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DUST TRAPPING EXPERIMENTS AT TRISTAN AR

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Abstract

We developed an experimental system investigating trapping of dust particles and installed it to an electron storage ring (TRISTAN AR) where one can reproduce a condition that microparticle trapping artificially occurs. Using this system called micro particle analyzing system (μPAS) , trapping of microparticles was systematically observed for the first time in a manner that a well-defined microparticles are dropped into the electron beam. It was found that trapping of metallic microparticles does not occur but trapping of ceramic microparticles and diamond microparticles do for several ten minutes. This would be explainable based on heating and radiation cooling of microparticles which determines a lifetime of trapped microparticles in conjunction with an electron beam current.

1. Introduction

Phenomena that a beam lifetime drops suddenly have been seen in some electron storage rings[1-6] including the observation of it in TRISTAN AR[7]. It was recently reported by DESY group that a considerable problem of the sudden beam loss has been found in HERA ring and has limited the operation for the luminosity run[5, 6]. In HERA ring the problem is attributed to operation of the integrated ion pumps (at the dipole magnets) where dustparticles which are generated and positively charged at the anode surfaces are ejected through the pumping slots to the beam duct so as to be trapped by the electron beam. But neither many experiments to reveal the mechanism were made nor the details of the trapping have been made clear. Moreover all the trappings can be explained by the same scheme while efforts to explain some observation theoretically were done.

The most difficult thing in observation of microparticle trapping in reality is that one could not reproduce the trapping at any time. One might see trapping by exploring operation conditions of a beam of a ring and the related equipments of the ring such as applied voltage of ion pumps for instance. This is again difficult since it is impossible to control generation of dust at all and dusts generate spontaneously under a complex condition.

Therefore we tried to establish an active observation system where microparticles are able to be given to an electron beam at any required time. This system would be able to ensure observation of trapping under a condition that information about both the microparticle such as its atomic composition and its size distribution and operation conditions of the ring is well known. In this report we mention the installation of μPAS and the first observation of microparticle trapping which was reproducible in TRISTAN AR under defined conditions.

2. Experimental

A schematic of μPAS is shown in Fig. 1. μPAS mainly consists of a microparticle launcher, a microparticle collector, a vacuum system and a monitoring system. In the launcher there are small eight holders where option of a species of microparticle can be made and dropping of the microparticles is carried out by remote computer control and is confirmed by a CCD camera. After a free fall of 250mm, microparticles are crossed over the electron beam probably as a cluster. The horizontally cross-sectional size of the cluster is restricted by a guide tube to be no more than 1mm in a diameter before the crossing. σ_x and σ_y are typically measured to be 2.2mm and 0.1mm, respectively. The crossing time was estimated to be 90μs. The crossing is finally controlled by adjusting COD. Microparticles which are passing down through the beam are collected at the bottom of the vacuum system. The all flange ports of the beam duct at μPAS are equipped with many small holes (5 mm in a diameter) for shielding RF. The vacuum of μPAS is maintained by turbo molecular pumps (TMPs) and a sputter ion pump (SIP) giving a base pressure of 10^{-8} Pa. Total and partial pressures of residual gas in the system are measured by residual gas analyzers (RGAs) .

The geometrical configuration of the

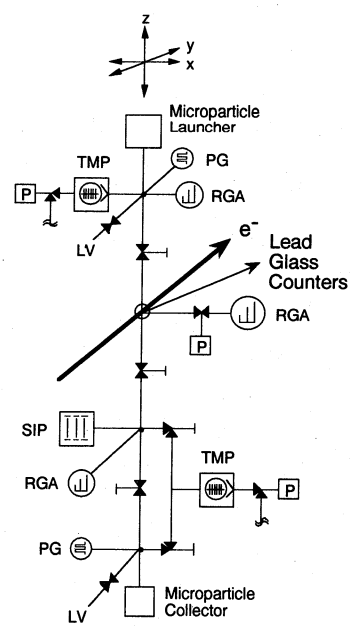

Fig. 1 A schematic of the experimental set-up of μPAS which was installed to TRISTAN AR.

