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STRUCTURE AND SURFACE MORPHOLOGY OF CoCrTa THIN FILMS DEPOSITED AT LOW SPUTTERING PRESSURE

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ABSTRACT

Thin films of $Co_{78.6}Cr_{18.9}Ta_{2.5}$ were deposited on ultra-flat and smooth glass disk substrates. The structure and surface morphology of the films were studied by optical and electron (scanning and transmission) microscopy. The combination of the inertness of the substrate and the low deposition pressure used lead to the development of isolated grains. The surface morphology of the films remained smooth and fairly flat with average surface roughness of 1.64*nm*. The sample deposited at the highest pressure of 1.2 x 10^{-2}*mbar* showed the greatest deviation of the roughness value from Gaussian (normal) distribution of the glass disk substrate. The low surface roughness values are indicative of good potential of the use of the technique in the production of media that could employ very low flying heights in magnetic recording.

Keywords: Surface morphology, CoCrTa, and Sputtering pressure.

INTRODUCTION

Nano-crystallite systems have stimulated great interest in both the scientific community and industry for their prominent roles in the core technologies of chemical catalysis and magnetic recording systems[1, 2]. The properties thin films are considerably influenced by their structures. Not only does the method used in the production of the films govern the structure, small changes in a production conduction often leads to large changes in the structure and the underlying properties[3]. In alloy magnetic thin films, the segregation of non-(or less) magnetic elements to grain boundaries has been shown to enhance the magnetic properties of the films[4, 5] and also to significantly affect the signal-to-noise ratio performance of the films in information storage/retrieval[5, 8]. The presence of nanostructures between the grains of the film may hamper the exchange interactions between adjacent grains but may leads to enhanced dipolar interactions across the grains. Magnetically isolated grains structures were obtained by deposition alloy films at elevated temperatures and at high deposition pressures[5, 7]. For high density information recording, where these interactions actually count, microscopically flat and smooth surfaces are desired to allow for the use of very low flying height[5]. The use of high deposition pressure in the fabrication of films for this purpose may not be a wise choice.

In this work, thin films with nanostructured grains that are isolated from one another by voids have been deposited by a combination of ultra-flat and inert substrate and the use of low sputtering pressure. The combination of the inertness and smoothness of the substrate has made the formation of isolated grain possible at pressures much lower that reported. The structure and surface morphology of these films are reported here.

METHOD

Thin films of $Co_{78.6}Cr_{18.9}Ta_{2.5}$ were deposited from solid CoCr alloy and Ta targets onto Nippon glass disk substrates by sputtering process achieved by the use of (*d.c.*) Triode Sputter System (L.M. Simard Triode—Magnetron source) with no substrate bias or heat treatment. Background pressure in the chamber before deposition was $1.0x10^{-6}$ *mbar* or better. Argon gas sputtering pressure was varied from 2.0–12.0 x 10^{-3}*mbar*. Specimen composition and thickness were determined on Jeol scanning electron microscope using the energy dispersive analysis of x-ray spectra (EDAX). The microstructure of the films were observed on a Jeol transmission electron microscope operating at 200 kV while the surface morphology and grain structure were studied by a combination of optical and scanning tunneling electron microscopy.

Table 1 show some of the coating parameters of the samples studied. The samples have an average thickness of 40.5 ± 2.5*nm*.

Table1: Coating parameters of samples

Sample	Thickness (nm)	Ar gas pressure (x 10^{-3} *mbar*)
A1	41	2.0
A2	39	4.0
A3	42	6.0
A4	40	8.0
A5	43	10.0
A6	38	12.0

RESULTS AND DISCUSSION

The microstructure of the some of the samples studied is shown in figures 1 to 3. The sample deposited at an argon gas pressure of 4.0 x 10^{-3} mbar (A2) has a uniform contrast both in bright and dark field micrographs, Figures 1a and 2a. This is characteristics of amorphous materials. Even though crystalline, the microstructural units could be seen to quite small, continuous and very much connected. Samples A1 and A3 deposited at 2.0 and 6.0 x 10^{-3}*mbar* share similar microstructure and grain character.

