A Beam Test of the Radiation Tolerance of the Au Coating on the Belle Beampipe

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Abstract

We have performed a beam test to examine the radiation tolerance of the Au coating on the Belle interaction-region beampipe using a beamline of the photon factory at KEK. No significant deteriorations in its adhesion and electric conductivity have been experimentally confirmed.

1 Introduction

In the Belle experiment [1] at the KEKB asymmetric energy e^+e^- collider [2], the radius of the interaction-region (IR) beampipe was designed to be as small as possible in order to improve the resolution of the decay-vertex reconstruction for B-meson decays. However, a reduction of the beampipe radius usually results in more beam-induced backgrounds and beampipe heating. A gold (Au) coating is applied inside the current Belle IR beampipe to cut synchrotron-radiation photons and to reduce the image-current heating[1] .

We have performed a beam test, in June 2001, using the beamline #21 of the photon factory at KEK in order to examine the radiation tolerance of the Au coating for the expected largest amount of the synchrotron radiation from the High Energy Ring of the KEKB.

[1]Due to the skin effect, an image current flows only near the surface, where the skin depth is of order 1 μm for Au in the relevant condition of the KEKB/Belle.

2 Experimental setup and the irradiation

We used a test piece for the new Belle IR beampipe with a radius of about 1 cm and a length of about 10 cm. It consists of the tantalum (Ta) and stainless steel (SS) parts, with which we can investigate a possible difference between different materials of the beampipe. The test piece was cut in half lengthwise as seen in Figure 1, and one of them was used. A cooling copper tube was brazed on the outer surface by Ishikawajima-Harima Heavy Industries (Figure 2). Then an Au coating with a thickness of about 10 μm was applied on the inner surface by ULVAC with a vacuum evaporation (Figure 3).

At the beamline #21 of the photon factory, a white synchrotron-radiation photon beam is provided from the 2.5 GeV electron synchrotron, where the radiation source is about 15 m away from the target. The photon beam has a critical energy of 4.0 keV and a width of 5×5 mm^2 which is determined from the size of the collimator window located about 1 m upstream from the target. In the first stage, a photon beam was irradiated on the SS part, and a clear spot appeared on the Au coating as seen in Figure 4. In the second stage, a photon beam was irradiated on the Ta part, and again a clear spot appeared (Figure 5). We can see a significant difference on the brightness between the two spots.

Figure 6-(a) shows the irradiation powers. The total energies irradiated on the test piece are 2.3 MJ for the SS part and 2.7 MJ for the Ta part. Figure 6-(b) shows the pressures in the vacuum chamber in which the test piece was located. The pressure in the Ta irradiation was factor of two better than in the SS irradiation. Figure 6-(c) shows the temperatures of the test piece, which were measured with a thermocouple attached to the center of the outer surface of the test piece.

3 Resistance measurement and adhesion test

The surface resistance was measured using an Au-coated pin head (Figure 7) and a digital multimeter (KEITHLEY2000) with a resolution of 0.1 mΩ. We adopted the four-wire method in order to cancel the resistance in the lead wires and to obtain a better resolution. The pin head was fixed to an equipment and movable only up and down as seen in Figure 8, which made it possible to repeat equal measurements. Figure 9-(a) shows an example of measured resistance values as a function of time, and Figure 9-(b) shows the corresponding resistance distribution in the measurement

period. Fitting the distribution with a Gaussian function, a mean value is obtained as a final one ($10.03 \pm 0.02\,\mathrm{m}\Omega$ in this example). Such kind of measurement was performed at four different points: the (not) irradiated points in the SS or Ta part. Then the above procedure with four resistance measurements ("cycle") was repeated five times to estimate the systematic error from the contact resistance between the pin head and the Au coating on the beampipe. The results are shown in Figure 10. The increase of the resistance due to the irradiation is defined as