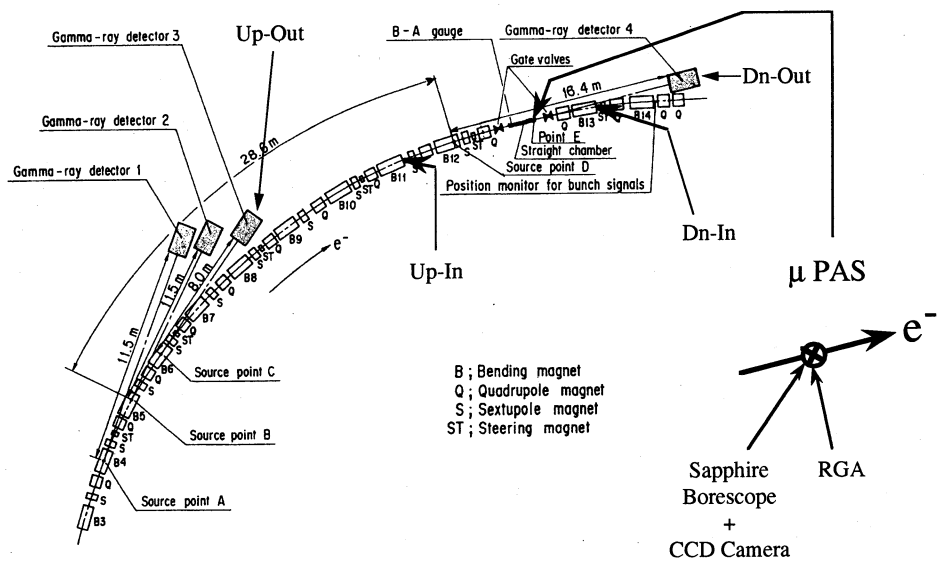

Fig. 2 The geometrical configulation of μPAS and lead glass counters.

monitoring system of μPAS and lead glass counters at a north-west arc section of TRISTAN AR is shown in Fig. 2. The electron bunches move forward clockwise. Four lead glass counters which are labeled Up-Out, Dn-Out, Up-In and Dn-In at the outside and the inside or the upstream and the downstream of μPAS were used in this experiment as shown in Fig. 2. Two counters of Up-Out, Dn-Out are for observation of γ-ray due to Bremsstrahlung and others of Up-In and Dn-In for monitoring beam loss. An ion source of one of RGA faces with the electron beam of the ring from its inside in order to monitor not only residual gas species but also possible evaporation of microparticles. Installation of a sapphire borescope with a CCD camera into μPAS was also made for visual observation.

Species of microparticle with information of their typical sizes are the followings : Al(0.1μm), Ti(45μm), Cu(0.1μm), Zr-V-Fe(unknown), C(diamond, 0.5μm), TiO_2(0.3μm), CuO(0.35μm), and SiC(1μm). The size distribution of microparticles for most of the materials are known. Less sized micropowders of Ti were not prepared due to its strong combustibility. Zr-V-Fe is a material of pumping elements of NEG. Its microparticles with a typical size of several ten μm were produced by grinding the material which had been used hard in vacuum and would have been strongly oxidized while the analysis was not done. Molal quantity of each species of microparticles which were introduced onto the beam was regulated to be 5 μmol except an amount of 10 μmol for diamond aiming an accuracy of 10% in the weighing. Purity of those materials except Zr-V-Fe were measured to be not more than 99.8 wt%.

3. Results and Discussions

Microparticles of CuO, TiO_2 and Zr-V-Fe were introduced into the electron beam in a series. Fig. 3 shows beam current, beam lifetime and signals of lead glass counters as a function of elapsed time when microparticles of CuO and TiO_2 were dropped. Note that time stamps of the current, the beam lifetime and the signals of the counters differ each other in the chart of a mechanical pen recorder and baselines of those records do each other as well. Therefore the introductions of CuO and TiO_2 are labeled by the symbols a and b in the figure, respectively.

The collision of CuO microparticles with the beam made the current reduced from 28 mA to 14 mA. Trapping, however, did not occur since the lifetime recovered in half a minute and the detector signals were observed only in a moment. In addition to this, trapping of the microparticles of Al, Ti and Cu was not observed either while they were repeatedly introduced into the electron beam for a couple of times and an interaction with the beam was confirmed by sharp signals from the detectors. Those microparticles would have been melted simply (m.p. of Al, Ti, Cu and CuO are 930, 1940,1360 and 1650 K, respectively) .

On the other hand, trapping of microparticles of TiO_2 (m.p. : 2100 K) and Zr-V-Fe (m.p. : 1600-3200K depending its oxidation) was clearly observed as shown for TiO_2 in Fig. 3. The beam current decreased from 14 mA to 6 mA at the moment of the collision with the microparticles. After a sudden drop of the lifetime, its slight recovery to 80 min was found with a remarkable Bremsstrahlung as seen in the signal of Dn-Out. Then the signal lasted roughly for 20 min with its monotonic decrease until the trapping ended. The lifetime that gradually got recovered was recorded to be 375 min by the end. The similar trend was found in the signal of Dn-In while the signal intensity was small, showing a beam loss for a long time.

