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WAVELENGTH DEPENDENCIES OF THE KERR ROTATION

AND ELLIPTICITY FOR THE MAGNETO-OPTICAL RECORDING MEDIA

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I. INTRODUCTION

Amorphous rare-earth-transition metal alloys are the conventional media of erasable optical storage. Recently there has been a flurry of activity in the area of thin film superlattice-type structures, such as Co/Pt and Co/Pd, suggesting that these materials may be used in second generation devices. In both cases, understanding the wavelength dependence of the megneto-optical Kerr rotation and ellipticity is important for the application of these media, as magneto-optical recording has the potential for higher data density at short wavelengths. Also understanding the physics of the magnetooptical interactions is dependent on the availability of accurate measurements of the spectral characteristics of the Kerr rotation and ellipticity[1,2]. In this paper we will present wavelength dependence measurements of Co/Pd and Co/Pt superlattice samples with different compositions. We will explore the relationship between the composition, and magneto-optical spectra. The induced magnetization in the Pt of Co/Pt or in the Pd of Co/Pd samples plays an important role in the magneto-optical activity[3] and it will be discussed for the samples we measured. In section II we present the experimental set up and describe the samples we used. In section III the measurement results of one Co/Pt

Appendix B

sample and a series of Co/Pd samples are discussed. Finally we present conclusions in section IV.

II. Experimental Procedure and Samples

Kerr rotation, ellipticity and reflectivity are measured simultaneously by a novel method of Kerr spectroscopy[1]. The spectral range of measuring system is from 350 nm to 1100 nm and the whole operation is fully automatic. The resolution of the system is about ± 0.005 degrees for Kerr rotation and ± 0.01 degrees for ellipticity.

The Co/Pd samples we used here are made by a sputtering process and have film thicknesses from 5.5 nm to 33 nm. They have a layer structure of 0.2 nm Co and 0.9 nm Pd. All of them are sputtered on glass substrates and have no overcoating. The measurements are done from both the film side and substrate side. All the samples have square hysteresis loops and have coercivity fields between 0.3 KOe and 2.5 KOe. A domain can be written on the 33nm thick samples. Table 1 shows the full list of all the Co/Pd samples. For the Co/Pt sample the composition of the sample is .4 nm Co and 1 nm Pt with a total thickness of 19.1 nm. It has no dielectric overcoating. The hysteresis loop is square for this sample and the coecivity field is 1.5 KOe. Good domains can be written on the sample. Disks made of this sample have a CNR value of 53.5 dB (with dielectric coating). The substrate material is glass.

III. Measurement Results and Discussions

The wavelength dependence of the Kerr rotation, ellipticity and reflectivity always consist of two contributions: one is the interference of the overcoating, the film and the substrate and the other is the electronic structure of the material. The interference effect has been known for years[4] and it plays an important role in enhancement of the magneto-optical signal in practice. To investigate the effect of the electronic structure of the materials, we need to separate these two effects. The material properties are determined by the dielectric tensor while the interference depends on the overcoating, the film and the substrate. For superlattice Co/Pt and Co/Pd samples without dielectric overcoating, it is well known that for samples thinner than 50 nm, there is enough light transmitting through the superlattice film, and the interference effect due to the substrate needs to be taken into account. The spectra for these types of samples are a combination of the substrate interference and the electronic structure of the materials. While for samples with more than 50 nm thickness, the absorption of the materials allows little or no light to transmit through the substrate. Therefore there is no interference effect from the substrate, and the spectra is determined by the electronic structure of the materials only.

The wavelength dependence curves of Kerr rotation, ellipticity and reflectivity for sample 4 of Co(2)/Pd(9) samples are shown in the Fig. 1. This sample is quite thin and the interference has a strong effect on the spectra. This is a typical figure for all the Co(2)/Pd(9) samples we measured in this paper. From this curve we can see some interesting characteristics. The reflectivity curve has a dip between 750 nm and 850 nm range while the Kerr rotation and the ellipticity curves also have a bump and dip respectively in the same range. These phenomena arise from the fact that when more light is trapped in the film, it gives more internal bouncing back and forth, and reflection and the magneto-optical Kerr rotation grows bigger. The ellipticity is quite large and it is negative for very short wavelengths and it becomes positive for longer wavelengths. The error bars on the curves are generated by standard deviation calcualation of several measurements. Fig. 2 is the Kerr rotation curves for all the 6 Co/Pd samples. There are