$$\Delta R \;=\; R' - R_0, \tag{1}$$

where R' indicates a resistance at the irradiated point, and R_0 at the not irradiated point. With the above subtraction, we can investigate a change of the resistance of only the Au coating including the beampipe. Taking a minimum and maximum value for ΔR from all the possible combinations among the five cycles, values of ΔR are estimated to be:

$$-0.42 < \;\Delta\mathrm{R}\; < +0.65\ \mathrm{m}\Omega \quad \text{for the SS part and} \tag{2}$$

$$-0.18 < \;\Delta\mathrm{R}\; < +1.43\ \mathrm{m}\Omega \quad \text{for the Ta part.} \tag{3}$$

The adhesion was tested using a Scotch tape after making scars in square at an interval of about 1 mm on the Au surface. No coating came off as seen in Figure 11. It was also found that an Au coating surface appeared in the scars. This fact means that the spots were made from dusts in the vacuum chamber, and allow us to explain the significant difference on the brightness between the two spots by the different degrees of vacuum during the irradiations (Figure 6-(b)).

4 Suumary

An Au coating is applied on the current Belle IR beampipe to cut synchrotron-radiation photons and to reduce the image-current heating. We have performed a beam test to examine the radiation tolerance of the Au coating using a beamline of the photon factory at KEK. The increase of the resistance is estimated, and the adhesion is inspected with a tape test. In conclusion, no significant deteriorations in its adhesion and electric conductivity have been experimentally confirmed.

Acknowledgments

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References

[1] A. Abashian *et al.* (Belle Collaboration), The Belle Detector, KEK Progress Report 2000-4, 2000.

[2] N. Toge(ed.), KEKB B-Factory Design Report, KEK Report 95-7, 1995; Y. Funakoshi *et al.*, in *Proceedings of the European Particle Accelerator Conference*, Vienna, 2000.

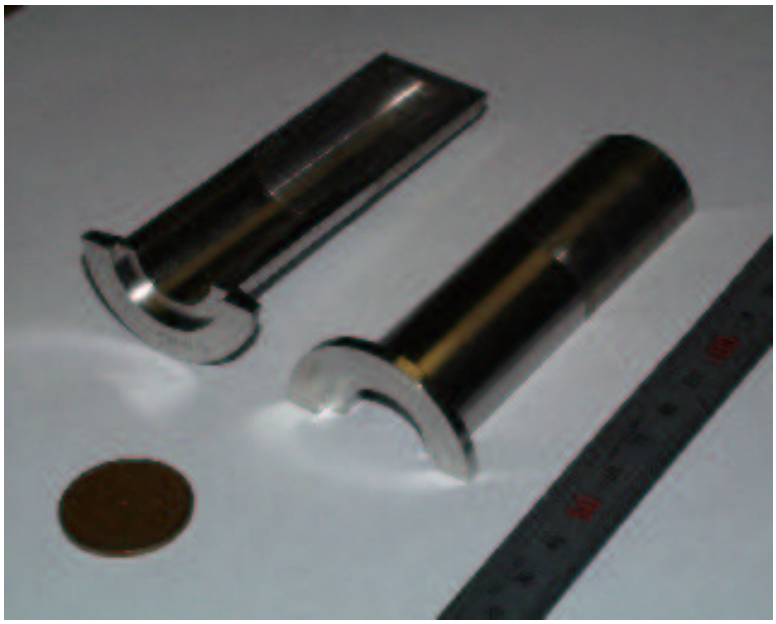

Figure 1: *The test piece used for the beam test, consisting of the Ta (that side) and SS (this side) parts.*

Figure 2: *The test piece with a cooling copper tube brazed on the outer surface.*

