Pulsed-Thermal-Processing of FePt Thin Films

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Introduction:

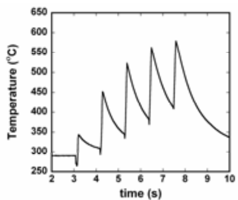
The $L1_0$ phase of FePt is a candidate material for next-generation ultra-high areal storage densities. This material's high K_u makes its magnetization direction thermally stable for achieving small bit dimensions for perpendicular storage applications. Upon sputter deposition, FePt adopts a solid solution face-centered-cubic phase, denoted as A1. A subsequent anneal near 600°C will chemically order the FePt film into the $L1_0$ tetragonal crystal structure with its superior magnetic recording properties. Detrimental grain growth accompanies the annealing process, which results in a loss of the narrow granular distribution required for uniform, ultra-high bit densities. We report the use of **Pulsed Thermal Processing** (PTP) to phase transform 20 nm and 100 nm FePt thin films with minimal grain growth.

Experimental Background:

Temperature calibrations were performed using an Infrared (IR) camera fitted with an NDII and ADA polarized filter. The camera captured the reflected specular radiation from the film surface during processing at a shutter speed of 400 μs and a frame rate of 60 frames/s. A type K thermocouple, attached to the back of a 100 nm FePt test film substrate with ceramic bonding agent, was used to calibrate surface temperature of the film. For the temperature calibrations, the test film was slowly annealed under the lamp to ensure thermal equilibrium of the film surface with the back of the substrate. The emitted specular radiation from the surface of the film was then captured by the IR camera and correlated to that particular steady-state temperature value. By collecting a range of temperatures from the test film during the calibration procedure, the relationship between specimen temperature and emitted IR signal intensity during PTP was determined.

As can be seen in the PTP annealing curve, the peak temperature increased with each pulse; consequently, we have reported the average peak temperature and the max peak temperature for each experiment. Future work is to optimize the PTP so that peak temperatures are consistent.

PTP Annealing Curve



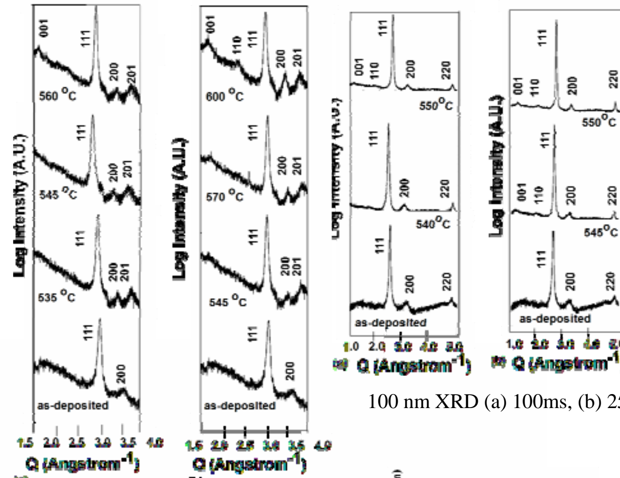
Experimental Matrix

Experiment	Peak 1 (°C)	Peak 2 (°C)	Peak 3 (°C)	Peak 4 (°C)	Peak 5 (°C)	Mean Peak Temp (°C)	Max Peak Temp (°C)
1	75.61	137.02	175.10	206.62	235.72	119.07	351.36
2	109.03	194.22	269.18	335.28	393.97	181.94	376.65
3	59.05	198.05	302.78	390.38	467.07	190.65	338.34
4	71.76	166.58	226.07	270.67	309.38	147.81	348.37
5	122.86	286.09	391.97	464.78	539.34	254.14	386.72
6	133.67	349.04	455.10	537.71	623.05	296.30	394.43

Vortek Plasma Arc Lamp

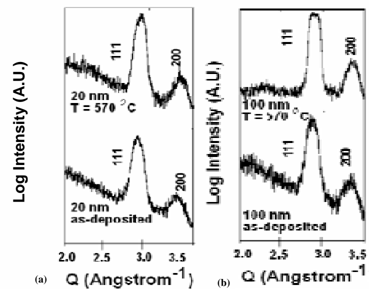
Phase Identification and Microstructural Analysis:

XRD patterns shown below for 20 nm and 100 nm thick specimens processed with pulse widths of 100 ms and 250 ms. The phase transformation from A1 to $L1_0$ was observed from the evolution of the (001), {200}, {220}, and {201} superlattice reflections. By tilting the specimen ~90° to the incident beam, in-plane of grain size can be determined by the Scherrer equation. The in-plane scans, illustrated below, show little change in the breadth of the FWHM of the {111} reflection, indicating little to no lateral grain growth.

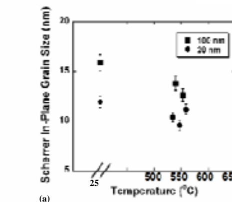


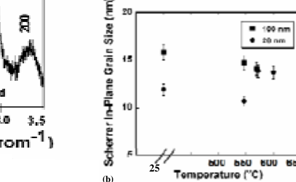
20 nm XRD (a) 100ms, (b) 250 ms

100 nm XRD (a) 100ms, (b) 250 ms



In-plane XRD (a) 20 nm (b) 100 nm

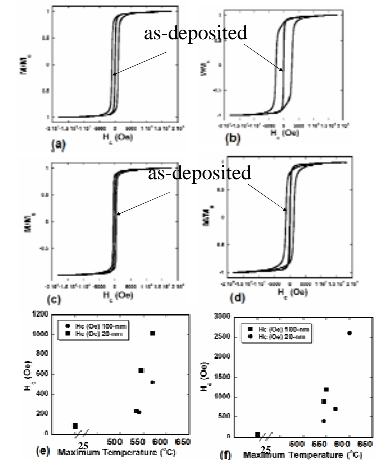




In-plane Scherrer Analysis (a) 100ms (b) 250 ms

Magnetic Characterization:

In all the films, the coercivity increased with processing temperature and longer pulse widths. Longer pulse widths produced higher coercivities for equivalent film thickness, suggesting more growth of the $L1_0$ phase with longer times.



20 nm (a) 100 ms, (b) 250 ms

100 nm (c) 100 ms, (d) 250 ms

(e) 100 ms H_c, (f) 250 ms H_c

Conclusions:

- The PTP technique successfully phase transformed FePt thin films
- During pulsing, the peak temperature increased with each subsequent pulse over the pulsed cycle
- Peak temperatures should be optimized to ensure consistent film temperature throughout the pulsed cycle
- TEM of microstructures are needed to confirm Scherrer grain size estimates