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ESTABLISHING A LASER TREATMENT TO SUPPRESS THE SECONDARY ELECTRON EMISSION

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Abstract

Laser treatment has a significant influence on suppressing the secondary electron emission (SEE) in electron storage rings. A new synchrotron radiation light source, the Hefei Advanced Light Source(HALS), is under consideration and it has a strict requirement to suppress the SEE. In this paper, we used a laser with the wavelength of 355nm to process with copper sample. After the laser treatment, the secondary electron yield (SEY) reduces from 2.05 to 0.86. We also used the scanning electron microscope (SEM) to analysis the surface of the sample after the laser treatment. This paper reports the experiment set up and preliminary results.

INTRODUCTION

In the next generation synchrotron light sources, the electron cloud (E-cloud) is a factor limiting the beam energy, intensity and lifetime of the electron beam in the storage ring. It has been studied in many synchrotron facilities. Many mothed have been studied and applied in the accelerators such as coating with low SEY material (TiN, a-C, NEG), and modifying geometry on the surface [1]. As a new method to suppress the E-cloud, laser treatment method has a lot of advantages. It is easy to implement, with low cost and high stability [2].

The diffraction-limited storage ring, HALS, is a base on the National Synchrotron Radiation Laboratory(NSRL). It has higher requirements in beam intensity and vacuum system. Reducing the secondary electron yield (SEY) of the vacuum tube is essential. The method of laser treatment on the accelerator vacuum chamber has been researched since 2014 [3], which has been applied on the High Luminosity upgrade of the LHC collider (HL-LHC) in CERN [4]. To make use of the advantages of laser treatment method on reducing the SEY, this paper reports a preliminary study of this method with a laser treatment instrument on the copper material. The experiment result shows this method can effectively reduce the SEY of the copper material.

EXPERIMENT INSTRUMENTS

In this paper, an ultraviolet (UV) laser with λ=355nm is used, which has a repetition frequency in the range 20~200kHz, and an avenge power of 3W. An optical path system is designed to fulfil the requirement of a much smaller laser spot. After the parallel beam emits from the laser instrument, it passes through a 10× expander lens firstly, and then focused by lens with the focus spot being 10μm. The sample is fixed on a three dimensional high-precision mobile platform. In order to make the surface of sample consistent with the focus spot, the z axis of the platform is moved, and the x, y axes are used to control the scanning speed and interval. The copper sample is used, with a size of 15×15mm and a thickness of 0.5mm.

Laser Instrument

A Nd:YVO4 laser instrument is used to generate the laser pulses. The output power has a good stability, which is smaller than3%RMS, and M^2≤1.2. The laser instrument is shown in Fig. 1.

Figure 1: Schematic of the laser instrument.

Focus System

Figure 2: Schematic of the focus system.

The focus system in Fig.2 is consisted of a 10× expander lens and a special laser focusing lens. In order to obtain a much smaller spot at the focus, the divergence angle is reduced by using the 10× expander. The laser focusing lens is specifically designed for the laser instrument in this work.

Three-dimensional Scanning System

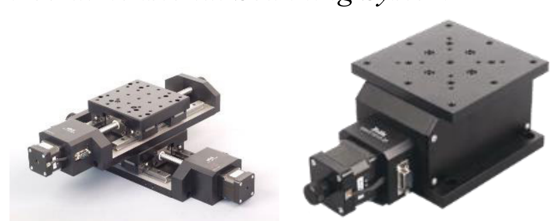

Figure 3: Schematic of the three dimensional high-precision mobile platform. The left figure shows the adjustment

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of x, y axes and the right one shows the adjustment of z axis.

A three–dimensional scanning system shown in Fig. 3 is used to set the sample, which can be adjusted along three mutually perpendicular directions. The z axis is used to adjust the distance between the sample and the laser instrument to make the focusing spot consistent with the sample surface. The x and y axes are used to adjust the scanning speed and interval.

Laser Treatment System

Figure 4: Schematic of the assembled system.

The laser instrument shown in Fig. 4 is placed vertically, making it easy to operate for adjusting the focusing spot. An aluminum alloy foothold is used to guarantee the system stability.

Other Auxiliary Devices

Figure 5: The left figure shows the controller of the platform, and right one shows the cooling device.

In order to keep the internal temperature of the laser constant, a suitable water cooling device shown in Fig. 5 is equipped. This not only ensures the operation stability, but also prolongs the service lifetime of the equipment.

EXPERIMENT RESULT AND DISCUSSION

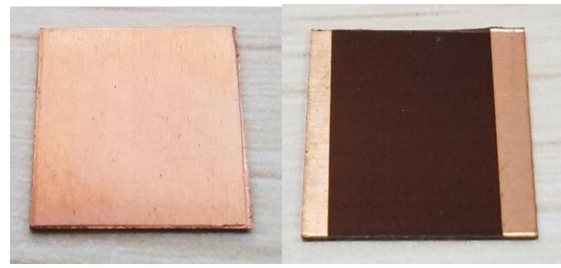

Figure 6: The copper sample before and after the laser treatment.

