RadBioMat-Project ◇

W. Assmann, S. Ellgas, M. Schubert, J. Will [a], I. Gilbert [a], I. Lanzl [b], A. Pichler [b], E. Oestreicher [c], B. Weber [c], R. Sader [d], F. Zeilhofer [d], P. Jürgens [d], P. Kneschaurek [e], B. Röper [e], H. Busch [f], K. Schenk [f], Ch. Kreiner [g], Ch. Lingenfelder [g], and M. Huttenlochner [h]

[a] Zentralinstitut für Medizintechnik (ZIMT), TUM [b] Augenklinik, MRI/TUM
[c] HNO-Klinik, MRI/TUM [d] Hightech-Forschungs-Zentrum (HFZ) am MRI/TUM
[e] Klinik für Strahlentherapie, MRI/TUM [f] NTTF GmbH [g] *Acri.Tec GmbH [h] Ophthacryl GmbH

Radiation therapy is often dose limited by the normal (healthy) tissue surrounding the tumor volume. Unlike conventional radiation therapy with beams delivered from outside the body, radiation sources used by the so called brachytherapy are inserted into or close to the tumor to deliver radiation at a short distance. If pure β-emitters are used as radioactive isotopes for this purpose such as ^{32}P (E_{max} = 1.7 MeV) the dose can be concentrated inside a very small volume due to the short range of the electrons. Thus the tumor dose can be increased while saving the surrounding tissue. Besides high dose irradiation for tumor sterilization, low dose therapy is applied in benign diseases to reduce cell proliferation. One example is prevention of keloid formation, another one inhibition of neointima formation and in-stent restenosis in coronary arteries after stent implantation. For this treatments a local dose concentration is desirable and temporary or permanent radioactive implants are presently applied.

The aim of this new project (RadBioMat, Radioactive Bio-compatible Materials) is the development, production and application of new materials for use as radioactive implants in brachytherapy. The financial support for this project by the Bayerische Forschungsstiftung is linked to the condition that the project is equally founded by Bavarian companies. Thus this project joins effords from both Munich universities as well as three manufacturers of medical products. The following sub-projects have been defined and will be described briefly in this article:

– Installation of an implanter for radioactive ions
– Cell irradiation experiments, bio-compatibility tests
– Production of radioactive implants at FZK
– Development of organic implant materials
– Animal experiments with radioactive implants

The first subproject is located at the accelerator laboratory of the MLL and covers design and construction of a radioactive ion implanter. It follows ideas developed at the Research Center Karlsruhe (FZK) where an implanter with mass separation for 60 keV ^{32}P ions has been installed for production of radioactive stents [1]. The plasma source, a special designed ECRIS, is operated with deuterium gas and fed with red phosphorus which is activated before by thermal neutrons via the reaction ^{31}P (n,γ) ^{32}P. Unfortunately, the capture cross section is only 0.17 barn resulting in a typical ^{32}P concentration in the 10 ppm range. Therefore the high output current of a plasma source is advantageous which is 30 μA ^{31}P typically. However, the measured current at mass 32 is about 500 nA – two orders of magnitude more than what can be expected from the ^{32}P content. Apparently, the ^{32}P current is heavily contaminated with undesirable molecules like ^{31}PH in spite of source operation with deuterium.

Opposite to metallic stents radiation sensitivity is a major concern for organic materials which are mainly envisaged in this project. Unnecessarily high ion doses could influence the surface of the implant materials in an unfavorable way especially in case of biodegradable materials. Thus we were looking for another type of ion source which avoids PH formation and the additional distribution of ^{32}P ions in different charge states. Based on the experience acquired over many years at our accelerator laboratory a negative ion sputter source has been designed and built which uses an Al sputter target with an AlP insert (provided by Detia Freyberg GmbH). Al does not create radioactive impurities during neutron activation thus the whole sputter target can be exposed to thermal neutrons prior to inserting it into the sputter source. Stable long term operation with unactivated AlP has been demonstrated showing negative ^{31}P currents of more than 5 μA and practically zero at mass 32. For the activities required in our project this current seems to be sufficient. First measurements of the beam emittance show the expected small values of a sputter source which is a precondition for beam spots smaller than 1 mm. The sputter source itself is a rather simple and cheap construction which can be completely replaced in case of a failure and repaired after cooling down of the ^{32}P activity ($T_{1/2}$= 14.3 d).

The ^{32}P implantation should remain in the implant materials as long as possible and wash out minimized, therefore we decided to increase the implantation energy to 180 keV which shifts the mean implantation depth of ^{32}P ions from 130 to 350 nm. As our existing mass separation magnet has sufficient bending power, the ions can be accelerated before the magnet which improves the ion optic and mass separation as well. The implanter is designed for production of implants of millimeter size as for example radioactive sutures. To deliver the necessary small spot size, besides the small emittance sputter source quadrupole triplets are foreseen after the sputter source and before the production chamber. A completely oil free pumping system was chosen in order to avoid accumulation of radioactivity inside the pumps. The whole setup will be premounted and tested with (stable) ^{31}P ion beams in target room II within 2004 (fig. 1). After the acceptance tests the whole implanter will be moved to the application center which is presently under construction near the new research reactor FRM II.

A second subproject is carried out in collaboration with the Central Institute for Medical Engineering (ZIMT/TUM) and has two major tasks:

◇ This project is supported by the Bayerische Forschungsstiftung (PN 503/02)