several points we can draw from this figure. All the samples have similar wavelength dependent shapes and the difference is that the peak Kerr rotation position shifts from about 400 nm for the 33 nm thick film to about 540 nm for the 5.5 nm thick film. This peak shift is purely interference effect and it only depends on the refractive index and absorption coefficient of the material. For 150 nm thick film, there is no interference effect andthe Kerr rotation peak is located at a wavelength less than 350 nm as shown in the Fig. 7 of Ref. 1. The Kerr rotation vs. film thickness for each wavelength can also be seen in this figure. For wavelength below 560 nm the Kerr rotation peak is at thickness of 16.5 nm (curve 3) while for wavelength above 560 nm value, the peak is at thickness of 11 nm (curve 2). The two curves in the Fig. 3 is the Kerr rotation vs. film thickness curve for wavelength of 450 nm and 750 nm respectively. The phenomenon that the peak of Kerr rotation vs. film thickness shifts to thicker film thickness as the wavelength decreases can be explained quanlitatively by interference. For a fixed refractive index n and absortion coefficient k material, as film thickness increases, the corresponding anti-reflection wavelength will decrease and the anti-reflection wavelength is also the peak Kerr rotation wavelength for the reason that the Kerr rotation is inversely proportional to the reflectivity.

Fig. 4 is the ellipticity curves for all the Co/Pd samples. For film thickness increase from 5.5 nm to 33 nm, the ellipticity curve shifts upwards with a little tilt downwards on the long wavelength side. Fig. 5 is the reflectivity curves for all the Co/Pd samples. It is clear that the reflectivity curves are similar for all the different thickness samples and the value increases as the film thickness increases. The interference effect is less pronounced in the reflectivity curves, and only the small drop of relative values on the short wavelength side gives the indication of interference effect. For applications the parameter with more direct relation to the signal-noise-ratio is called the Figure Of Merit (FOM) and it is defined as $\sqrt{R}\sqrt{\theta_k^2 + \epsilon_k^2}$. The wavelength dependence of the FOM for all the Co/Pd samples are plotted in the Fig. 6. From the curves we can see that they

all have the same shape and all the FOM peak at about the same wavelength of 480 nm. The highest FOM for all the wavelength between 350 nm and 1050 nm is the film with 16.6 nm thickness.

We also measured all the Co/Pd samples from the substrate side. The Kerr rotation, ellipticity, reflectivity, and figure of merit curves are shown in Fig. 7, 8, 9, and 10 respectively. From these figures we can see clearly that the interference effect is much smaller than the results from the film side. The reason is that from the substrate side there is a much better index match between the glass and the first layer of the M-O film than from the film side measurement case, in which the matching is between the air and the first layer of the M-O film. The Kerr rotations are higher from the substrate side due to the lower reflectivities from this side. The above differences are purely optical effect and magnetic properties are the same.

Fig. 11 is the Kerr rotation, ellipticity and reflectivity measurement for the Co/Pt sample. Compared with the Co/Pd smples, the Kerr rotation wavelength dependence shape is quite different, which indicates the different inter-layer interactions for these two types of materials. The Kerr rotation values of the Co/Pt sample are much larger than the Co/Pd samples with the same Co content of Co/Pd sample 6. It is very interesting to notice that the wavelength dependence of reflectivity is very similar for the Co/Pt and Co/Pd samples, which indicates that their refractive index and absorption coefficients have similar wavelength dependence.

IV. Conclusions

The wavelength dependence of Kerr rotation, ellipticity and reflectivity for Co/Pd and Co/Pt superlattice samples are measured with a new technique. The series results of differernt thickness of Co/Pd samples clearly show the interference effect on the spectra.

The clear understanding of ~~of~~ the interference effect cleared the way for further investigating the material properties. By getting the wavelength dependence of the refractive index and absorption coefficient and together with the Kerr rotation and ellipticity results, the dielectric tensor can be calculated and the physical properties can be studied directly. Comparing the spectral dependence of the two Co/Pd samples and the Co/Pt samples, we can see that the interactions between the Co layers and the Pd layers are very strong and the magneto-optical properties for the superlattice samples are determined by these inter-layer interactions.

References

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2.   D. Weller and W. Reim, Appl. Physics A, <u>49</u>, 599 (1989)

3.   E. R. Moog, J. Zak, and S. D. Bader, to appear in J. Appl. Phys. (1991)

4.   G. A. N. Connell, Appl. Phys. Lett., <u>40</u>(3), 212 (1982)

Table 1

Sample	1	2	3	4	5	6
Composition Co/Pd	2/9	2/9	2/9	2/9	2/9	2/9
Number of Layers	5	10	15	20	25	30
Total Thickness (nm)	5.5	11	16.5	22	27.5	33

