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LIFE ESTIMATION OF CARBON OVERCOAT ON MAGNETIC MEDIA FOR HEAT-ASSISTED MAGNETIC RECORDING USING NOVEL RAMAN SPECTROSCOPY

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ABSTRACT

A heat-assisted magnetic recording (HAMR) is expected for a future high density recording of a hard disk drive. However, a carbon overcoat (COC) composed of diamond-like carbon (DLC) or a lubricant film is possibly damaged when a magnetic medium, i.e. CoPt alloy, is heated at around Curie temperature (Tc) of 600K by a near-field HAMR head. We carried out HAMR simulation experiments by using newly developed Raman spectroscopic systems, composed of plasmonic sensors for surface-enhanced Raman scattering (SERS), a pulsed laser heating, and an in-situ temperature measurement with an intensity ratio of anti-Stokes/Stokes lines. It was found that the heated temperature of the COC is higher than that of the magnetic film, i.e., 580 ℃ and 366 ℃, respectively. Intensity changes of G-band peak in Raman spectra for DLC films were observed during the pulsed laser heating. The Raman intensity was exponentially decreased by oxidation in air, where time constants were calculated as a parameter of a pulse width. Degradation life of the DLC film can be estimated from a critical pulse width, where the time constant is extrapolated to zero. The estimated pulse width for no degradation was 250μs at the heating temperature of 580 ℃. The result shows no damage can be estimated in DLC films for HAMR because the effective irradiation time is 5ns and the accumulated irradiation time is 0.5ms in HAMR operations.

INTRODUCTION

Heat-Assisted Magnetic Recording (HAMR) is expected as one of the future high density recording technologies. When the magnetic film is heated in the Curie temperature (Tc) around 600K (357℃), DLC film and lubricant film are considered to be thermally damaged as chemical degradation [1], i.e. decomposition, oxidation, or evaporation, as well as mechanical degradations, i.e. friction or wear. We have developed new measurement systems based on Raman scattering spectroscopy. Our tool can measure chemical structures of ultra-thin layers with high sensitivity of several thousand greater than that of the normal Raman spectroscopy in magnitude. The depth resolution is also 0.1 nm or less. Besides, our system can measure dynamic chemical change and temperature of their thin films with a high speed of millisecond. In this study, we report the estimation of the life on DLC films with HAMR simulation experiments in a chemical viewpoint of thermal degradation.

EXPERIMENTAL

Our plasmonic sensor [2] is composed of a convex quartz glass substrate on which Ag nanoparticles are coated as shown in Fig.1. Raman spectra are acquired by irradiating a laser beam focusing on the contact point where the sensor is placed on the sample surface. Raman signal of the sample surface is strongly enhanced by plasmonic field generated at around Ag/sample surface.

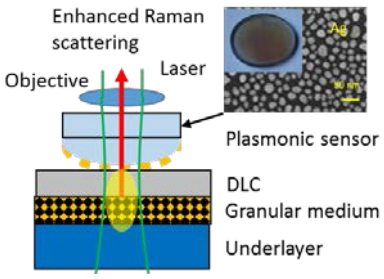

Fig.1 Schematic measurement diagram for layered hard disk sample using plasmonic sensor.

Intensity of Raman spectra is enhanced by 1,000 times and more because Raman intensity is proportional to the 4th power of electric light field. We had carried out simulation experiments for HAMR using plasmonic sensors with other technologies as follows.

The temperature of heated sample was simultaneously measured while irradiating the laser beam with the intensity ratio of anti-Stokes to Stokes lines as shown in the following equation (1).

$$I_{aSt} / I_{St} = \exp(-h\nu / kT) \quad (1)$$

h:Plank constant ν :Wave number
k: Boltzmann constant T: Absolute temperature

The temperature of DLC films can be calculated by the above equation from Raman spectra of the DLC film. We prepared layered HD media, i.e. DLC films on granular media in which Raman active metal oxide is embedded in CoPt alloy films as a non-magnetic segregant, to examine the temperature for the layered structure.

Pulsed laser beam was irradiated onto the sample to simulate HAMR because rotating HD media were heated discontinuously by near-field HAMR heads.

RESULTS AND DISCUSSION

Figure 2 shows Raman spectrum of the HD sample, consisting of the DLC film on the granular magnetic film. Other than DLC peaks, a peak of oxide in granular film is observed at around 687cm^{-1}. Anti-Stokes peaks of oxide and DLC are also observed. Calculated temperature is 580℃ for DLC and 366℃ for oxide, respectively. The temperature of the DLC film is higher than that of the oxide in granular film, related to the difference of thermal conductivity for DLC and Co metal as shown in Table 1. The temperature of oxide is considered to be same as that of Co because the oxide is embedded between Co alloy nanoparticles with diameter of several nanometer. The temperature of DLC film with low thermal conductivity is higher than that of the recording film.

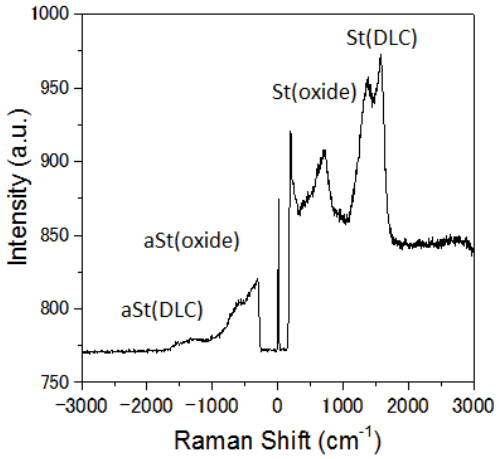

Fig.2 Raman spectrum of DLC on granular film.

