RADIATION DAMAGES AND CORROSIONS IN TRISTAN VACUUM SYSTEM.

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ABSTRACT

The critical energy for synchrotron light of TAR and TMR is 40 KeV (7.5 GeV) and 150 KeV (26 GeV), respectively. Corresponding attenuation length is 7 mm and 28 mm. The existence of NO_3^- and SO_4^{--} is confirmed from the liquid sticked around the γ-ray extracting window. Most of the metals are corroded by the acids. Therefore moisture control is important to protect metals. The protecting methods are to cover by another metal, to exchange water by another gases, and to eliminate water by evacuation. Damage of organic and inorganic materials also received the influence of the acids. In addition they received direct and indirect radiation. They burned or increased brittleness. To protect them complete lead shield is necessary for both TAR and TMR.

INTRODUCTION

Electron storage rings at KEK, the photon factory(PF), TRISTAN accumulation ring(TAR), and TRISTAN colliding ring(TMR) produce high energy synchrotron light. Beam energy of the rings are 2.5, 7.5, and 26 GeV for PF, TAR, and TMR, respectively. At PF, light is already utilized in physics and medical science. TMR is originally used as an electron-positron colliding ring. Most of the light in TMR is dispersed except one used for monitors. The dispersed light brings about radiation damages for materials and equipments. The damages are out of imagination because of the highest energy in the world. These new experiences in the ring give us much impression and therefore must be reported. This paper discribes the damages and corrosion related to TRISTAN vacuum system.

BASIC CHARACTERISTICS OF SYNCHROTRON LIGHT.

Critical energy (ϵc), spectrum intensity, and attenuation length

Critical energy of the light and spectrum intensity of PF, TAR, and TMR is shown in Fig. 1. The energy ranges from several KeV to several hundred KeV. Spectrum intensity of the light is continuous which contains from infrared to hard X-ray. Therefore synchrotron light shows thermal and chemical effects. Power density in arc sections of TAR and TMR is shown in Fig. 2 and Fig. 3, respectively. Mechanism of scattering is dependent on energy. Attenuation length is also dependent on energy. Attenuation length for aluminum, copper, and lead is shown in Fig. 4.