Co(2)/Pd(9), 22 nm

Kerr Rotation
– – – Ellipticity
• • • Reflectivity
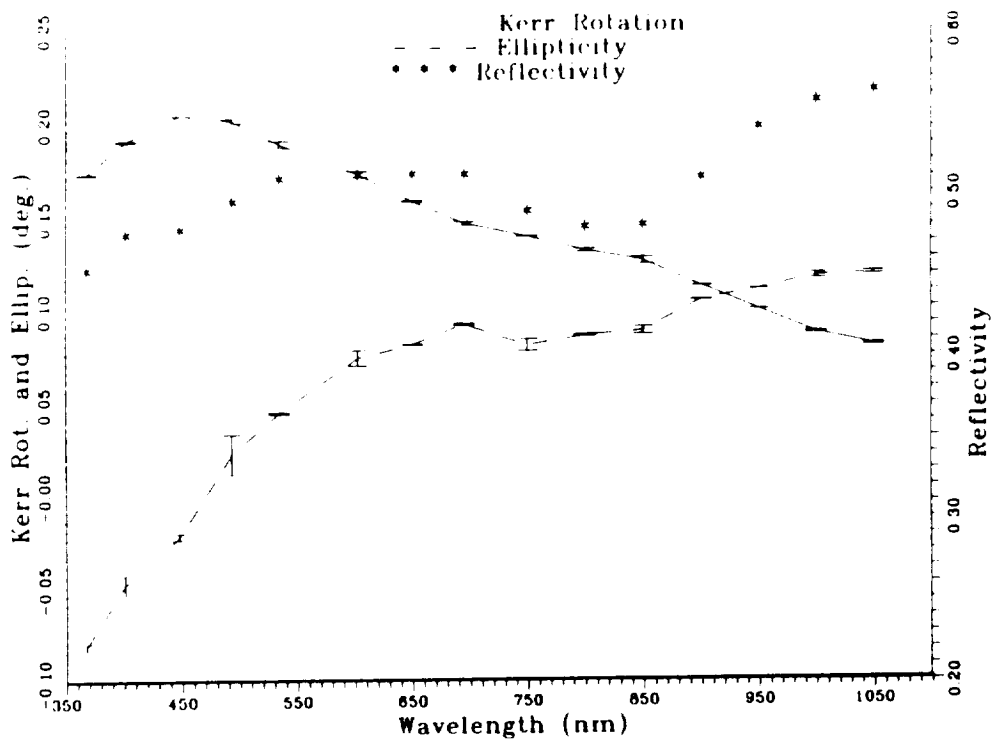
Figure 1. Wavelength dependence of Kerr rotations, ellipticity and reflectivity for Co/Pd sample 4. Solid line is Kerr rotation curve, dashed line is the ellipticity curve, and the "" is the reflectivity curve.

Co(2)/Pd(9), FILM SIDE

1 – 5.5 nm
2 – 11 nm
3 – 16.5 nm
4 – 22 nm
5 – 27.5 nm
6 – 33 nm
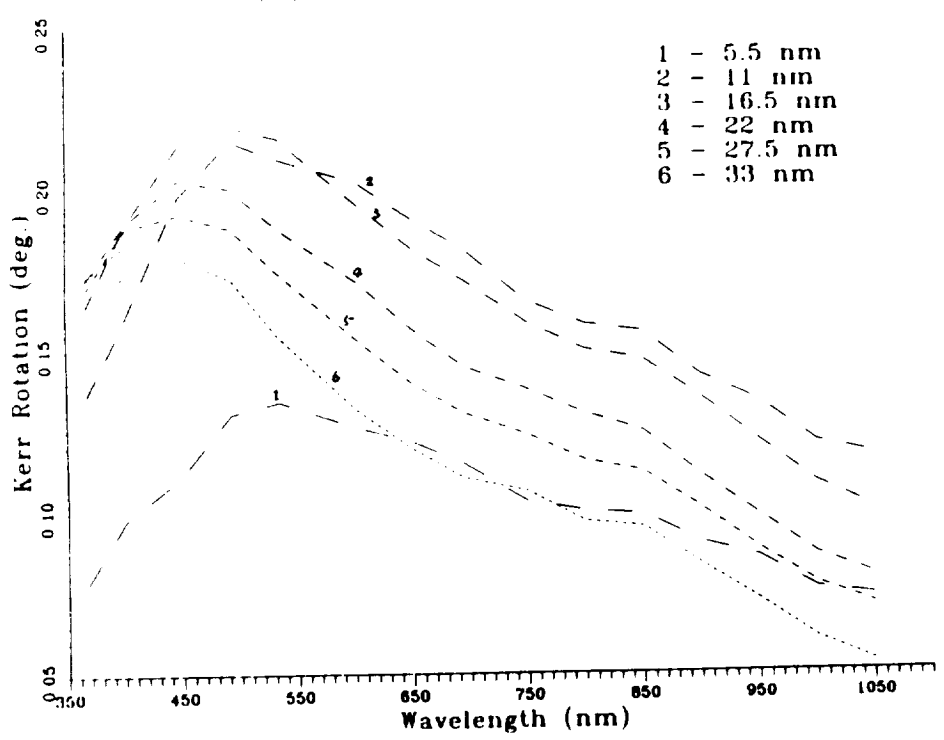
Figure 2. Wavelength dependence of Kerr rotations for the 6 Co/Pd samples, measured from the film side.