Table 1 Thermal conductivity of DLC and Co metal.

Material	Temperature (℃)	Thermal conductivity (W/m/K)
DLC	580	0.2～30
Co	366	99.2

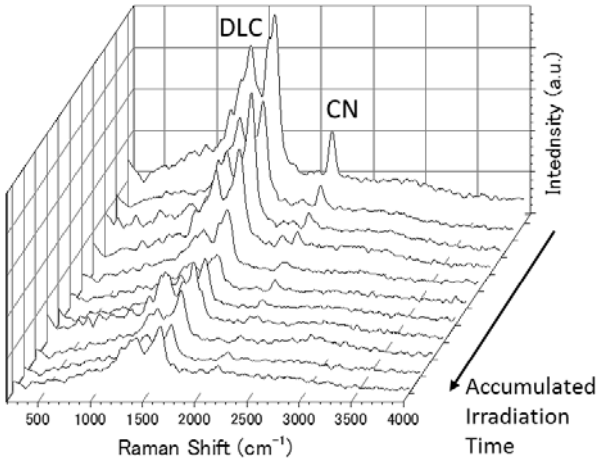

Figure 3 Raman spectral change for N:DLC on continuous CoPt medium as a function of elapsed accumulated irradiation time for pulsed laser beam.

Figure 3 shows Raman spectral change for nitrogen doped COC [3] on continuous HD medium with pulsed laser heating as a function of elapsed accumulated irradiation time. Raman intensity of DLC peaks, D and G, and CN peak is decreased with irradiation time because of oxidation and decomposition of nitrogen doped layer.

Figure 4 shows the intensity change of G-peak as a function of accumulated irradiation time when DLC film is heated by pulsed laser with pulse width of 0.1s at 580℃. The intensity is exponentially decreased with the elapsed irradiation time, thus the time constant τ is calculated from a fitting curve as shown in the equation (2). Figure 6shows calculated time constants as a function of pulse width. The time constant is decreased with decreased pulse width. The mechanism is considered that the oxidation reaction is delayed because the diffusion of oxygen gas is rate-determining. Extrapolated pulse width to zero of the time constant, i.e. a critical pulse width with no degradation, is 250μs as sown in Fig.6. The result shows no chemical damage can be estimated in DLC films for HAMR because the effective irradiation time is 5ns and the accumulated irradiation time is 0.5ms in HAMR operations.

$$I = A \cdot \exp(-t/\tau) + B \quad (2)$$

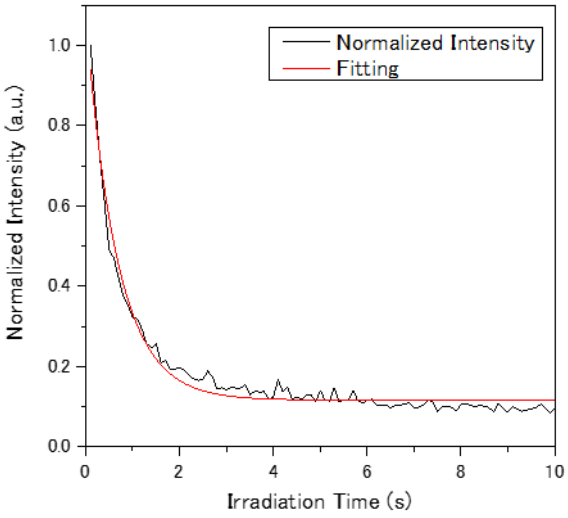

Fig.5 Intensity change of G peak of DLC film as a function of accumulated irradiation time with pulse irradiation of 0.1s at 580℃

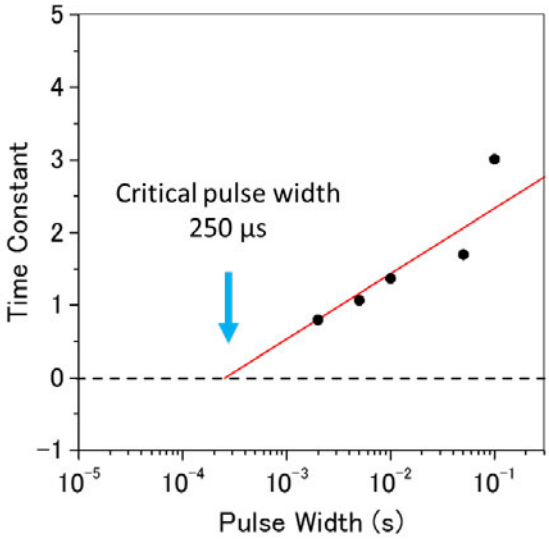

Fig.6 Time constant for DLC as a function of pulse width heated at 580℃.

CONCLUSIONS

Heating temperature measurement on layered materials by the laser heating technique was carried out. The temperature of the DLC film on the granular magnetic film, composed of the segregant oxide mixed with the CoPt alloy, was 580℃ when the magnetic medium was heated at around Tc (366℃). The temperature difference corresponds to the difference of the heat conductivity. HAMR simulation experiments were carried out by using the pulsed laser heating and the SERS spectrum measurement with the plasmonic sensor. Intensity changes of G-band for DLC films were observed during the pulsed laser heating. The Raman intensity was exponentially decreased by oxidation in air, where time constants were calculated as a parameter of a pulse width. Degradation life of the DLC film can be estimated from the extrapolated pulse width, the critical pulse width, where the time constant becomes zero. The estimated pulse width for non-degradation was 250μs at the heating temperature of 580℃. The result shows no damage can be estimated in DLC films for HAMR because the effective irradiation time is 5ns and the accumulated irradiation time is 0.5ms in HAMR operations

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