The monotonic decrease of Bremsstrahlung for 20 min implies that mass of the trapped microparticles slowly decreases through its evaporation as a result of high temperature where beam heating and radiation cooling become equilibrium. A number of the

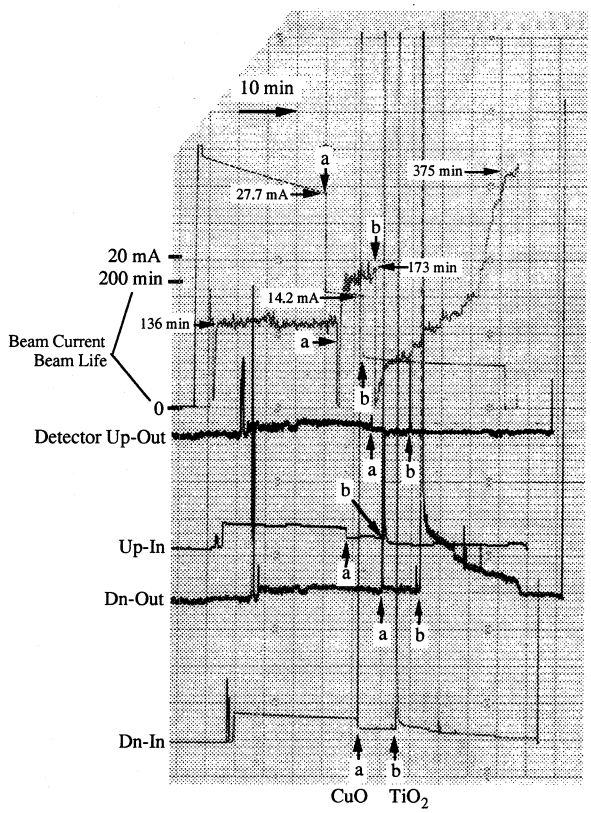

Fig. 3 Beam current, beam lifetime and signals of lead glass counters as a function of elapsed time when microparticles of CuO and TiO_2 were dropped into the electron beam.

trapped microparticles is unknown. But the spikes and the steps which were seen in the monotonic decrease of Bremsstrahlung would suggest that some amount of the microparticles occasionally escapes from the trapped volume and microparticles or a cluster of microparticles sometimes get burst due to the heating. Trapping of TiO_2 was reproducible. Trapping of Zr-V-Fe microparticles was also observed while it lasted only for several minutes, showing smaller signals of the detectors. Fig. 4 shows trapping when microparticles of diamond (m.p. : 4000 K) were introduced into the beam. Different from the result of TiO_2, the beam current gradually decreased almost to null for a few minutes and the lifetime hardly recovered. Looking into the detail, the lifetime which slightly recovered to about one minute in half a minute after the sudden disruption resulted in a lifetime of 3 minutes during a few minutes. In the mean time, the signals of the counters smoothly decreased showing relatively stable thermal evaporation except a stepwise decrease which is coincident with the recovery of the lifetime.

According to a preliminary result of calculations on the microparticle in a condition, diamond microparticles have a lifetime of a few minutes though Cu microparticles melt away in a time of less than ms. This result does not contradict the observation and gives a qualitative explanation that microparticles of a material which has high melting point would get easily trapped.

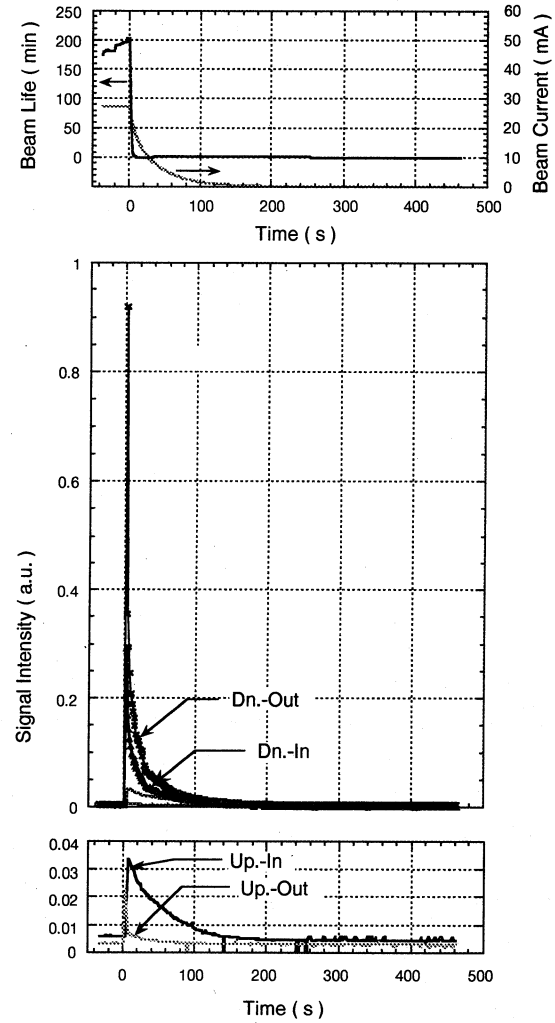

Fig. 4 Beam current, beam lifetime and signals of lead glass counters as a function of elapsed time when diamond microparticles were introduced into the beam. Note the different ordinates and the zoomed ordinate of the lower plot.

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