Figure 1a

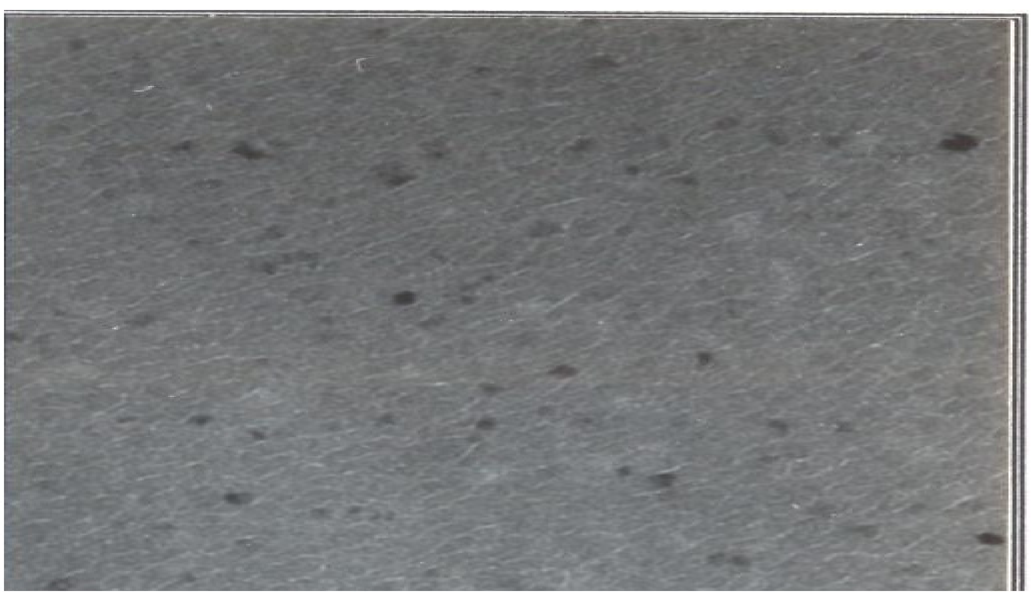

Figure 1b

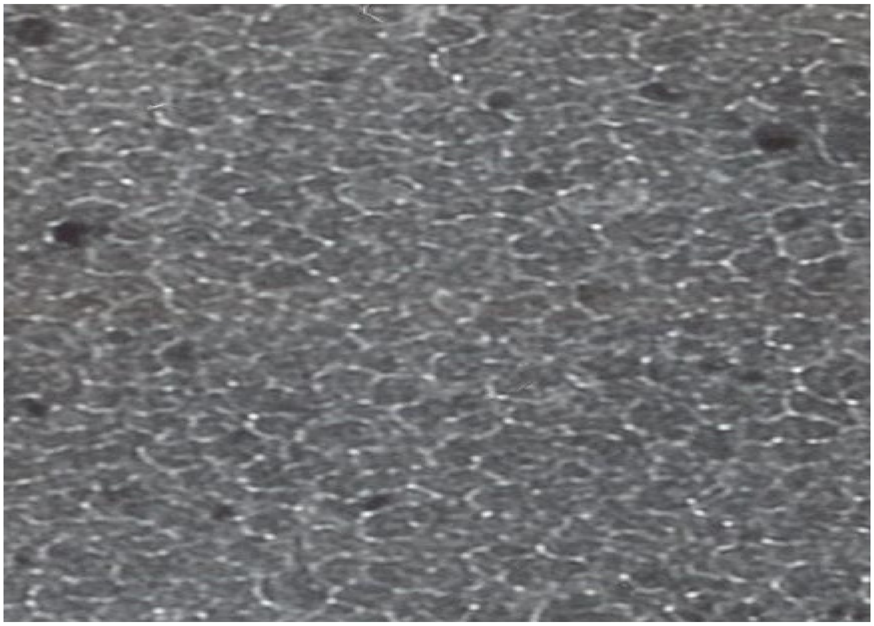

Figure 1c

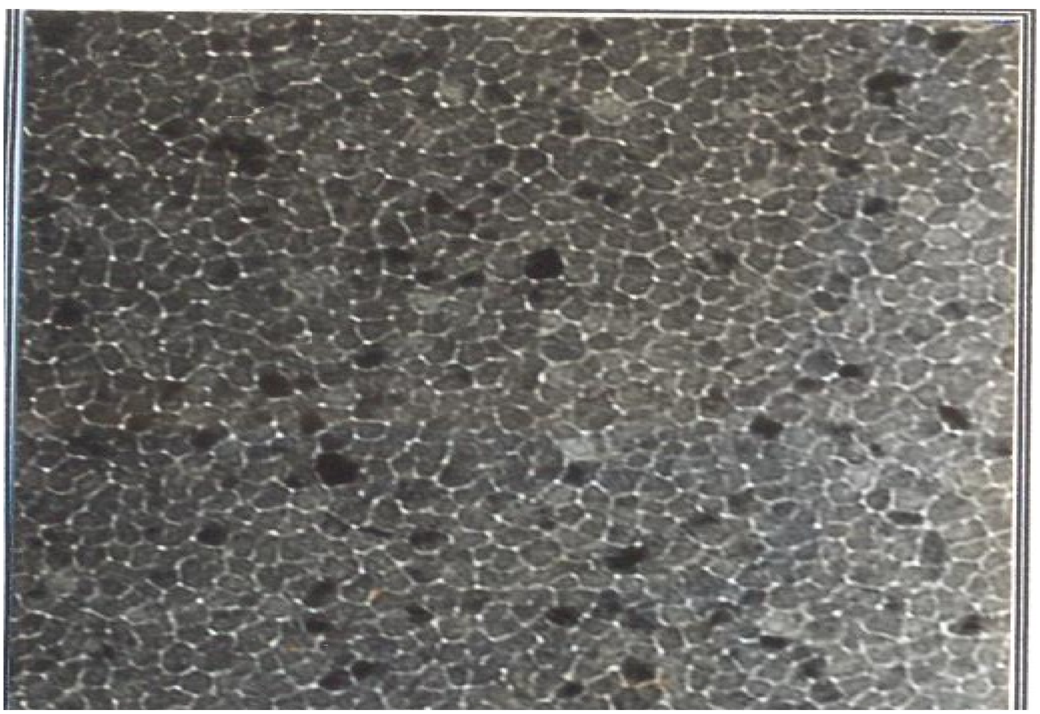

Figure 1d

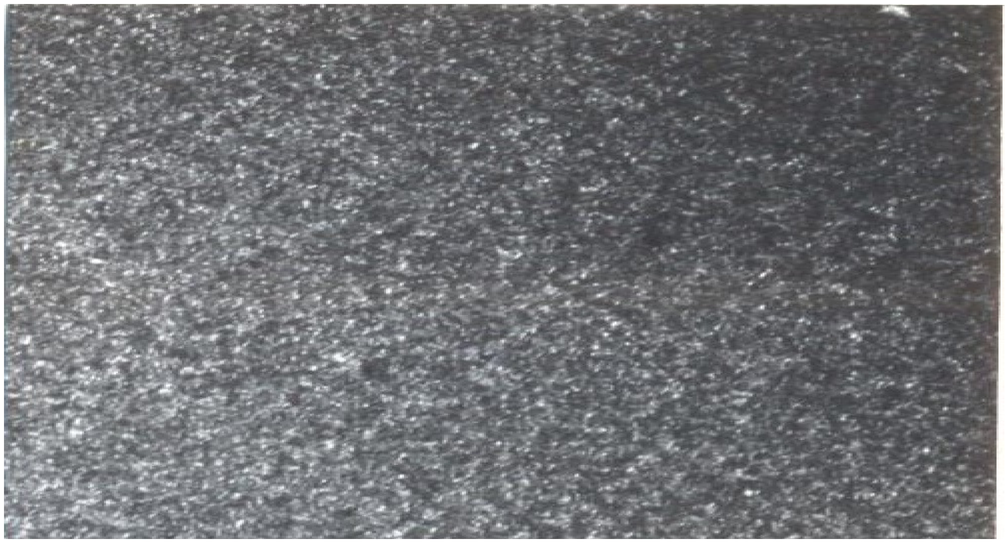

Figure 2a

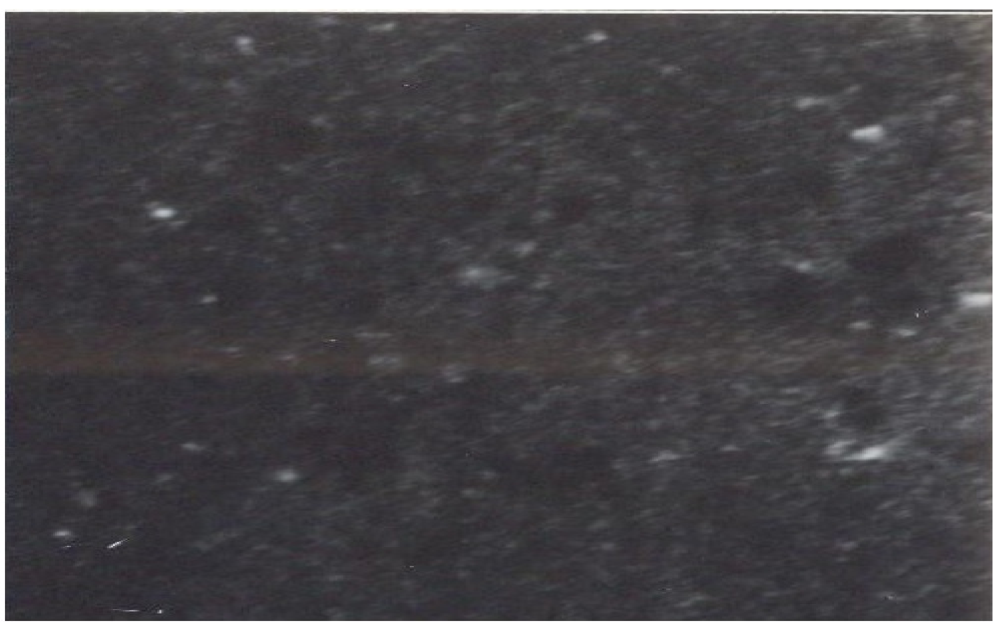

Figure 2b

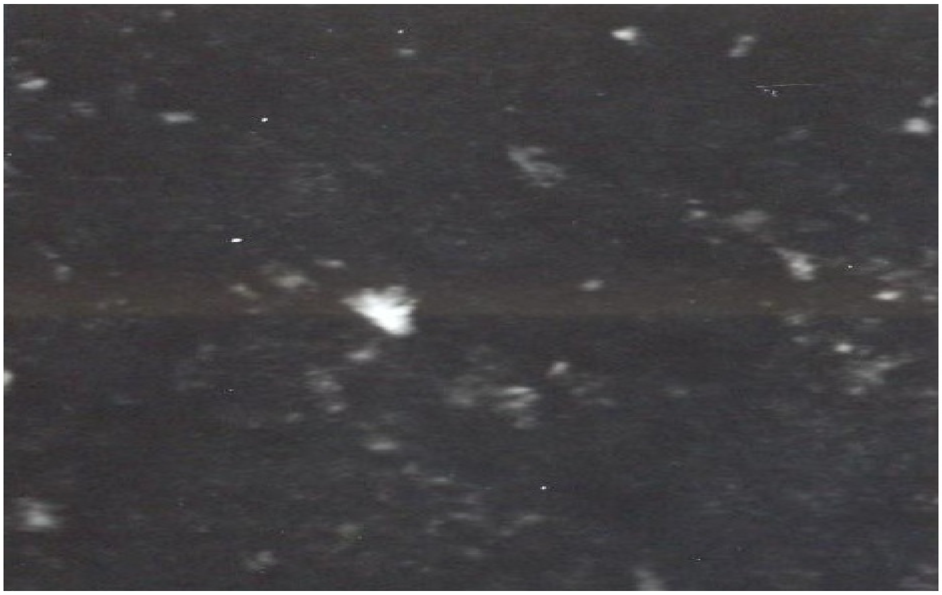

Figure 2c

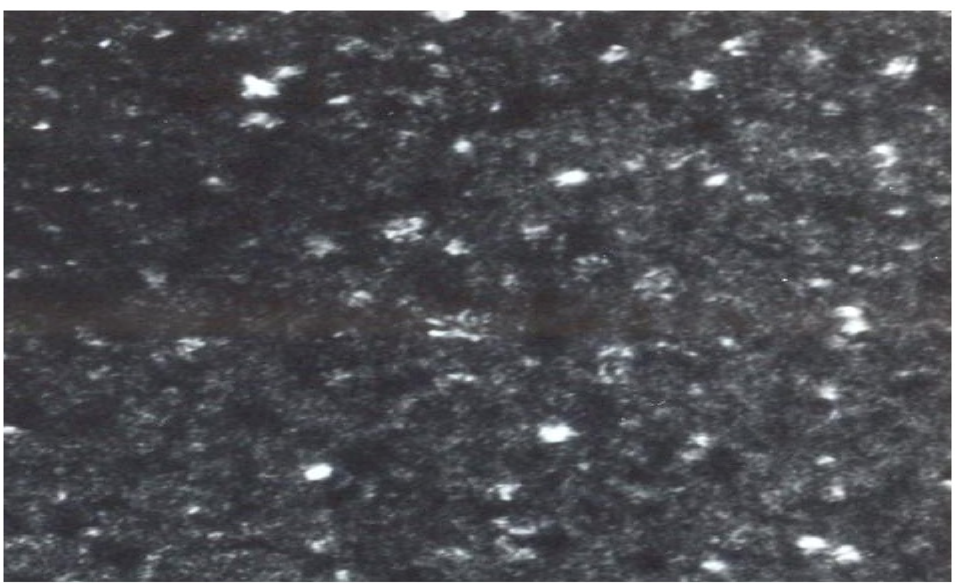

Figure 2d

Figure 3a

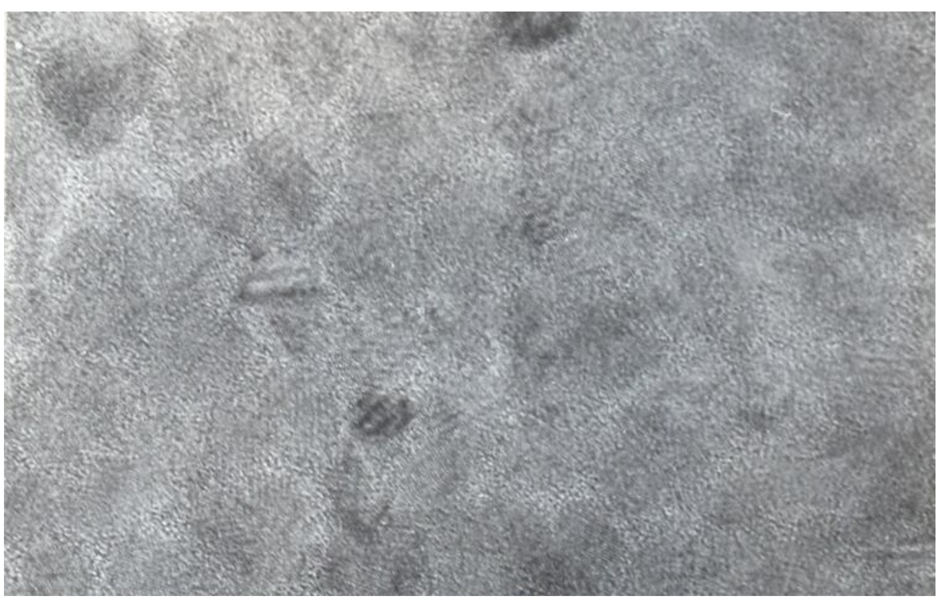

Figure 3b

The sample deposited at a pressure of 8.0 x 10^{-3}mbar (A4) could be seen in figures 1b and 2b (bright and dark field images respectively) to have larger and partially isolated microstructural units. Sample A6 has the strongest crystallinity showing the best grain contrast in both the bright and dark field images, figures 1d and 2 d respectively. The grains could be seen