Appendix B
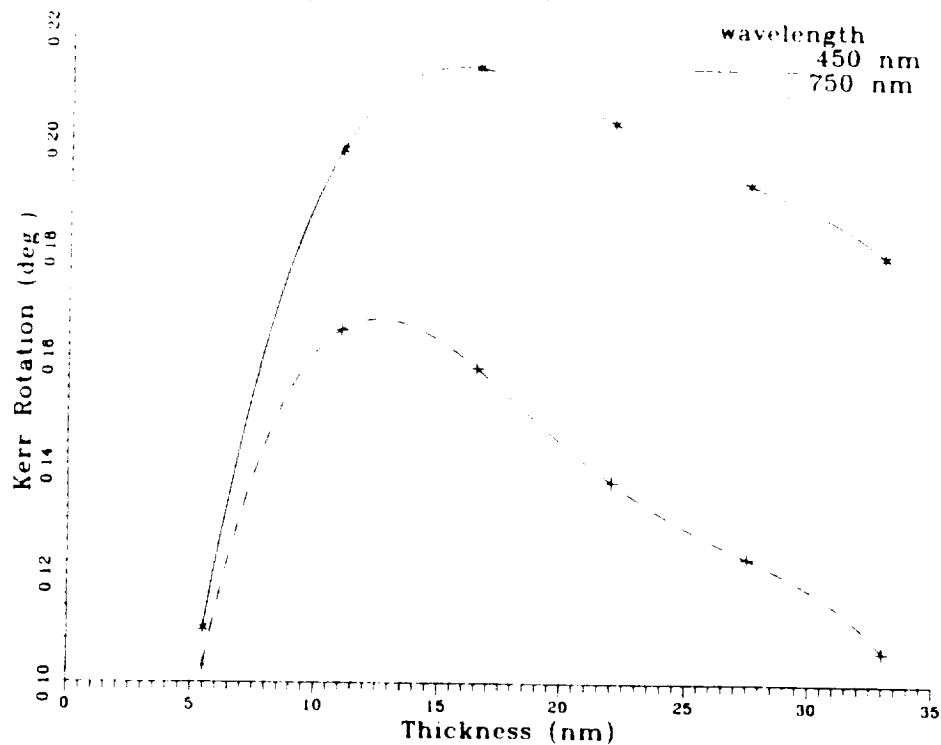
Co(2)/Pd(9). FILM SIDE

Figure 3. Thickness dependence of Co/Pd samples. Solid line is for 450 nm wavelength and dashed line is for the 750 nm wavelength.

