Novel Metal Nanostructure and 4th-Generation Super-RENS Optical Disk

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Abstract: We recently discovered that the decomposition of silver oxide thin film can be transformed into silver nanoparticles and nanowires with a uniform diameter of 20-30 nm by dry process under hydrogen and oxygen gas plasma. The nanostructures may be applicable to 4th-generation super-RENS disk, which is read out by huge electrical field enhancement of localized surface plasmons (LSP). In this paper, we describe the fabrication method in detail and show potential of producing a nanometer-scale dot pattern of GeSbTe whose diameter is each 50 nm. Also, we will discuss their unique nonlinear optical characteristics to control LSP and light-scattering intensity of the advance super-RENS disk.

1. Introduction

High-density recording beyond the optical diffraction limit has attracted a lot of attentions besides optical holographic memory and 3-dimensional recording because this is a challenging science and technology to overcome our present knowledge of optics. Towards the technical direction, in general, it has been long time expected that near-field optics plays a major role in reading out such small pits. Up to now, large amounts of basic studies and researches have been carried out, in particular, for the last decade. For examples, solid immersion lens (SIL) systems have intensively been studied and developed by Stanford and Univ. Arizona groups at the early stage, and recently, a SONY group has demonstrated good performances on the actuating system to fly the head with a few tens nanometer height. On the other hand, super-resolution near-field structure (super-RENS) has also been revolutionizing from 1st-generation disk using an Sb layer to 3rd-generation with a PtOx layer, through 2nd-generation with AgOx. According to the most recent research of 3rd-generation super-RENS disk, more than 40-dB CNR from 200-nm mark trains was obtained in stable even after more than 50,000 readout, and the signal output wave was actually observed [1]. According to the TEM observation of the disk cross-section, Pt nanoparticles due to the thermal decomposition were confirmed with each size of 10-nm. At the moment, the detailed mechanism of such huge signal enhancement generated even in less than 100-nm marks has not been understood yet; however, the nanoparticle condensation suggests that the localized surface plasmons (LSPs) be largely related to the readout process: light-scattering from the recorded pits. Therefore, detailed study of LSPs generated between noble metallic nanoparticles is very important for the future near-field recording (NFR).

In this paper, we first introduce a novel method to fabricate metallic nanoparicles on a 12-cm polycarbonate disk surface and then describe its unique nonlinear optical characteristics.

2. Fabrication and optical nonlinear performance of Ag nanoparticles and nanowires

The base material to fabricate Ag nanostructures is a thin film of AgOx, which is the active mask layer used in 2nd-generation super-RENS disk. As our previous group member, D. Büchel (now Seagate Technology, US) first discovered Ag nanowires, when the film was used as an active material for surface-enhanced Raman spectroscopy, the AgOx film has a unique nature in wet condition [2]. Under the consideration, a flat AgOx film can be also transformed into nanostructures in dry condition. At glance, it seems simple and easy to transform the film into Ag nanostructures by use of the redox with hydrogen gas. However, the film is rapidly reduced to the flat Ag film without nanostruture we expect. In order to change the flat film to the nanostrutures, first we have to control and slow down the redox speed of O of the AgOx film by introducing O_2 gas together with H_2. Even under the condition, the reduced film showed a random nanostructures: the particle size is in the broad range from 10 nm to several 100 nm. It was found that the key technology to uniform the particles size was a pretreatment of a reactive ion-etching chamber (RIE) with CF_4 gas, whose fragments in the plasma may become seeds; at the moment, the chemical reaction of the initial has not been identified. Under these conditions, we first succeeded in transforming the AgOx film into Ag nanoparticles or nanowires [3]. Fig. 1 shows reflectivities against light wavelength (a), and a specific plasmon drops were observed at 326 nm after the redox. Fig. 1(b) is the SEM image after 5 min redox, and uniform Ag nanoparticles were identified with each diameter of 20 nm. Hence, the AgOx was deposited on a Si wafer. On the other hand, in Fig. 2, the film was deposited on a 12-cm polycarbonate substrate, whose surface was covered with a ZnS-SiO_2 film (20 nm). After the redox, then the AgOx film was transformed into Ag nanowires, whose diameter was also 20-30 nm as shown in Fig. 2(a). The disk was set at a disk drive unit (DDU-1000/ wavelength 635 nm/ NA 0.6) and the resolution characteristics were observed due to LSP effect. As shown in Fig. 2, the disk showed the super-resolution effect more than 200-nm marks even at 1.0 mW readout power.

3. Summary

AgOx was at first transformed into Ag nanoparticles and nanowires by dry process. The nanostrutures had a uniform diameter and are fabricated on a very wide area. The nanostructured film showed a very large optical nonlinear and super-resolution effect itself without a recording film.

Acknowledgement

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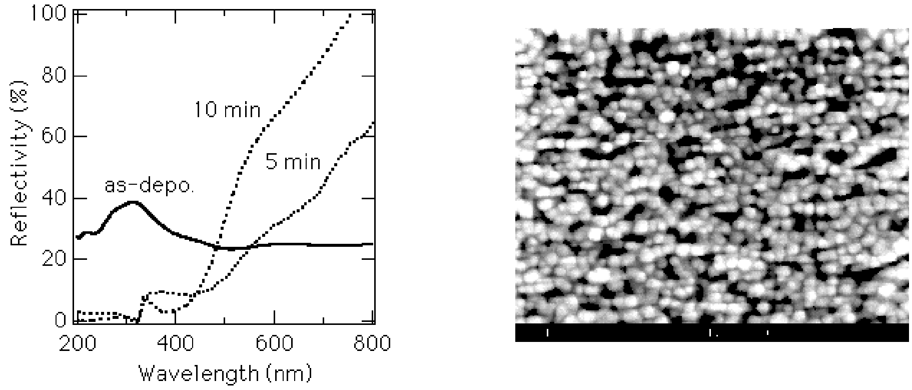
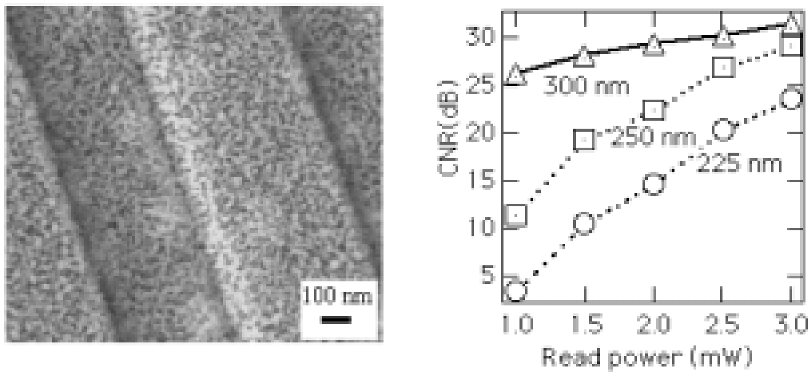


(a) Spectrum change

(b) SEM image after 5 min etching

Fig.1 Reflectivity change of the hydrogen-etched AgOx film and the SEM image. (a) spectra before and after the hydrogen-dry-etching, and (b) the deoxidized Ag particles. The deposited film thickness of the AgOx was 200 nm.



(a) TEM image of Ag nanowires

(b) Signal intensities

Fig. 2 Surface plasmon scattering from pit arrays of the Ag nano-composite thin film. (a) reflectance and (b) signal intensities from different pit arrays. The wavelength and NA of the system used was 635 nm and 0.6, respectively. The disk was rotated at a linear velocity of 9.0 m/s.

References

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