

# A Study on SPDT of Metal Reflector and Correlation Between Recrystal Annealing Temperature and Reflectivity

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## Abstract

Commercially available diamond turning machines offer high levels of accuracy where the full potential of the machine is realized. This paper deals with the SPDT technique of metal reflector and provides the measuring results of the surface roughness ( $R_{max}$ ,  $R_a$ ) and reflectivity in IR region. In addition the correlation between recrystal annealing temperature and the reflectivity is discussed preliminarily.

## 1. Introduction

One of the reasons of optical industry rapidly growing is the laser development. Recently, the output power value of the laser has amounted to 5~20kW, and will be improved in direction of high power. Due to the fact that the reflectors and lenses used in  $CO_2$  laser for oscillation, transmission and focusing, if the glass material is used, can be damaged by the high power laser beam<sup>[1]</sup>, so the glass mirrors are replaced by the metal mirrors which have the high damage threshold<sup>[2]</sup>. On the other hand, the wavelength of  $CO_2$  laser is  $10.6\mu m$  and the surface roughness  $R_{max} = 0.01\mu m$  is enough.

The Single Point Diamond Turning (SPDT) was used during the 1960s at some government laboratories to fabricate ultra-precise machined parts and high-energy laser mirrors, but it was until the mid-1970s that industry became involved. The prime stimulus for industrial activity came from the rapidly expanding demand for infrared optics. The current situation appears to be nearly completely devoid of the basic research that relates to machining mechanisms or machined surface formation mechanisms in order to provide the finished surface roughness ranging from  $0.01\mu m$  ( $100\text{\AA}$ ) to  $0.001\mu m$  ( $10\text{\AA}$ ).

This paper deals with the manufacturing techniques of metal reflector used in CO<sub>2</sub> laser and provides the measuring results of the surface roughness (R<sub>max</sub>, R<sub>a</sub>) and surface reflectivity (R) and discusses the regularity of different annealing temperature affecting the reflectivity.

## 2. SPDT of Metal Reflector

### 1. An example of CO<sub>2</sub> laser machining system

Fig.1 shows a CO<sub>2</sub> laser machining system. Generally, within the laser oscillation device, the transmission component uses flat reflector and convex-concave spherical reflector, Focusing component used in welding or cutting uses paraboloid reflector, Surface heat treatment component uses sector reflector.

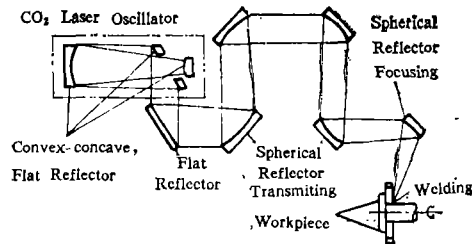


Fig.1 An example of CO<sub>2</sub> laser machining system<sup>[1]</sup>

### 2. Experimental apparatus and method

Fig.2 Shows a schematic layout of the Pneumo MSG-325. A versatile 2 axis ultra precision contour turning system for use with single point diamond tools to achieve optical quality finishes and figure on nonferrous metal and plastic parts to 550mm diameter. CNC control with 0.000001 inch resolution and closed loop laser interferometer feedback together with vibration isolation and air bearing slides and spindle allow the finest possible accuracy and finish to be obtained on plane, cylindrical and contoured (spherical) surfaces.

Tool: Single crystal diamond, tool orthogonal rake  $\gamma_0 = 0^\circ$ , tool orthogonal clearance  $\alpha_0 = 6^\circ$ , nose radius = 5mm.

workpiece material: OFHC-Cu (99.98% Cu)

Cutting condition: main spindle revolution  $n = 1000\text{rpm}$ , cutting depth  $a_p = 0.5 \sim 1\mu\text{m}$ , feed  $f = 5\mu\text{m/rev}$

Roughness measuring instruments: R<sub>max</sub> ... maximum peak-to valley height within the sampling length L (measured with Talystep System), R<sub>a</sub> ... arithmetical mean deviation of the profile within the sampling length

L (measured with Form Talysurf)

Form Talysurf is a stylus instrument with a wide dynamic measuring range. The range achieved by using a laser interferometric transducer, the signals from which are transmitted to a microcomputer for detailed processing. When fitted with the 60 mm diamond tipped stylus arm for

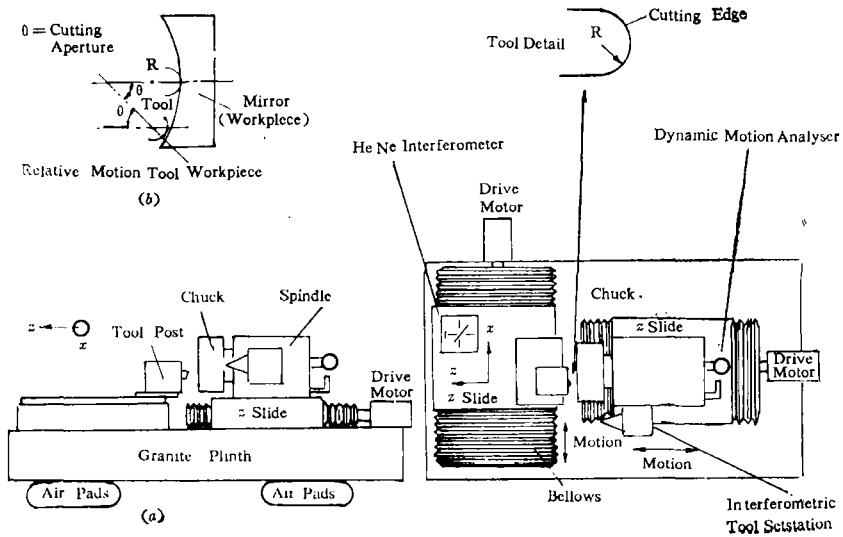


Fig. 2 Schematic layout of MSG 325 diamond turning lathe<sup>(9)</sup>

surface texture or form measurement the vertical range is 4 mm with a resolution of 10nm, or approximately 1/64 of the wavelength of helium neon laser light.