Co(2)/Pd(9). FILM SIDE
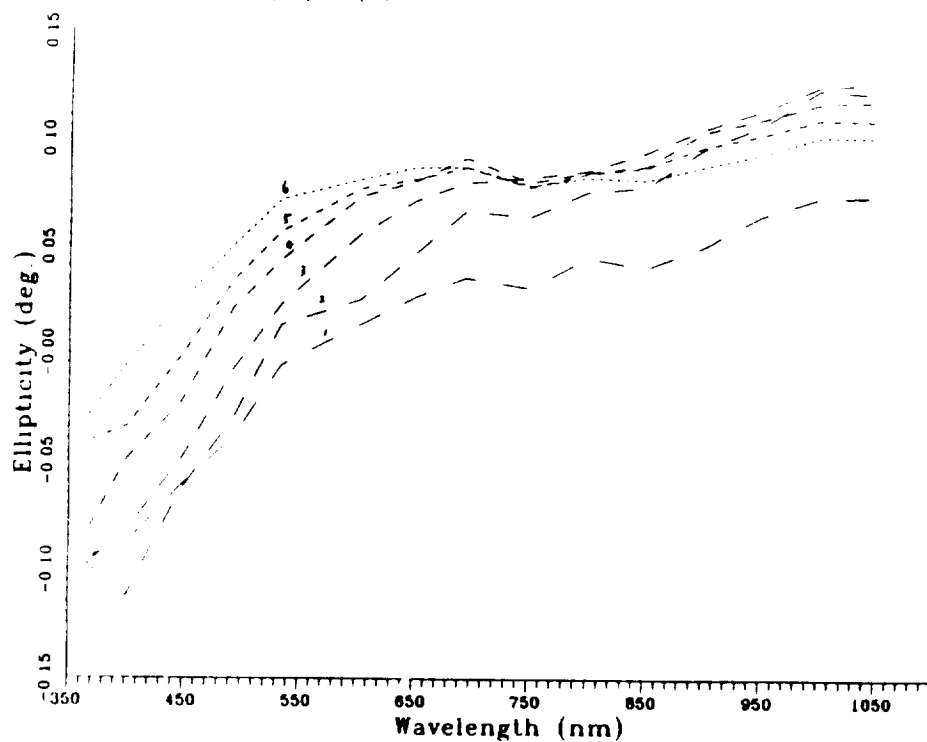
Figure 4. Wavelength dependence of ellipticity for the 6 Co/Pd samples, measured from the film side.
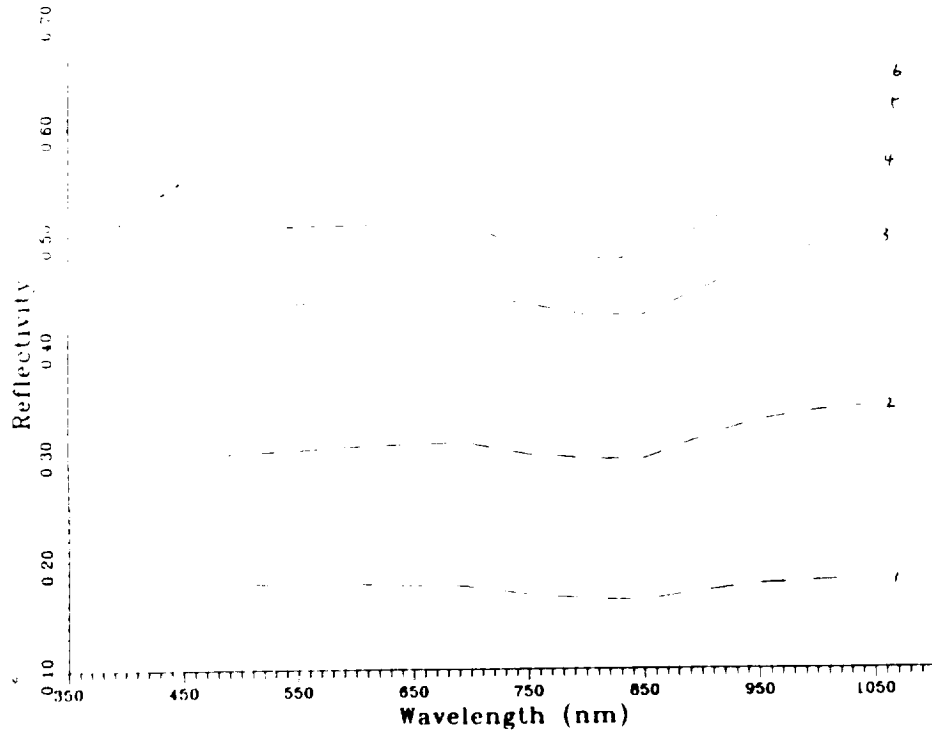
Co(2)/Pd(9), FILM SIDE