Figure 3: *The test piece with an Au coating on the inner surface.*

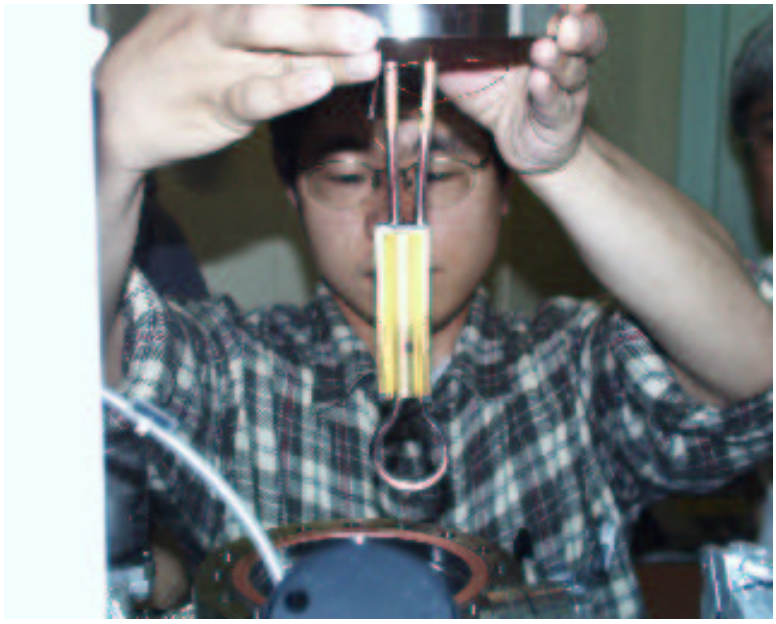

Figure 4: *The author takes the test piece out from the vacuum chamber after the irradiation on the SS part.*

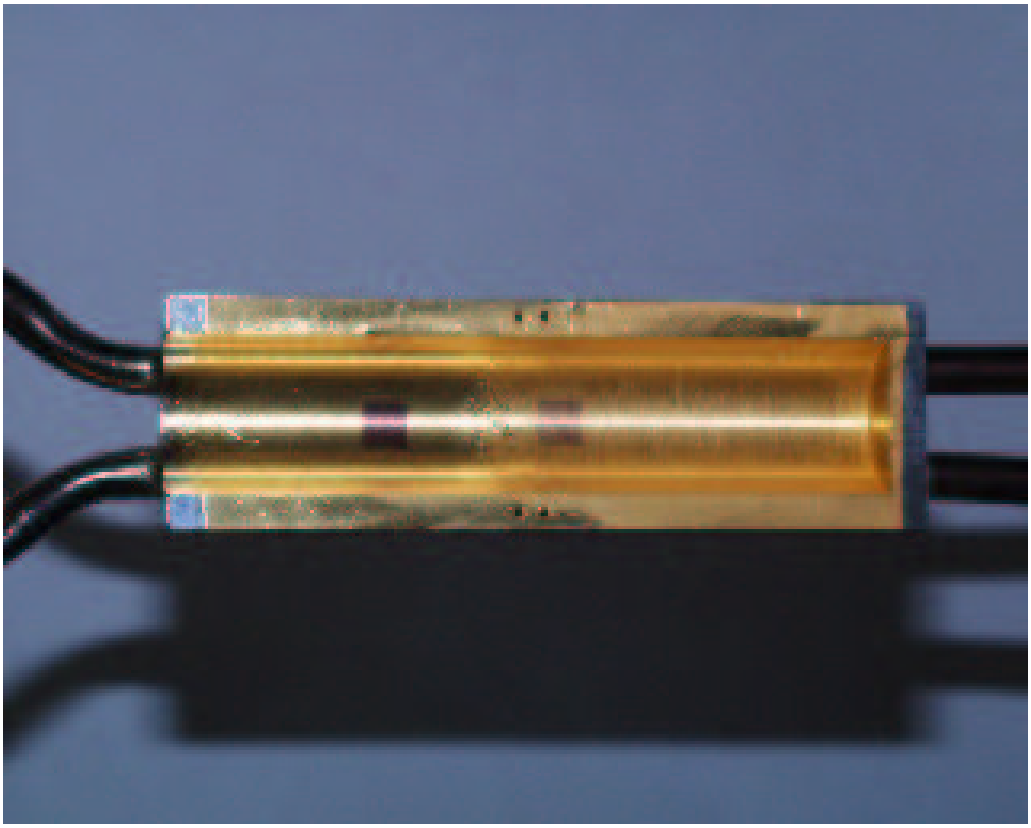

Figure 5: *The test piece after the two irradiations on the SS and Ta parts. The left part is the SS and the right is the Ta.*