Talystep operates on the same principle as the Form Talysurf, although the traverse length is very much less (1mm each side of the central position). The mechanical and thermal stability of the instrument is such that at  $V \times 10^6$  it can resolve features down to  $0.0005 \mu\text{m}$  (0.5nm) high (which is one-thousandth of the wavelength of light).

Reflectivity (R) measuring instrument, Lambda 9 UV/VIS/NIR Spectrometer. Lambda 9 is a versatile, high performance double-beam, doublemonochromator UV/Visible, Near Infrared spectrometer usable in a wide range of applications as indicated by its performance specifications. It combines an all-reflecting optical system with microcomputer electronics, video display and soft key operating system. Its wavelength varies from 185nm to 3200nm.

### 3. Experimental Results and Discussion

#### 1. Machined surface generated

Fig.3 and Table 1 show the machined surface profile resulting from the MSG-325.

The surface exhibits 96.03% ( $\lambda = 1.5\mu\text{m}$ ) reflectivity, and the roughness  $R_{max} = 0.12\mu\text{m}$ ,  $R_a = 0.010\mu\text{m}$

2. OFHC-Cu heat treatment and machined surface

OFHC-Cu is usually treated with two kinds of method, one is the cooling deformation+recrystal annealing, the other is the direct recrystal annealing treatment. The paper specializes in discussing the direct recrystal annealing heat treatment method and exploring the correlation

Table 1 Surface roughness measured with form talysurf

$F_1$ -Analysis	Mode	Cut Off	Filter	Reference	Ignore
	ROUGHNESS	0.08 mm	ISO	STRAIGHT	0 %
	259 Test	Yu		23	10 90
$R_{1m} = 0.078\mu\text{m}$	$L_o = 400.024\mu\text{m}$			$R_a = 0.010\mu\text{m}$	
$R_{2m} = 0.037\mu\text{m}$	$R_p = 0.073\mu\text{m}$			$R_q = 0.015\mu\text{m}$	
$R_y = 0.162\mu\text{m}$	$R_o = 0.089\mu\text{m}$			$R_{z\mu} = 0.8$	
$R_{11} = 0.162\mu\text{m}$	$R_t = 0.162\mu\text{m}$			$R_{zu} = 8.2$	
$R_{12} = 0.037\mu\text{m}$	$SLOPE = 0.04\text{Deg}$			$D_{1q} = 1.77\text{Deg}$	
$R_{13} = 0.039\mu\text{m}$				$L_{amq} = 3.059\mu\text{m}$	
$R_{14} = 0.034\mu\text{m}$				$S = 2.174\mu\text{m}$	
$R_{15} = 0.117\mu\text{m}$				$S_m = 2.742\mu\text{m}$	
				$R_{3z} = 0.057\mu\text{m}$	
				$R_{3y} = 0.114\mu\text{m}$	

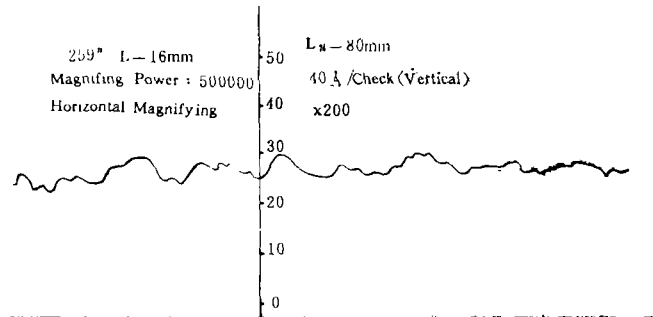


Fig.3 Roughness Rmax measured with talystep

between the recrystal annealing temperature and the surface reflectivity.

Fig.4 shows the reflector reflectivity varying with the raising of annealing temperature. Reference to Fig.4, with the raising of the temperature T, the reflectivity R varies inobviously, although it can enhance the 1 ser-ind-uced damage threshold which will be published otherwheres.

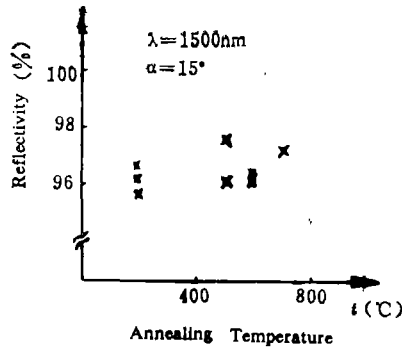


Fig.4 Correlation between the recrystal annealing temperature and the reflectivity

#### 4. Conclusions

When used in infrared region (including the reflector of CO<sub>2</sub> laser), the diamond-machined finish has very high reflectivity. For this wavelength region, the surface finish is obtained with relative ease and lower cost. The value obtained for finished surface roughness using OFHC-Cu (99.98%Cu) was Ra = 100 Å, Rmax = 120 Å.

With the raising of the recrystal annealing temperature, the reflectivity R varies inobviously, as shown in Fig.4.

#### 5. Acknowledgement

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#### References

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### 金属反射镜的SPDT技术及再结晶退火温度对其表面反射率的作用

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摘要: 讨论用单点金刚石切削技术制作金属反射镜, 并给出其表面粗糙度 (R<sub>a</sub>, R<sub>max</sub>) 和反射率的测试结果。另外, 初步探讨了再结晶退火温度对镜面反射率的作用。