Figure 5. Wavelength dependence of reflectivity for the 6 Co/Pd samples, measured from the film side.
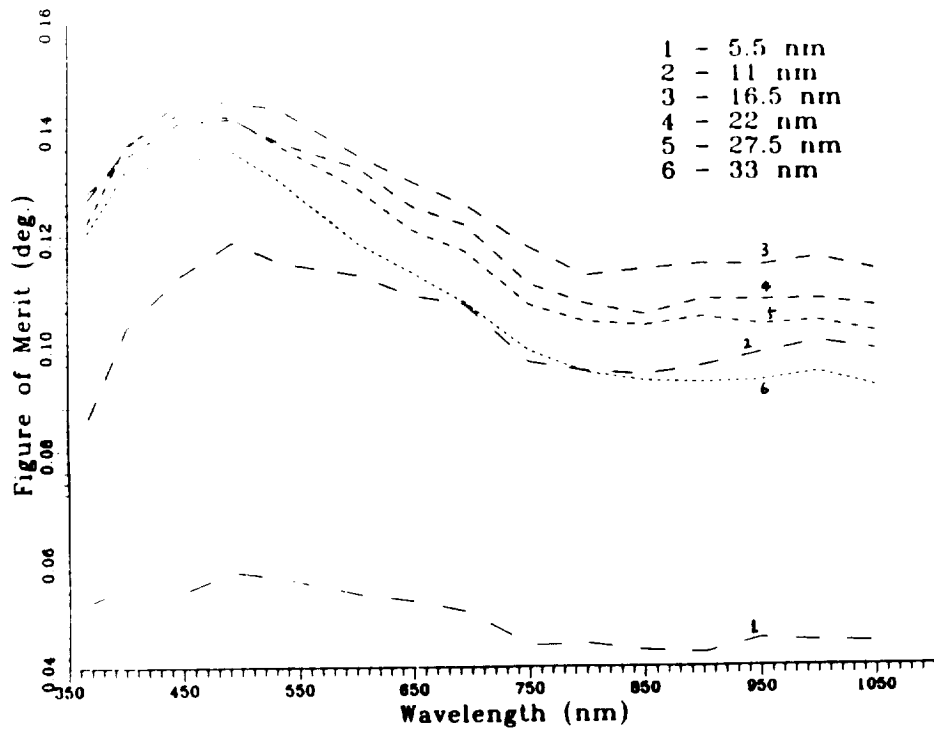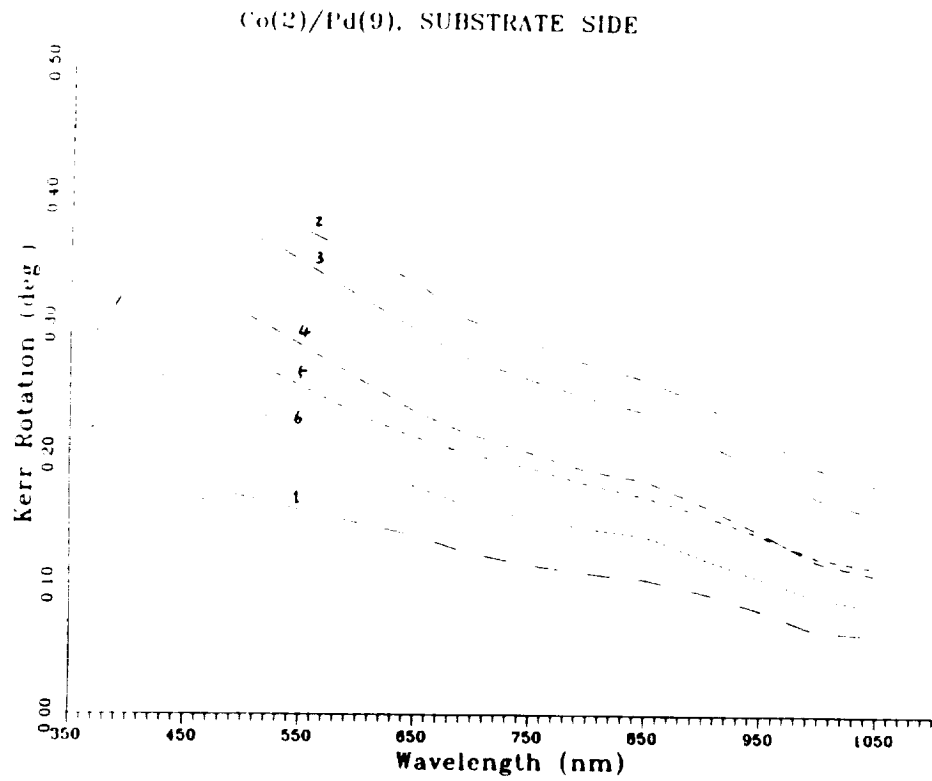
Co(2)/Pd(9), FILM SIDE

1 - 5.5 nm
2 - 11 nm
3 - 16.5 nm
4 - 22 nm
5 - 27.5 nm
6 - 33 nm

Figure 6. Wavelength dependence of figure of merit for the 6 Co/Pd samples, measured from the film side.

Co(2)/Pd(9), SUBSTRATE SIDE

Figure 7. Wavelength dependence of Kerr rotation for the 6 Co/Pd samples, measured from the substrate side.