to be standing by themselves and completely isolated from one another. Sample A5 (deposited with a gas pressure of 1.0 x 10^{-2}mbar) could be seen to have relatively larger grains (figures 1c and 2c) compared to this sample with the best crystallinity. Measurement of the inter-granular separation by travelling microscope showed a constant increase, from about a nanometer for sample A4 to about 1.5 *nm* for sample A6.

High resolution transmission electron micrographs, shown in fig 3, indicate a near complete absence of any long range order in sample A2. From the dark field image of the sample, Figure 2a, very fine micro-crystallites might be expected but the high resolution micrograph does not show any form of order. The dark field image has been formed, as is always the case, from a diffracted beam selected from the spots (in this case rings) of the selected area diffraction pattern (SAD). In this respect, the dark field image show grains that are similarly oriented in the same contrast (bright) in the overall dark contrast of the image. The high resolution image was formed from the central transmitted electron beam and therefore aggregates all orientations. The contrast very minute grains may show could be lost in the overall bright contrast of the image.

Sample A6 with the best crystallinity observed could be seen in figure 3b. The pronounced grain separation could also be confirmed. From the orientational distribution of the (002) lattice fringes among the grains of the film, this figure showed the sample to have almost isotropic distribution of the crystallographic (hcp) c-axis within the plane of the film.

