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1 of 1

POSITRON MICROSCOPE GRANT

I. PROGRESS REPORT (JANUARY 1990-SEPTEMBER 1990)

Introduction

Progress on the positron microscope has moved forward in three main areas: hardware construction and detailed optical design (Sections 1 and 2); auxiliary projects, partially supported by the larger Michigan positron physics group, to make intense positron sources and to make and test transmission remoderators (Sections 3 and 4); and three papers written on experimental and theoretical aspects of positron microscope applications.

1. Microscope Optical Design

The detailed optical design of the magnification section of the positron microscope, as well as that of the remoderated positron beam to illuminate the target, have both been completed. The magnifying optics are similar in many respects to those employed in current emission microscopes (such as the photoemission microscope), although certain modifications are necessary to maintain the high transmission required by the small intensities of positron beams. Much of the positron beam design is novel, however. The beam will be able to employ either two or three remoderators, depending on the brightness required by a particular application. (In general, scanning microscope applications will require three stages of remoderation, while magnifying microscope applications will require only two.) The first remoderator will operate in the reflection mode that has been used in previous brightness-enhanced positron beams, and will incorporate a 90° deflection to extract the beam from background radiation due to the source. The second and third remoderators, however, will operate in the transmission mode. While transmission remoderators have been studied in the laboratory, they have never been used in an operational beam. Especially when the diameter of the beam is smaller than roughly 10 μm , the improved geometry of a transmission mode remoderator permits larger brightness gains per stage than is possible using the reflection design.

The optical design of an electron beam has also been completed. The electron beam will be emittance-matched to the positron beam, and will use many of the same focusing elements. This will permit the detailed comparison of electron and positron images of a sample. Care has been taken to permit switching from electron to positron beams and back with a minimum of effort (see Section 2 below).

During the process of performing optical design calculations for the microscope and its associated beams, a fairly powerful set of computer programs have been developed to aid in these calculations. In addition to aiding in the evaluation of the performance of the various optical systems as they are installed, these programs will permit a quantitative study of the brightness characteristics of various types of transmission and reflection moderators and remoderators (see Section 3 below).

2. Microscope Construction

Construction of the positron microscope is well under way at this time, and is expected to be largely completed during FY91. At this point, the vacuum system has been designed and constructed, as has most of the support framework for the microscope. The shielding and support components for the radioactive source have been designed to accomodate sources having activities in excess of 100 Ci. Construction of this source shield is partly complete, and should be finished in several months.

Some of the electrostatic lenses and deflectors that make up the microscope optical system have been designed and constructed, and with the recent completion of the full optical design (see Section 1), the remainder of these elements should be able to be completed soon. Some questions of electrostatic shielding, alignment, and vibration isolation remain to be solved, but it should be possible to resolve enough of these issues within a several month time-frame so that initial installation and testing of the microscope will not be delayed. The instrument is being designed in such a way that additional alignment and vibration-isolation components can be added as required to obtain maximum ultimate resolution.

Some of the voltage supply system for the optical elements has been designed, and necessary components have been purchased or built. Because of the need to support several different microscope and positron beam configurations (eg. electron vs. positron, scanning vs. magnifying microscopy, two vs. three remoderators), the voltage supply system will be relatively complex. To achieve the necessary flexibility, extensive use will be made of computer controlled voltage supplies and switching modules. This will also permit the use of automatic beam tuning programs, a feature which should greatly facilitate the complex alignment and tuning process for the microscope. Some of the computer controlled power supplies necessary for the voltage supply system have been purchased, but a significant purchase of power supplies during the remainder of 1990, and early in 1991, will be required. Most of the other voltage supply components (computer controlled switching modules, voltage isolation components, etc.) are custom built, and the majority of these are complete.

The on-line computer which will control the optics of the microscope, as well as control experimental systems, and collect and analyze image data, is installed and operational. The computer system has thus far been used primarily to perform the calculations necessary for the optical design of the microscope. A major task for FY91 will be to generate the programs necessary for beam control, and for the collection and analysis of microscope data.