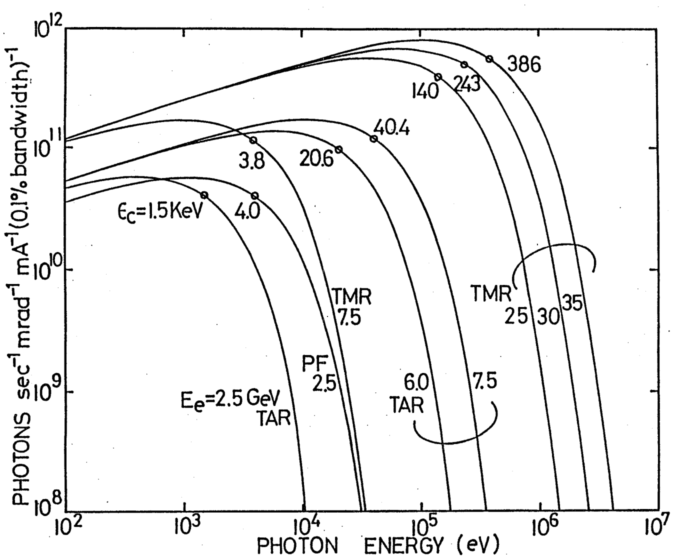

Fig. 1. Spectrum intensity of PF, TAR, and TMR

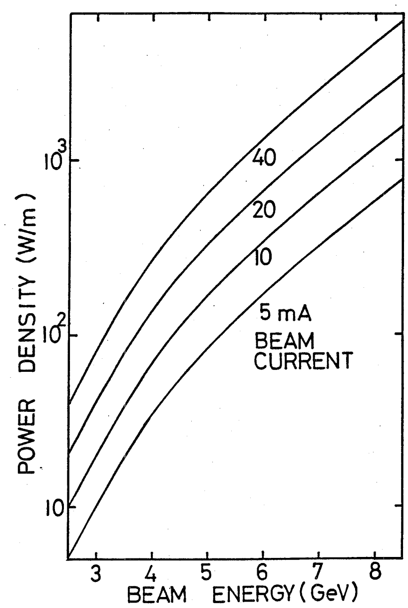

Fig. 2. Power density in arc sections of TAR as a function of beam energy

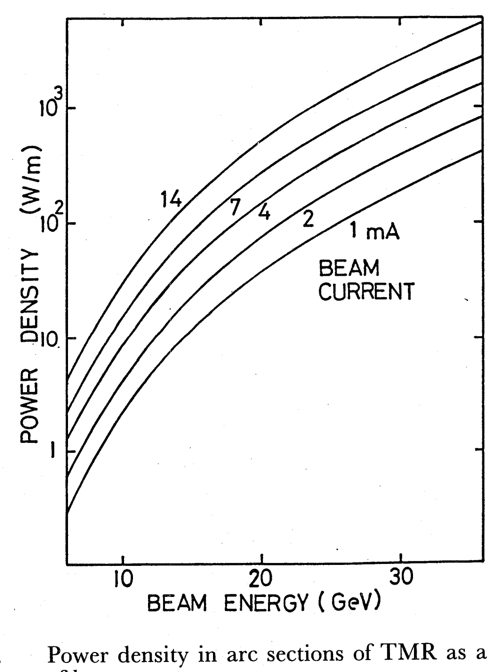

Fig. 3. Power density in arc sections of TMR as a function of beam energy

EXAMPLES OF THE DAMAGES

(1) Damages of metals

Beryllium and aluminum films are used for injecting and extracting windows for beams, synchrotron light and γ-rays. The metal windows are heavilly damaged by the light and γ-rays. More precisely, synchrotron light and γ-ray produce NOx and SOx in atmosphere around the extracting windows. These oxides combine with moisture and become mist of nitric and sulfuric acids. The acids corrode the metal surface. The existence of two acids was found in TAR by analizing liquid sticked around the extracting window of γ-rays. Another example of

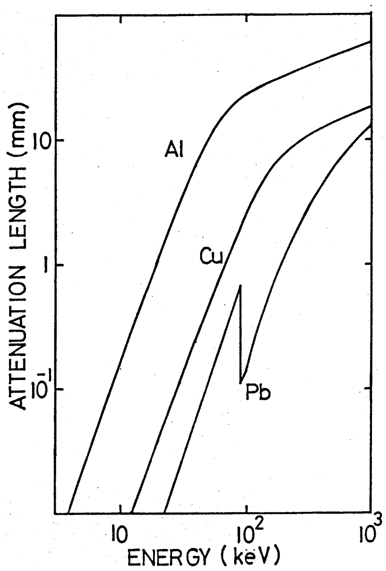

Fig. 4. Attenuation length for Al, Cu, and Pb as a function of photon energy

damages of this type was found on thermal insulating films. Aluminum beam chambers have lead shields 10 mm thick. The surface of the lead shields is wrapped threefold by thermal insulation films. The base film is made of Kapton (25 μ m). On both sides of Kapton film, aluminum film (0.05 μ m) is coated. The coated film is embossed to increase insulating efficiency. The coated aluminum film disappeared at many places. At these places, cooling pipes, high voltage connectors, sextupole magnets, and port for monitors are located. There, gaps of between lead shields or incomplete lead shields exist. As a result, it was estimated that leaked synchrotrom light or secondary radiation damaged the aluminum foil. Therefore, to protect metals, especially alminum vacuum system, moisture control is the most dominant. Though the metal surface has been protected by helium gas flowing or by evacuation using a rotary pump, the best way can be pumping by a roughing system with a turbomolecular pump and a rotary pump.

An exposure test of the gas of Jet Cleaner(Fron 12, 400 cm^3) with water(150 cm^3) at the γ-ray extracting port (max 7.5 GeV beam energy) shows that Cl^-(2.9 g/l), F^-(1.6 g/l), NO_3^-(0.4 g/l), and SO_4^{--} (0.027 g/l) are contained and that pH of the water is less than 1. This result reminds us again that the existence of water has big influence on the corrosion, especially of metals.

Internal Target[1] (IT)

In TAR, two beam lines were set for calibration of lead glass counters utilizing γ-ray produced by electron beam(5GeV) hitting a molybdenum rod, called as an internal target(IT). The molybdenum rod is in a vacuum chamber. γ-ray was extracted through a beryllium window 0.3 mm thick. The extracting port consists of an ICF-152 and an ICF-070 aluminum flanges. On the 152 flange with a rectangular hole, the 070 flange on which a beryllium window is electron beam welded is set. A beryllium window was covered by an alminum cylinder sealed by an aluminum foil(80μ m)using epoxy resins. Inside the cylinder, helium gas(1cm^3/min) was introduced to protect the beryllium surface from corrosion. At the first operation of IT, Kapton film was used instead of an aluminum foil. However the Kapton film was burned by several day operation (Photo 1). Since then an aluminum foil has been used. The radiated part of the foil was relatively clean, on the other hand, white powder like material was observed on neighborhood of the radiated part. An aluminum foil covered with bömite film was used to reduce corrosion. But no significant difference was observed compared with an ordinary aluminum foil. This is because the binding energy of the film is very low compared with that of the light. Miscontrol of the helium gas flow caused corrosion of beryllium surface and sealing failure of the vacuum chamber(Photo 1). For further reduction of the beryllium corrosion, inside the cylinder was evacuated by a rotary pump instead using helium gas flowing. By this method protection of a beryllium plate was improved. (Photo 2). The radiated part of the beryllium plate is clean and the place adjacent to the part is covered by black material. The similar was observed inside surface of the aluminum foil (Photo 2). The material can be carbonated oil. One more method to protect the surface is to cover the surface by Vacseal. This is effective to obtain longer life of the beryllium plate.