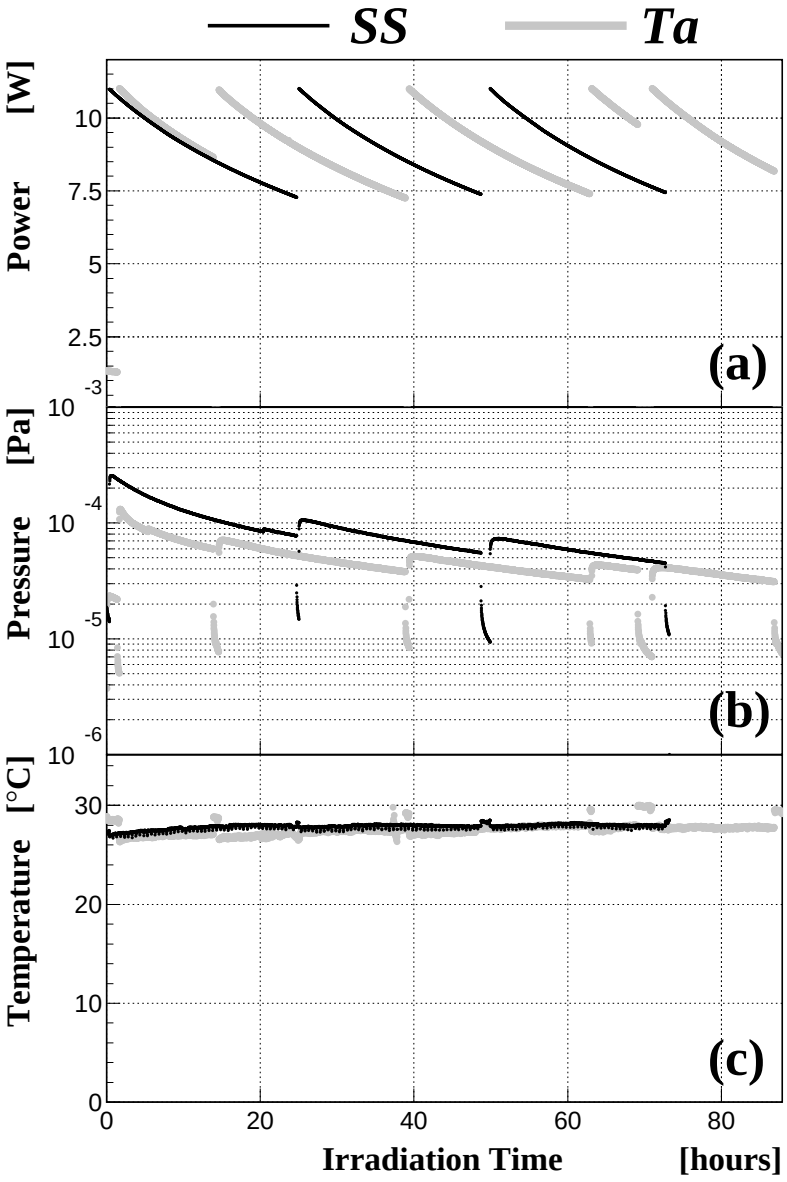

Figure 6: *(a) The powers of the photon beam onto the test piece, (b) the pressures in the vacuum chamber and (c) the temperatures of the test piece during the irradiations. The black lines denote the irradiation for the SS part, and the gray ones for the Ta part.*