The micrographs of the surface morphology of some of the films studied are shown in figures 4 and 5. The scanning tunneling micrographs, figure 4, confirmed the structures observed in the transmission images – the grain structures improve with increase in deposition pressure and grain isolation is also seen to be enhanced.

Surface roughness is seen in figure 5 to increase with increasing deposition pressure but maintain very low values with the largest 1.64 nm for the sample deposited at the highest pressure (sample A6). Moreover, this sample also shows the strongest deviation from normal distribution of the roughness that the glass disk substrate shows in figures 6a and 6b.

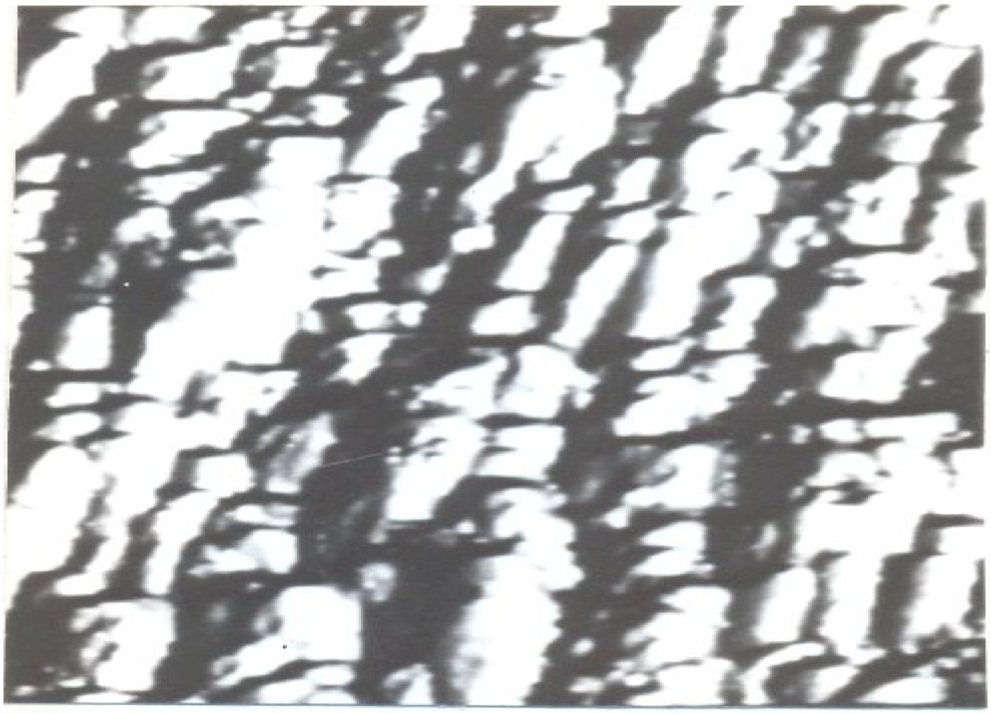

Figure 4a

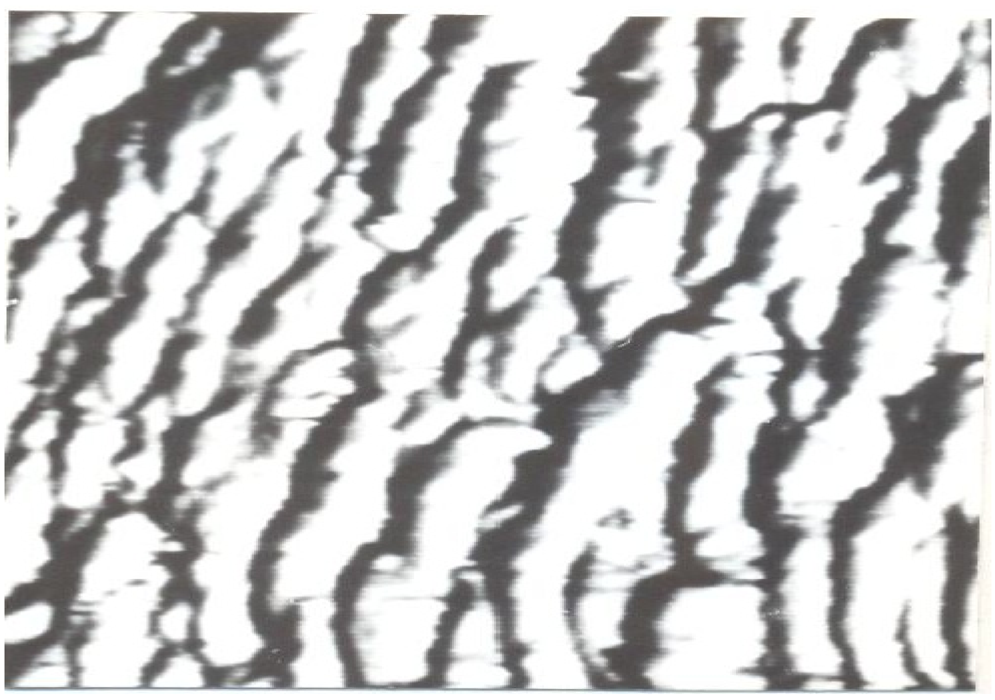

Figure 4b

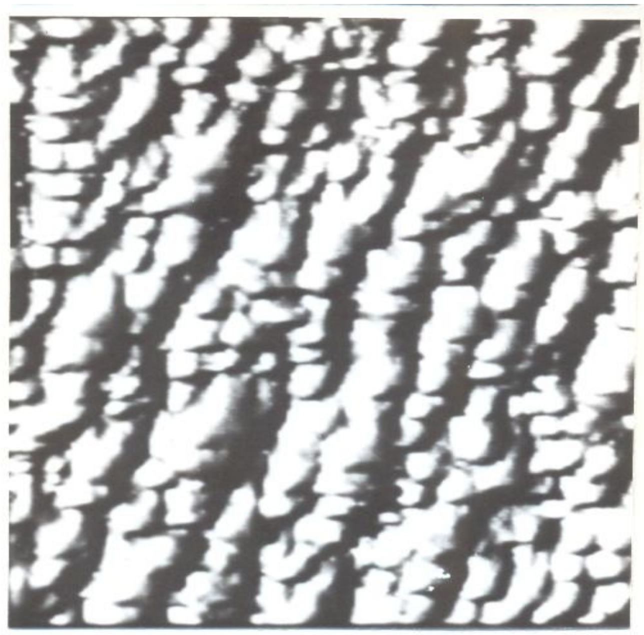

Figure 4c

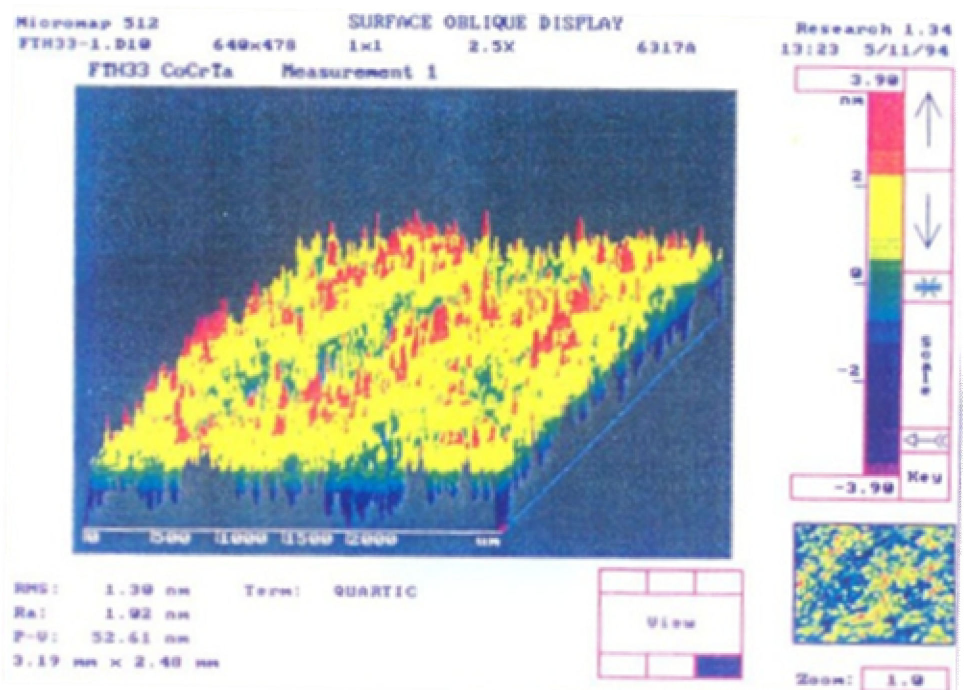