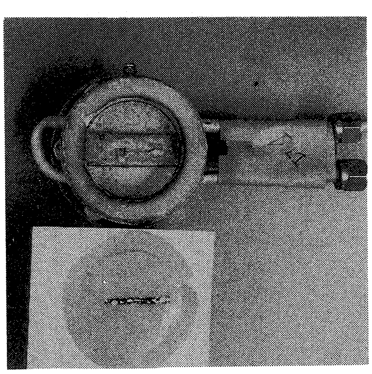

Photo 1 Be window for IT and a Kapton film cover (below).

Epoxy resin to seal aluminum foil changed its color from milky white to brown by the influence of radiation or the produced acids. Similar influence was observed on the Synflex(nylon) tube to supply helium gas. The colored pipe is brittle, therefore Synflex tube can't be used for movable equipments.

Extracting and injecting beryllium windows for electron and positron in TAR and TMR

Beryllium plates 0.3 mm thick and 1mm thick are used for injecting windows in TAR and TMR and for extracting win-

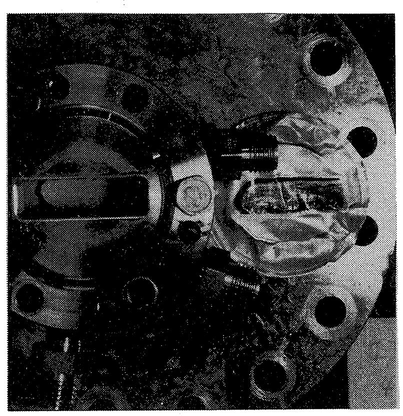

Photo 2 Be window for IT (left) and an Al foil (right).

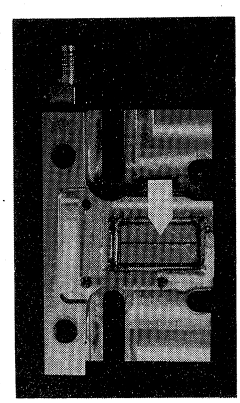

Photo 3 Be window for electron beam injection.

dows in TAR, respectively. Outside surface of the windows are coated by Vacseal and sealed by Kapton film. The window is masked by a molybdenum rod in vacuum not to be radiated by synchrotron light. Therefore the power of the light is reduced much compared with the windows of IT. However a little influence was still observed. The color of the Vacseal turned brown (Photo 3)

Aluminum X-ray windows for TAR and TMR

Several aluminum windows are used as beam profile monitors. An aluminum foil(80 μm) sealed vacuum chamber from atmosphere using a Helicoflex. To protect the aluminum surface a small cylindrical room is made for helium gas flowing (TAR) and for evacuation by a rotary pump (TMR). The room was covered by another aluminum foil using eposy resins. The surface of the foil was corroded. Similar corrosion was observed on the aluminum foil set in an extracting line (Photo 4, TAR). The line is utilized for medical science using synchrotron light at 5.7GeV beam energy (εc= 18KeV). The extracting window is an ICF-152 flange but the thickness is decreased to 2mm. The foil is set on a flange of the beam line and the surface of the foil show some white corroded material.

(2) Damages of organic and inorganic materials.

Gate valves in TMR

The gate valves of TMR have o-rings to seal the compressed air system for pressing the diaphragms against the isolation plate. Originally the O-rings are viton. The O-rings are located both sides of the isolating plate and around a beam pipe. In March 1987, sealing deterioration was found and all of the O-rings were exchanged to nitril O-rings. Elasticity of the viton O-rings were checked measureing the distortion by applying load of 1 kg on an O-ring. The elasticity of the deteriorated rings decreased to less than 20% of normal ones. The O-rings located outside of beam axis and faced to a sextupole magnet extremely deteriorated. This suggests that the deterioration is radiation damage and that radiation shield is incomplete in the side of the sextupole magnet. During the operation in July 1987, a sealing failure occured on a nitril O-ring. Therefore the O-ring seal is going to be changed to a lead wire sealing. In addition lead shield of 10 mm thick will be set both sides of the gate valves.