Figure 7: *The Au-coated pin head used as a probe in the resistance measurement. Two lead wires are connected to each pin for the four-wire measurement.*

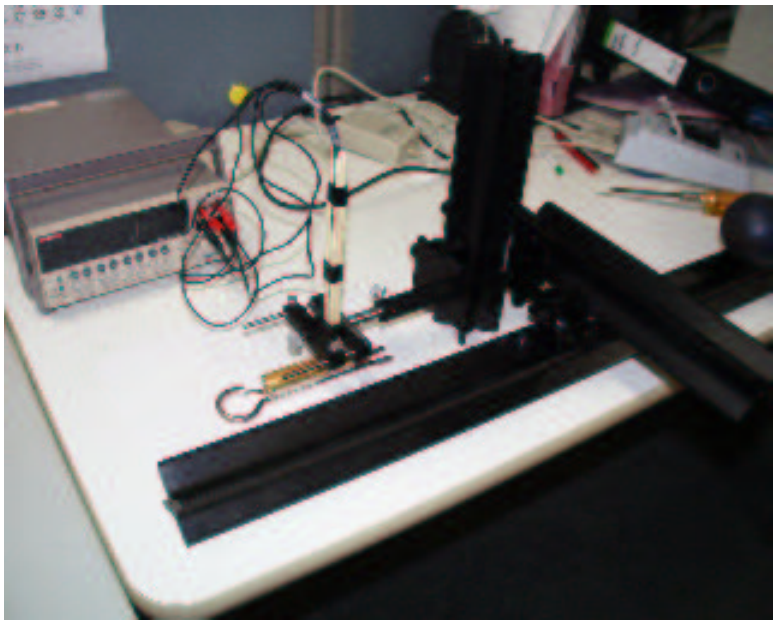

Figure 8: *The equipment to fix the pin head with a degree of freedom to move the pin head up and down.*