To test the effect of the laser treatment system on suppressing the secondary electron emission effect, a series of experiments is carried out using copper samples. Before the laser treatment, the copper is first washed with alcohol and ultrasonic cleaning machine. The copper sample is dealing with the laser treatment system. In the experiment, the focusing system is fine-tuned so that the laser pulse is well focused on the sample. After laser treatment, the surface of the sample has no metallic luster on the surface, which is shown in Fig. 6. SEM and SEY are carried out to further test the property of the copper sample after laser treatment.

SEM of Sample

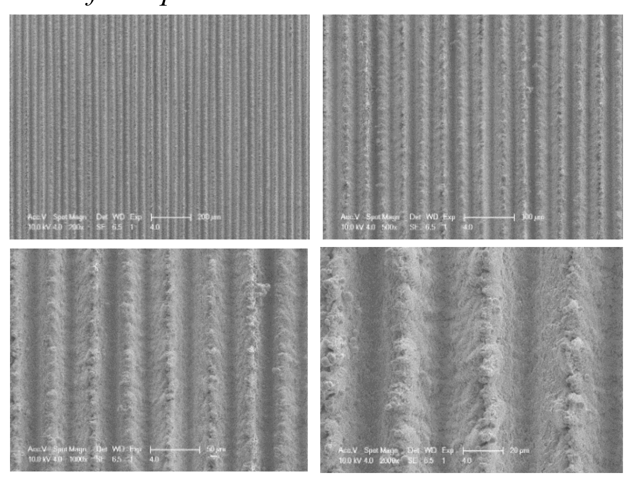

Figure 7: The SEM test result at different magnification with a 40µm scanning interval.

The SEM test is carried out to evaluate the surface property of the copper sample. The result is shown in Fig. 7, with magnification of 200, 500, 1000 and 2000 times, respectively. From the figure it can be seen that a ditch of about is 45µm-wide is formed after the laser treatment. These ditches are periodically arranged with consistent width. The SEM result shows that the laser treatment can effectively modify the surface of the copper sample. The ditch structure can reduce the secondary electron emission, as shown in the following part.

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SEY of Sample

To test the performance of the laser-treated copper sample on suppressing the secondary electron emission, existing measuring device in our laboratory is used to measure the SEY of the modified copper sample. The SEY of the copper sample before and after the laser treatment is measured as a comparison, and the result is plotted in Fig. 8. From the figure it can be seen that the SEY of the copper sample is obviously reduced after the laser treatment. It can also be seen that the maximum SEY (σ_{max}) is at about 350eV electron energy before the laser treatment, which is 2.04. After the laser treatment, σ_{max} becomes 0.86. This result shows the laser treatment method can effectively reduce the SEY of the copper sample.

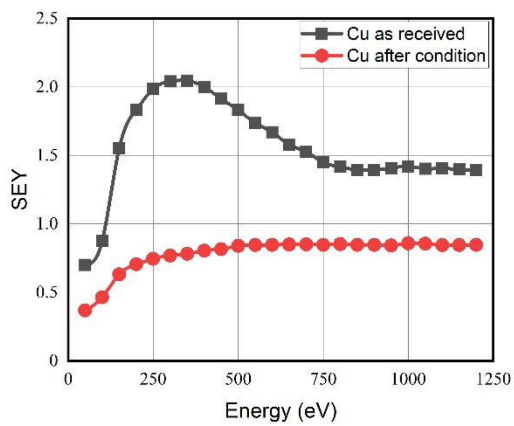

Figure 8: The SEY curves of copper before and after laser treatment.

The above experiment results show that the surface of the copper sample turns black after laser treatment, with no metallic luster. This may come from copper oxidize under high energy laser pulse. Periodic ditch structures are also generated after laser treatment. The primary electrons hit on the surface, and generate secondary electrons. Most of these secondary electrons are captured by the ditch structures. In these ditch structures, the electrons trip between the slopes, and become easier to be captured by the ditch structure as the slope increases. This process can effectively reduce the SEY of the copper sample. These experiments show the laser treatment method is effective in reducing secondary electron emission and can be applied in the new light source HALS.

CONCLUSION

This paper introduces the study of laser treatment method in reducing the secondary electron emission. The laser treatment system is set up and a series of experiment is carried out using copper as an example to test this system. The SEM and SEY test results show that periodic ditch structures are generated in the surface of the sample, and the SEY is obviously reduced. It is inferred that the ditch structure is one of the key factors that can reduce the SEY. The results show that the laser treatment method can effectively reduce SEY, which can meet the demands of the material of the vacuum system in the new light source HALS. Further work will be carried out to increase the performance of the laser treatment method and explore its effect on other kinds of materials, l.

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