Vinyl, epoxy resin, viton, nitril, and cotton

The entrance of the stock room in TAR is covered by sheets of vinyl 2 mm thick and 300 mm wide to prevent penetration of dust. Several sheets were burned about 150 mm long and 5 mm wide at 1200 mm in height(Photo 5). This is due to the light which comes from the end of the bending magnet about 6 m distant from the sheets. The light comes from a gap of lead shield on the bending magnet. The burning has not been developed by covering the gap by lead shield 1 mm thick.

Burning mark was observed on the cover (epoxy) of the coil of kicker magnets for the ceramic chambers(Photo 6). This fact confirms that the one end of several ceramics was not masked from synchrotron light by the aluminum absorbers. Since the length of the burning is several cm, it can be estimated that radiated area inside surface of the ceramics is longer.

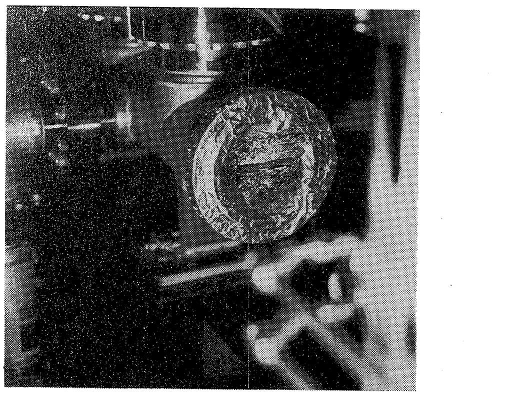

Photo 4 Al foil set on the beam line for medical science.

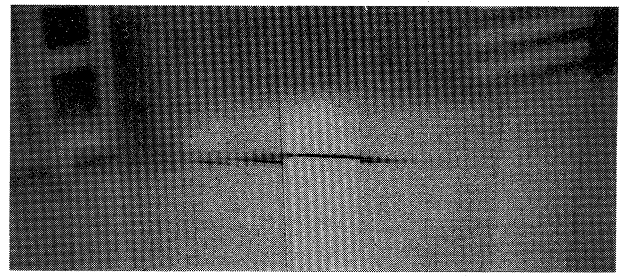

Photo 5 Burning of the vinyl sheets.

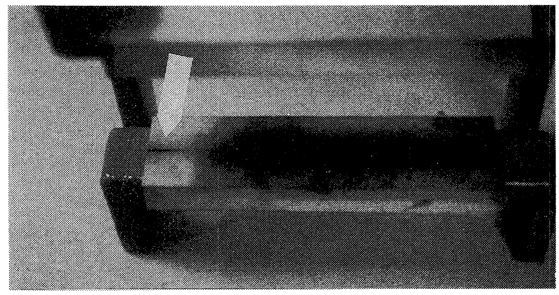

Photo 6 Burning of the cover of the coil of a kicker magnet.

To obtain good thermal contact heat pipes and some of the cooling aluminum pipes were attached using durmetal and epoxy resin mixed with conducting material, respectively. The mixture of epoxy resin and conducting material was not strongly damaged. The durmetal attached to the outside of beam chamber, where synchrotron light is the strongest, was burned and completely changed to ash about 2 mm wide.

In TMR, space between a bending and a quadrupole magnets has an address of its own. Several hundreds of DIP and IP are named using the address. To show the address each connector of the DIP and IP has a name card enclosed in a small envelope made of vinyl colored reddish violet. The envelopes are connected to cables by cotton string and many of them are set on the coil of the bending magnet very close to the beam level. Some of the envelopes were burned, others discolored, and remained ones not changed. The name cards made of paper were not discolored but became brittle. The cotton string also became brittle. They were damaged by leaked secondary light through gaps 1 to 5 cm between lead shields of a bellows and of DIPs. The cable itself is not deteriorated yet, but some lead shield having a cylindrical shape will be needed. The gap between lead shields is going to be covered by lead plates 10 mm thick.

CONCLUSION

Basic characteristics of synchrotron light of TRISTAN, examples of the radiation damages in TRISTAN vacuum system, and protecting methods is described. Corrosion of aluminum component and of other metals are basically due to nitric and sulfuric acids in atmosphere which are mixture of moisture and NO_X or SO_X produced by synchrotron light. Organic and inorganic materials are damaged by direct or indirect radiation together with by the acids. These materials, especially organic materials, are not recommended to use in storage rings as possible. Therefore to protect the whole vacuum system moisture control and complete shielding of radiation are important.

ACKNOWLEDGEMENT

The authors wish to thank Assoc. Prof. M. Kanda and Mr. M. Taira for their analysis of samples in TAR and TMR.

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