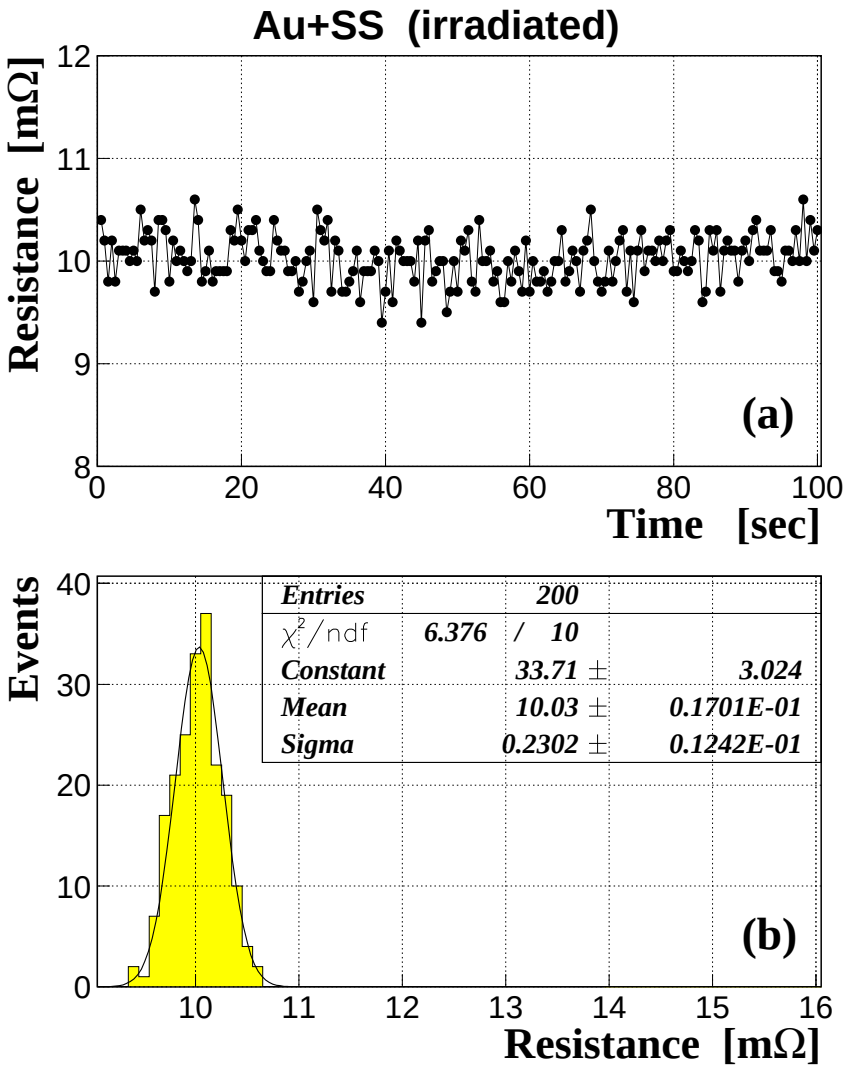

Figure 9: *An example of (a) measured resistance values as a function of time, and (b) the corresponding resistance distribution with a fit result.*

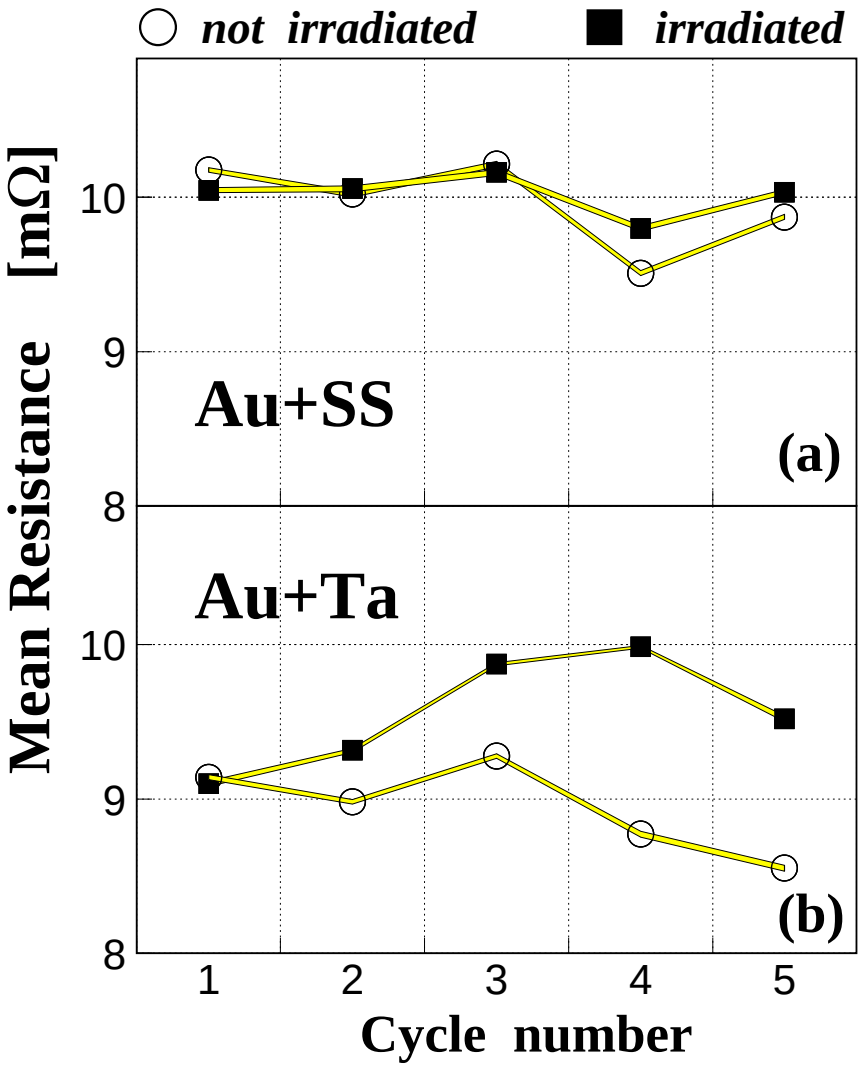

Figure 10: *The cycle dependence of the measured mean resistances for the (a) SS and (b) Ta part. The bands indicate statistical errors of the fit.*

