industry in Tianjin, China, an M.S. degree from Tianjin University in Tianjin, China and a Ph.D. degree from Cleveland State University, Cleveland OH, all in Chemical Engineering. Dr. Zhang's research interests include the use of therapeutic radio-isotopes for cancer therapy, medical physics, chemical and biomedical engineering, instrumentation, image processing, surface science and mass transfer.



Shan Gao is currently a Senior student in the Biomedical Engineering Department at the University of Electronic Science and Technology of China, Chengdu, China. Her research interests include the use of Monte Carlo simulation for radiation dose calculation, gas-filled microbubbles therapeutic applications, computer vision approaches to image processing and analysis, as well as signal processing. She is planning her Graduate study abroad.



Lei Sun is currently a Senior student in the Biomedical Engineering Department at the University of Electronic Science and Technology of China (UESTC), Chengdu, China. Her research interests include medical image and signal processing and bioinformatics. She will continue her Graduate study at UESTC.

NASF Welcomes New Members

(as of March 9, 2009)



Daniel Church

Haviland Products Co., Grand Rapids, MI

Claudia De La Cruz

Standard Aero, San Antonio, TX

Peter Forth

JBC 2001 Ltd., Chatham, ON, Canada

Anthony Guglielmo

Technic, Inc., Pawtucket, RI

Donald Kline

Products Finishing Magazine, Cincinnati, OH

Gordan Lozic

Master Finish Company, Grand Rapids, MI



Brian Milligan

Walgren Company, Grand Rapids, MI

Robert Scharaswak

Walgren Company, Grand Rapids, MI

Tiffany Skidmore

TM Deer Park Services, LP, Deer Park, TX

Steve Van Cleve

Orscheln Products LLC, Moberly, MO

Scott Walker

Products Finishing Magazine, Cincinnati, OH

Richard Workman

Walgren Company, Grand Rapids, MI