

Magneto-Optical Analysis of Magnetic Domains and Walls under varying Fields on GOES processed with various Pulsed Lasers



O. Maloberti^{a,b,*}, P. Dasonvalle^a, M. Nesser^a, J. Dupuy^c, S. Panier^b, P. Dupont^a



26th Conference on Soft Magnetic Materials - SMM

CONTEXT – PULSED LASER SURFACE PROCESSES – MAGNETIC DOMAINS REFINEMENT

1st analysis = Pulse Durations (LPL, SPL or USPL) **2nd process parameters: Energy and Peak Power** **3rd process parameter: Laser line spacing d**

affected zone

SPL IRRADIATION-SCRIBING vs USPL ABLATION

Laser process and affected zones

EXPERIMENTS, SPECIMENS AND IMAGING TECHNIQUES

EXPERIMENT 1: Selection of laser pulse duration (LPL, SPL or USPL) **EXPERIMENT 2: Optimisation of laser Ablation parameters**

IMAGING TECHNIQUE: MOKE **IMAGING TECHNIQUE: MOIF**

Grade: RXX27 (thickness 0,27 mm) **Samples size: 60*60 mm²**

Definitions: Sensitivity in our microscope:

- Longitudinal: System is sensitive to magnetization component vertical in the image plane
- Transverse: Sensitive to magnetization component horizontal in the image plane
- Polar: Sensitive to magnetization component perpendicular to the image plane

Material grade: 30MXX (thickness 0,3 mm)

Samples size: 10*10 mm²

	CED (J.cm ⁻²)	PPD (TW.cm ⁻²)	sample
a1	354	12,6	α
a2	1029	12,6	
a3	1286	12,6	
a4	1886	12,6	

	CED (J.cm ⁻²)	PPD (TW.cm ⁻²)	sample
b1	1302	36,2	β
b2	1302	20,7	
b3	1302	14,5	
b4	1302	4,8	

SELECTION OF PULSE DURATION – MAGNETO OPTICAL KERR EFFECT MICROSCOPE (MOKE VIDEOS)

Magneto-Optical Contrast

Definition of an area of interest ~6*6 mm²

Contrast z // sensitivity with a grey scale

Renormalization to improve the contrast z

$-1 < z(x, y, t) < 1$
 $[0, z] \rightarrow [0, 1]$

LPL

SPL

USPL

BEFORE **AFTER**

Magnetization and Domains Size

Contrast averaging

Surface magnetization

Hysteresis loops

$$M_y(t) = \sum_{j=1}^u \sum_{k=1}^v z(x_j, y_k, t)$$

FFT2D ⇒ Domains width

$$\tilde{z}(k_{xp}, k_{yq}, t) = \sum_{j=1}^u \sum_{k=1}^v e^{i2\pi(j-1)(p-1)} e^{i2\pi(k-1)(q-1)} z(x_j, y_k, t)$$

Probability spectrum

$$p(k_{xp}, t) = \frac{|\tilde{z}(k_{xp}, 1, t)|}{\sum_n |\tilde{z}(k_{xp}, 1, t)|}$$

Domains width

$$\bar{k}_x = \text{median}(p(k_{xp}, t))$$

$$\langle d_w \rangle = (2\bar{k}_x)^{-1}$$

Walls Speed & Mobility (25 mT, 5 mHz)

$$\tilde{d}z(k_{xp}, k_{yq}, t) = \sum_{j=1}^u \sum_{k=1}^v e^{i2\pi(j-1)(p-1)} e^{i2\pi(k-1)(q-1)} dz(x_j, y_k, t)$$

Differential FFT2D

Walls mobility

$$dz = \frac{dz}{dt} dt$$

$$\frac{dz}{dt} \propto \frac{dm_y}{dt}$$

$$\frac{dm_y}{dt} \propto 2S_w n_w M_s V_w$$

$v_w = \eta_w H$

$d_p = p(\tilde{d}z)$
 $= p(S_w n_w \eta_w)$

SELECTION OF PROCESS PARAMETERS AND PATTERNS – MAGNETO-OPTICAL INDICATOR FILM (MOIF)

Impact on Static Walls' density, Domains Refinement

Area of interest ~20*20 mm², Contrast // sensitivity with a grey scale, Renormalization to improve the contrast

BEFORE

AFTER

α **β**

domains refinement criterion at equilibrium

walls pinning limitation

Walls' Dynamics, Nucleation & Multiplication (2,5 mT, 5 mHz)

BEFORE **AFTER**

walls nucleation and multiplication criteria with varying field

walls pinning limitation

DISCUSSION, CONCLUSION AND FORTHCOMING

CRITERIA FOR SELECTIONS	Magnetization	Pulse Duration	Laser Process Parameters
Static domain walls' density, refinement ratio	weak	USPL	a4 b4 small line spacing d
Walls dynamics, nucleation, multiplication and mobility	strong	USPL	a4 b1 high line spacing d