Figure 5a

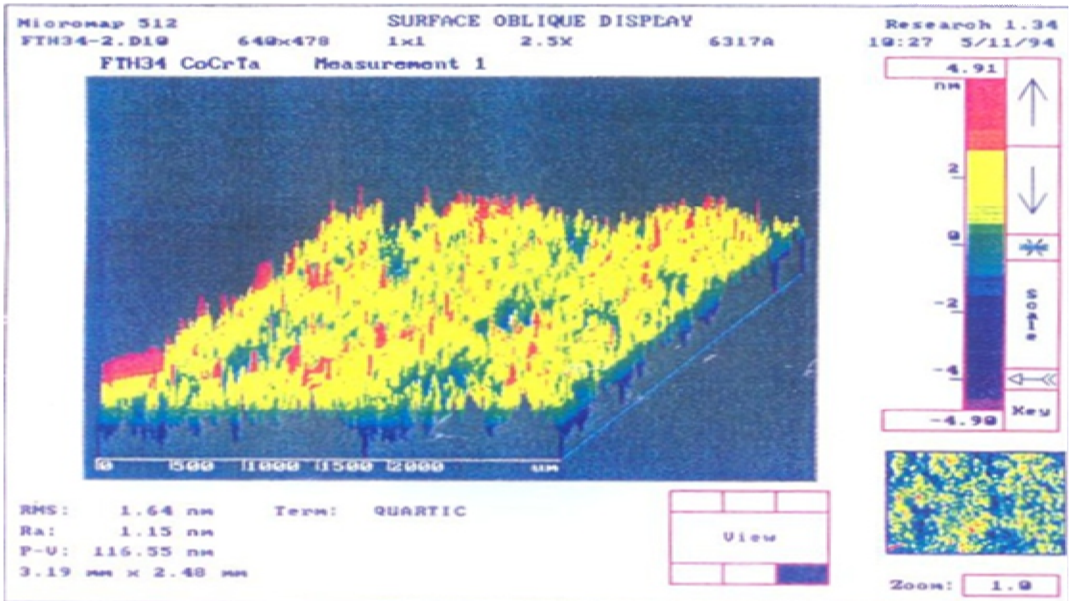

Figure 5b

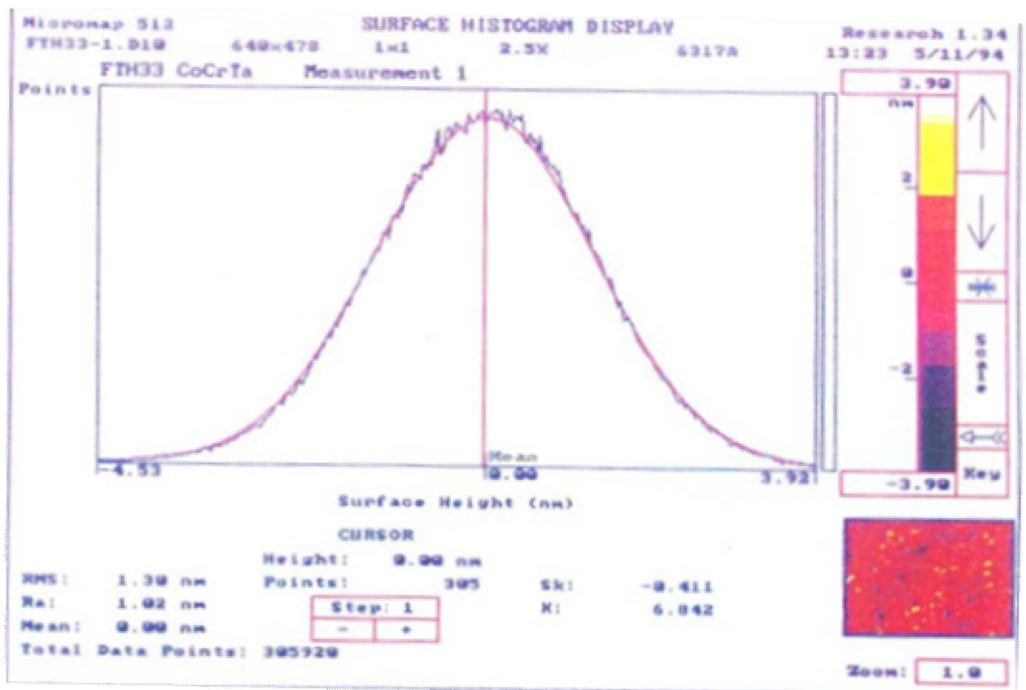

Figure 5c

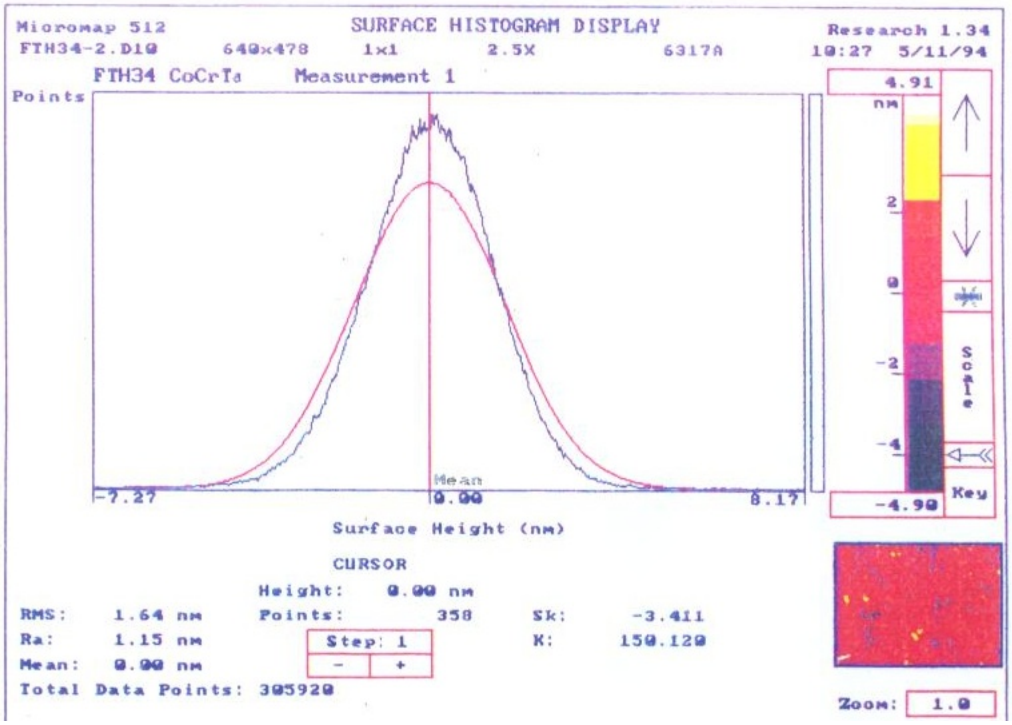

Figure 5d

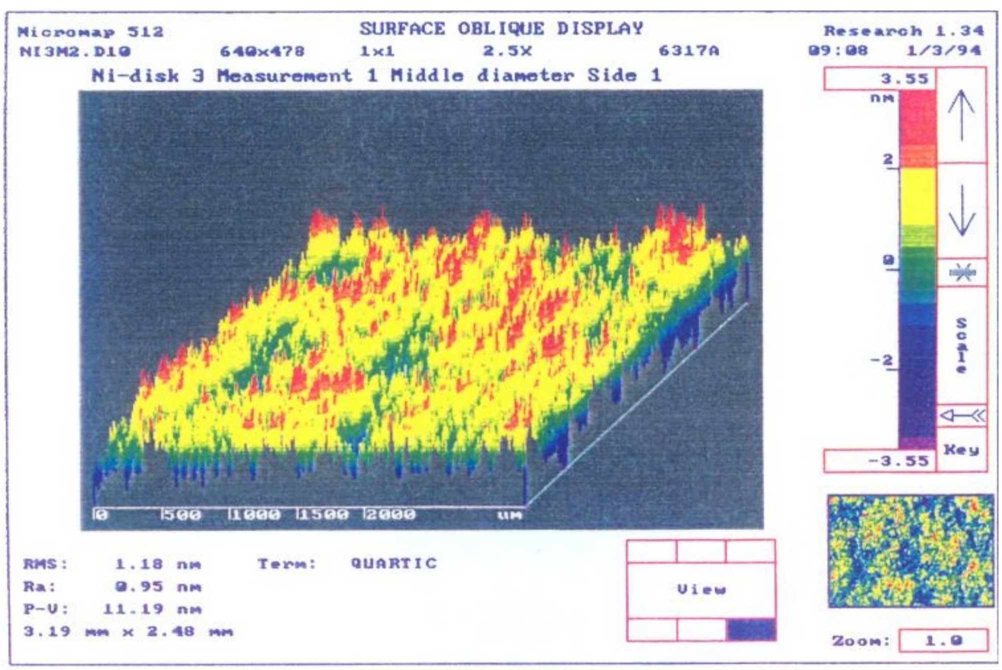

Figure 6a

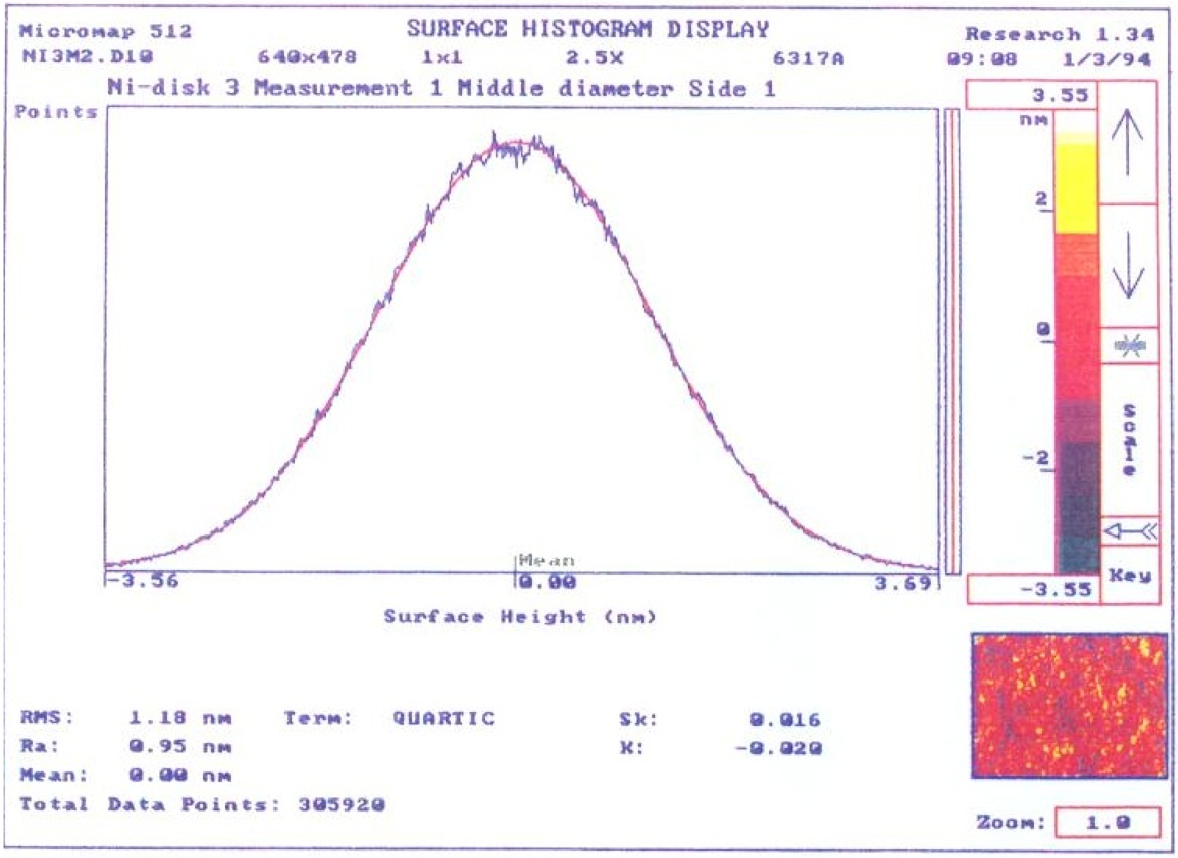

Figure 6b

CONCLUSION

The combination of the smoothness and inertness of Nippon glass disk substrates has been exploited in growing films having zone 1 structure of Thornton's[9] microstructure model at much lower sputtering gas pressure. The films, while showing good isolation of the 'magnetic' grains achieved by the growth method, also show excellent surfaces with very low roughness values and good uniformity. These conditions are ideal for the use of very low recording flying heights, getting 'cleaner' transitions and may lead to significant reduction of media noise.

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