Co(2)/Pd(9), SUBSTRATE SIDE
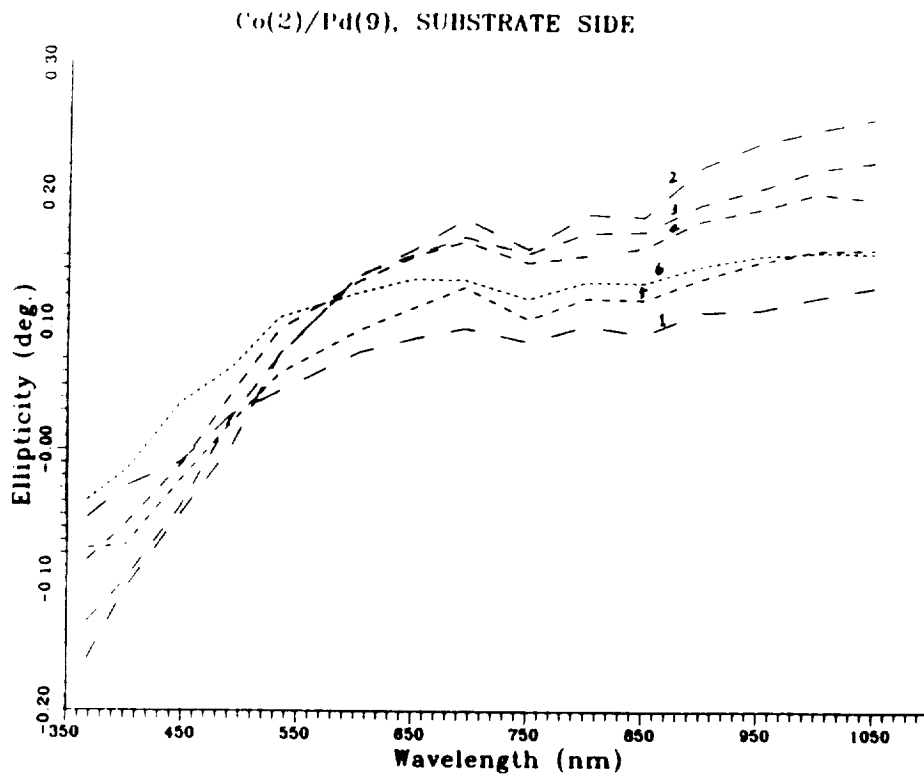
Figure 8. Wavelength dependence of ellipticity for the 6 Co/Pd samples, measured from the substrate side.

Co(2)/Pd(9), SUBSTRATE SIDE
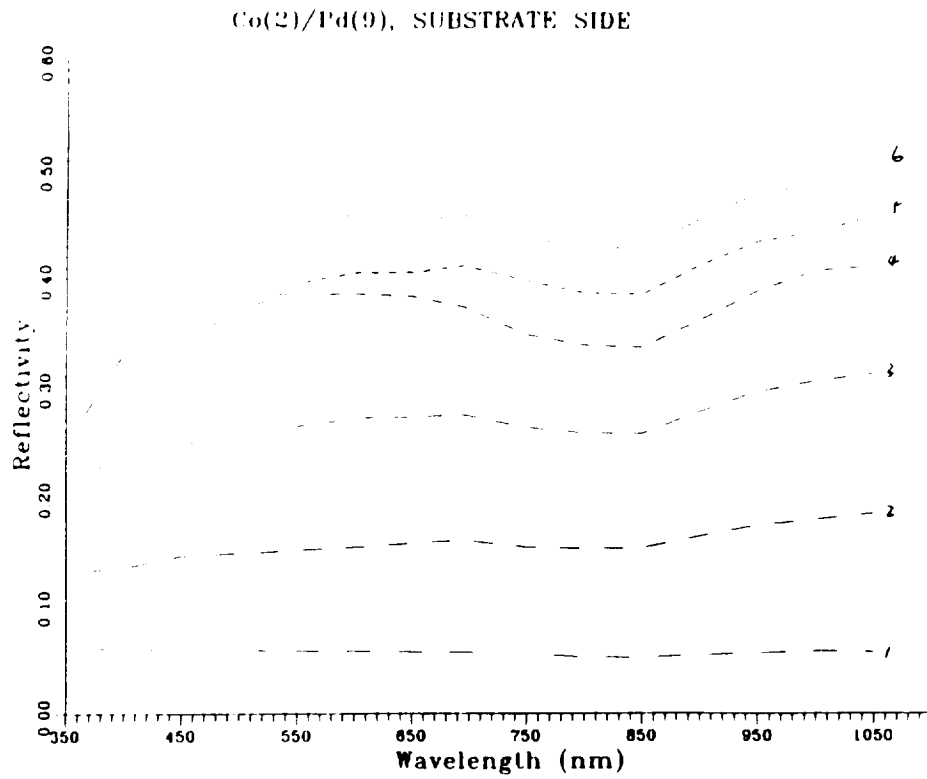

Figure 9. Wavelength dependence of reflectivity for the 6 Co/Pd samples, measured from the substrate side.