3. Remoderator Fabrication and Testing

Because of the crucial importance of high quality, transmission remoderators to the research of the Michigan positron physics group, and in particular to the success of the positron microscope, we felt it necessary to develop a facility for the fabrication and testing of transmission remoderators. Support for this effort is being shared between this grant and other funding sources. This project has involved the construction of a vacuum evaporation system incorporating an rf induction heater for the fabrication of thin metal foils, and a small positron beam for their testing. Most of the evaporator was complete prior to the start of FY90, but significant work on the test beam has taken place this year.

The remoderator development project is well under way at this time, and should provide us with the reliable supply of transmission remoderators we need. We are currently able to produce high quality, self supporting, thin (1500 Å), Ni foils, and will soon begin work on the production of similar W foils. The test beam, which should be finished by the end of 1990, will enable us to test not only transmission remoderators, but transmission moderators and radioactive sources (see Section 4) as well. A fairly careful theoretical evaluation (Section 1) of the acceptance and transmission characteristics of the test beam has been started while beam construction has proceeded. These studies should permit quantitative measurements of the emittance properties of remoderators and moderators beyond the scope of any measurements reported prior to this time.

4. Radioactive Source Fabrication

In order to assure the positron group of a supply of radioactive positron sources at a reasonable price, we have also found it necessary to embark upon a project to produce, purify, and electroplate the isotope ^{58}Co . Again, this project is being supported jointly by this grant and other funds. It represents an extension of research under way in our group for several years, in collaboration with Henry Griffin, Professor of Chemistry and an expert in nuclear chemistry.

Making use of the facilities of the Phoenix Memorial Laboratory here, including its associated 2 MW Ford Nuclear Reactor, we are irradiating Ni samples with the eventual goal of producing beta sources of up to several hundred Ci total activity. These sources will be purified by ion exchange chromatography, and deposited electrochemically on metallic substrates. Over the last 18 months, we have begun tests of all phases of this procedure, and have produced test sources in the several mCi range. In particular, we have irradiated a sequence of Ni samples over several months to measure the flux-cross-section production integral for a particular reactor port, and to determine the effective production lifetime in the presence of depletion by thermal neutron absorption. We have also constructed a prototype separation and deposition apparatus, and tested it both for tracer levels of ^{58}Co , and for mCi quantities. Results for the mCi size sources were encouraging, but

the resulting specific activity was not as large as anticipated. After improvements to the separation apparatus to increase the specific activity of the product, we plan to attempt larger sources in 1991.

5. Applications of Positron Microscopy

Despite the emphasis this past year on design and construction of the positron microscope, we have continued to consider potential microscope applications. Some of these applications are direct spin-offs from our NSF-funded surface physics research. For example, our experimental work on positrons tunneling through thin epitaxial films led us to formulate a new technique called Positron Tunneling Microscopy (PTM). (Solid State Comm. 74, 1079, 1990—reprint enclosed.) We have shown that the technique is not only sensitive to film thickness variations, but is also sensitive to such phenomena as pseudomorphic growth and interdiffusion alloying. Our most recent experiments on Co and Ni silicide films could benefit from positron microscopy and will be discussed in the proposed research. (This work on positron tunneling and PTM was also presented as an invited talk at the March meeting of the American Physical Society in Anaheim.)

A second paper entitled *Positron Reemission Microscopy and Its Applications* has been submitted to Nuc. Inst. and Meth. as an invited talk, presented at the 7th Symposium on Radiation Measurements and Applications (May, 1990, Ann Arbor). With the assistance of colleagues in chemical and electrical engineering, and in biophysics, we consider in this paper (preprint enclosed) a wide range of positron microscope applications in materials research, surface catalysis, solid state electronics, and biology. On this last topic of biological applications, James Van House and Arthur Rich (posthumously) have submitted an article to Nature entitled *Positron Microscopy of Organic Targets*. It reports the last results from the original prototype positron microscope (now complete and being phased out as the new second-generation microscope is phased in). In this paper (preprint enclosed) are reported studies of particular organic molecules with the goal of determining whether the PRM can distinguish proteins from lipids on the surfaces of cell membranes.

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