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FOREIGN TECHNOLOGY DIVISION

EXPERIMENTAL INVESTIGATION OF THE DESTRUCTION OF ThF$_4$ PROTECTIVE FILM BY A PULSED CO$_2$ LASER

by

Fang Huiying, Wang Cunkui, and Fu Yushou

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EXPERIMENTAL INVESTIGATION OF THE DESTRUCTION OF ThF₄ PROTECTIVE FILM BY A PULSED CO₂ LASER

Fang Huiying  Wang Cunkui  Fu Yushow
(Mechanics Institute, Academia Sinica)

Currently, gold film reflectors are commonly used in high power CO₂ laser resonance chambers and focusing systems. Gold-film reflectors are soft and easily soiled. They are easily damaged when cleaned and scratch marks frequently appear, so that the optical qualities of the reflector are affected.

In order to find a suitable protective film for gold-film reflectors, the Heilongjiang Technical Physics Institute has plated gold-film reflectors with ThF₄ protective film. Experiments demonstrate that the film possesses qualities that may overcome the defects mentioned above.

The optical films used in laser systems must possess not only the quality of high mechanical scratch-proof and erosion-proof capabilities, but also that of high laser-damage-prevention ability, i.e., high damage threshold. This is very important for prolonging laser lifetime and insuring good optical qualities.

Although the gold film's mechanical properties are enhanced by the ThF₄ protective film, will the ability to prevent laser damage of the gold film be maintained? This is a question concerning the user. For this purpose, we have carried out some experimental investigations on the laser-damage prevention ability of glass-based and copper-based gold film reflectors after being plated with the ThF₄ protective film. In the experiment, samples are irradiated with a CO₂ pulse laser of wave length of 10.6 micron (pulse width is 0.6 microsecond) at 4 different energy densities: 1.2X10⁶ watt/cm², 2.4X10⁶ W/cm², 2.7X10⁶ W/cm² and 3.9X10⁶ watt/cm². The damages are observed and analysed microscopically.

1
1. EXPERIMENTAL SET-UP

A double-discharge CO\textsubscript{2} laser made in the Mechanics Institute is used in the experiment. The output energy is measured with a carbon energy meter. The output energy is focused with a germanium lens with a focal length of 100mm onto the sample (the germanium lens is coated with a transmission enhancing film). The beam spot shape is displayed by shining the laser beam on carbon paper. The spot area is determined with a microscope and the following formula is used to calculate the power density

\[ I = \frac{E}{S \tau} \]

where \( E \) is the laser energy output, \( S \) - the beam spot area, and \( \tau \) the pulse width. The experimental set up is shown in Figure 1.

Figure 1. Diagram for the Experimental Set Up.

Figure 2. K\textsubscript{g} glass Cr/Au
power density 1.2X10\textsuperscript{5} W/cm\textsuperscript{2}
Enlarged 26 times.

Figure 3. K\textsubscript{g} glass Cr/Au/ThF\textsubscript{4}
power density 1.2X10\textsuperscript{6} W/cm\textsuperscript{2}
Enlarged 26 times.
TABE 1. Tabulated Experimental Set Up

<table>
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<tr>
<th>Base Material</th>
<th>Film Plated</th>
<th>Observed Result</th>
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<tbody>
<tr>
<td>$K_y$ glass</td>
<td>Cr/Au</td>
<td>1.2 x $10^6$ W/cm$^2$</td>
</tr>
<tr>
<td>$K_y$ glass</td>
<td>Cr/Au/ThF$_4$</td>
<td>2.4 x $10^6$ W/cm$^2$</td>
</tr>
<tr>
<td>Copper</td>
<td>Cr/Au</td>
<td>2.7 x $10^6$ W/cm$^2$</td>
</tr>
<tr>
<td>Copper</td>
<td>Cr/Au/ThF$_4$</td>
<td>3.5 x $10^6$ W/cm$^2$</td>
</tr>
</tbody>
</table>
2. EXPERIMENTAL RESULTS

From the above mentioned experimental results, we can see that there is a great difference in the degree of damage for mirrors of K₈ glass base plated respectively with Cr/Au and Cr/Au/ThF₄ films under 1.2 x 10⁶ W/cm² power density irradiation. The reflector base without the ThF₄ film has already cracked while for the mirror with ThF₄ film, only the surface film is damaged. Even under the power
density of $3.5 \times 10^7 \text{ W/cm}^2$, only the ThF$_4$ film starts to melt and crack for reflector with ThF$_4$ film.

The reflector with copper base plated with Cr/Au film under $2.4 \times 10^6 \text{ W/cm}^2$ not only has the film damaged, but the base has also been observed to crack. However, at the same power density, the mirror plated with ThF$_4$ protective film has no directly observable damage. When the power density is $2.7 \times 10^6 \text{ W/cm}^2$, the ThF$_4$ film begins to crack and flake. Only until we reach $3.5 \times 10^7 \text{ W/cm}^2$ does the ThF$_4$ film start to melt and wrinkle.

3. CONCLUSION

(1) Experimental analysis indicates that the damages on the ThF$_4$ film are mainly the layering, cracking and melting due to thermal effect.

(2) Plating with the ThF$_4$ protective film improves not only the anti-mechanical scratch and anti-erosion ability of the gold film reflector, but also its ability to prevent laser damage.

(3) The experimental result indicates that the damage threshold of the ThF$_4$ protective film is between $10^6 - 10^7 \text{ W/cm}^2$. This result agrees with the research result of ThF$_4$ protective film on silver-plated reflector in reference [1].

REFERENCES