Co(2)/Pd(9), SUBSTRATE SIDE
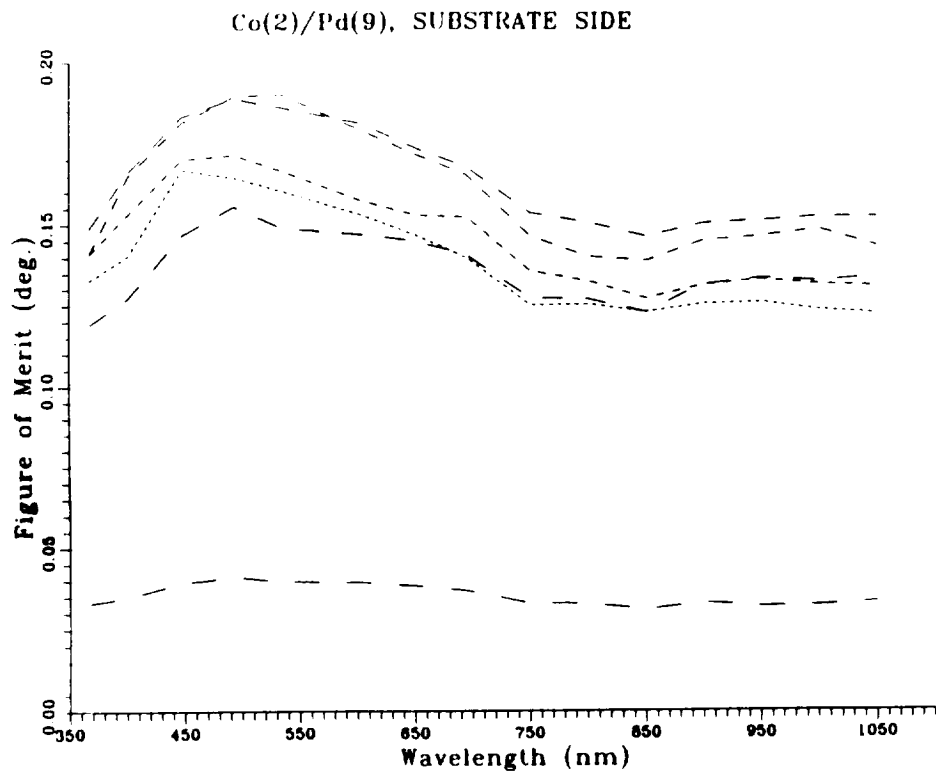

Figure 10. Wavelength dependence of figure of merit for the 6 Co/Pd samples, measured from the substrate side.
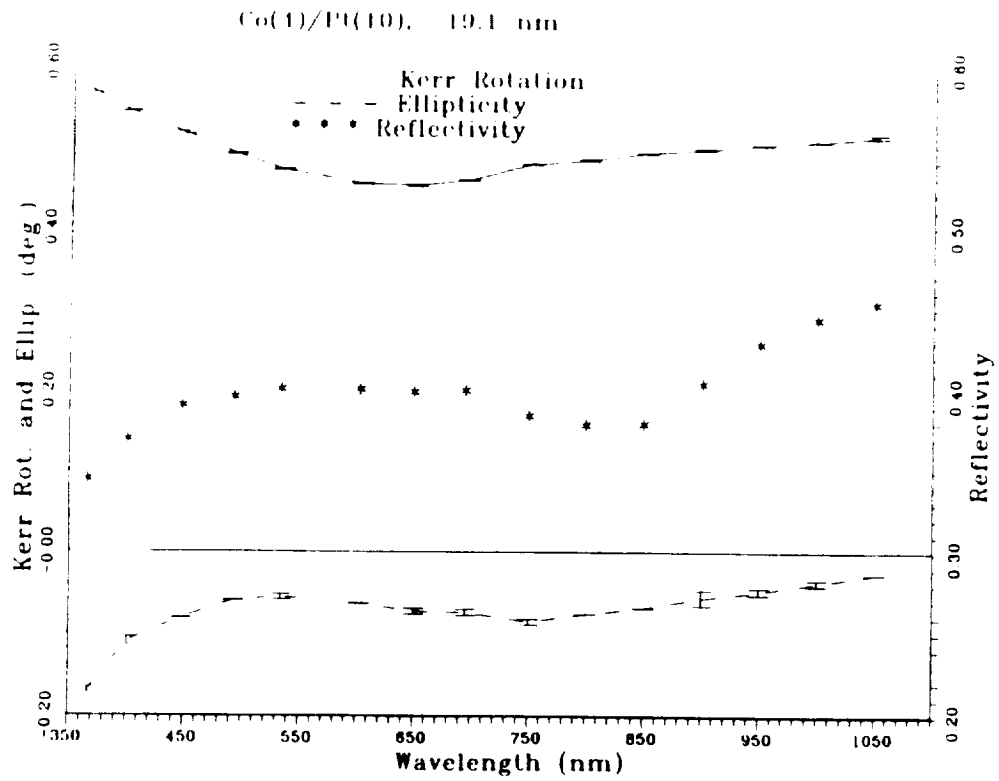
Appendix B

Figure 11. Wavelength dependence of Kerr rotation, ellipticity and reflectivity for Co/Pt sample. Solid line is Kerr rotation curve, dashed line is the ellipticity curve, and the "" is the reflectivity curve.