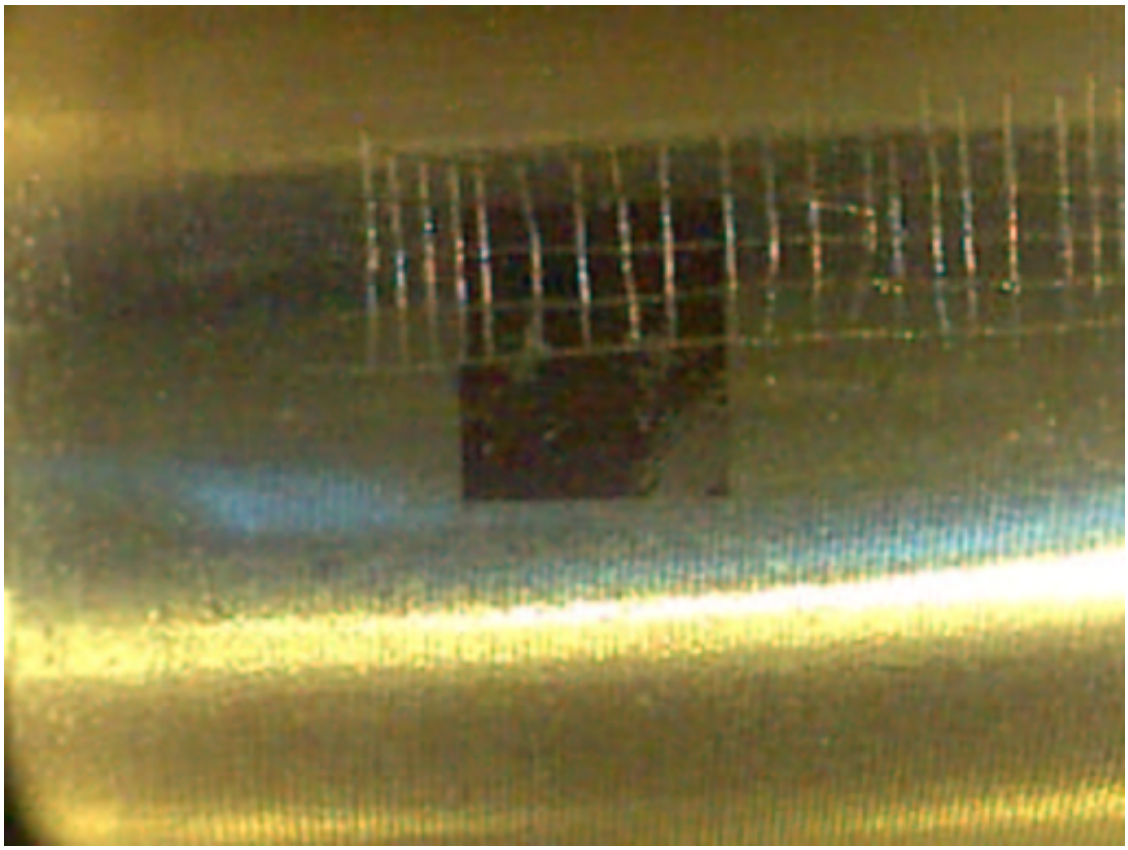

Figure 11: *The Au coating in the SS part with scars in square after the tape test. Making further scars in the lower right region using a sewing needle, an Au surface clearly appeared. The status in the Ta part is the same.*