Formation of the ordered $L1_0$ FePt phase in FePt films with an additional Au layer on and without substrates

Makushko P.V.[1], Shamis M.N.[1✉], Kotenko I.E.[2], Schmidt N.Y.[3], Verbytska T.I.[1], Makogon Iu.M.[1]

[1] Department of Physics of Metals, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37 Peremogy Ave., Kyiv 03056, Ukraine

[2] L.V. Pisarzhevskii Institute of Physical Chemistry of National Academy of Sciences of Ukraine, 31 Nauky Ave, Kyiv 03028, Ukraine

[3] Institute of Physics, University of Augsburg, Universitätstrasse 1, 86135 Augsburg, Germany

✉ E-mail: m.shamis-2021@kpi.ua

MOTIVATION

FePt thin films are of high interest as a promising material for ultrahigh density magnetic recording media in data storage and HAMR application due to a high magnetocrystalline anisotropy, high values of saturation magnetization and corrosion resistance of ordered $L1_0$ FePt phase.

AIM

was to investigate the effect of an additional Au layer, which is located at different positions of the layer stack (top, intermediate, bottom) on $A1$ FePt → $L1_0$ FePt transformation, the structural and magnetic properties of FePt-Au films without substrate annealed in-situ in Electron diffraction unit and on the substrate after vacuum annealed in furnace.

EXPERIMENTAL DETAILS

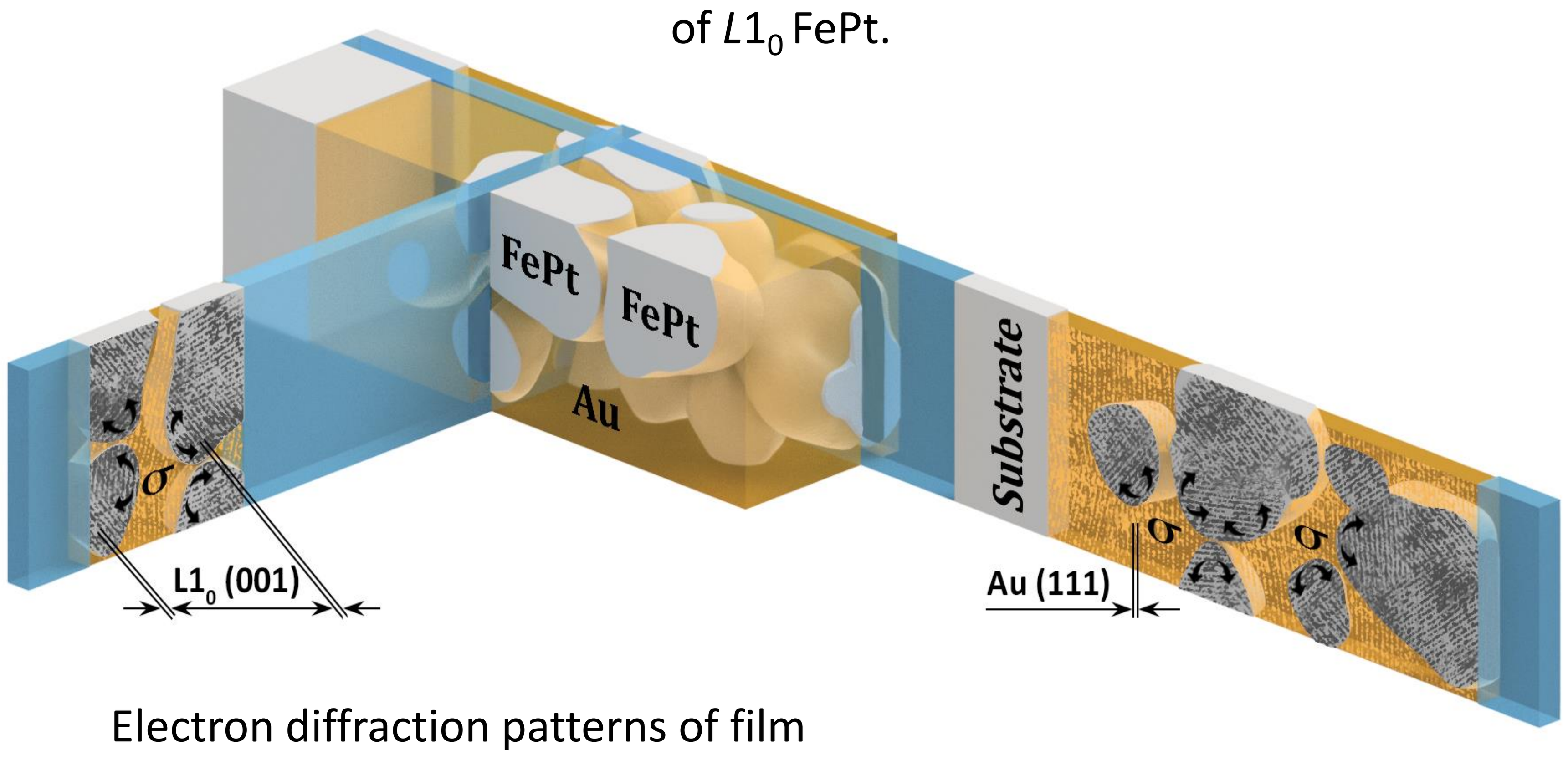
Thin $Fe_{50}Pt_{50}$ films with various location of additional Au layer: top Au(7.5 nm)/FePt(15 nm), intermediate FePt(15 nm)/Au(7.5 nm)/FePt(15 nm) and underlayer FePt(15 nm)/Au(7.5 nm), as well as reference sample FePt(15 nm), were deposited at room temperature by magnetron sputtering (Ar pressure $3.5{\cdot}10^{-3}$ mbar) onto Si(001)/SiO_2(100 nm) substrates.

Two annealing series were carried out. The set I of the post-annealing was done in vacuum ($1.3{\cdot}10^{-5}$ mbar) in the temperature range of 600 °C – 900 °C during 30 s. The structural properties of the as-deposited and annealed films were characterized by X-ray diffraction (XRD) and atomic force microscope (AFM) operating in tapping mode. The magnetic properties were determined using superconductive quantum interference device (SQUID) magnetometry.

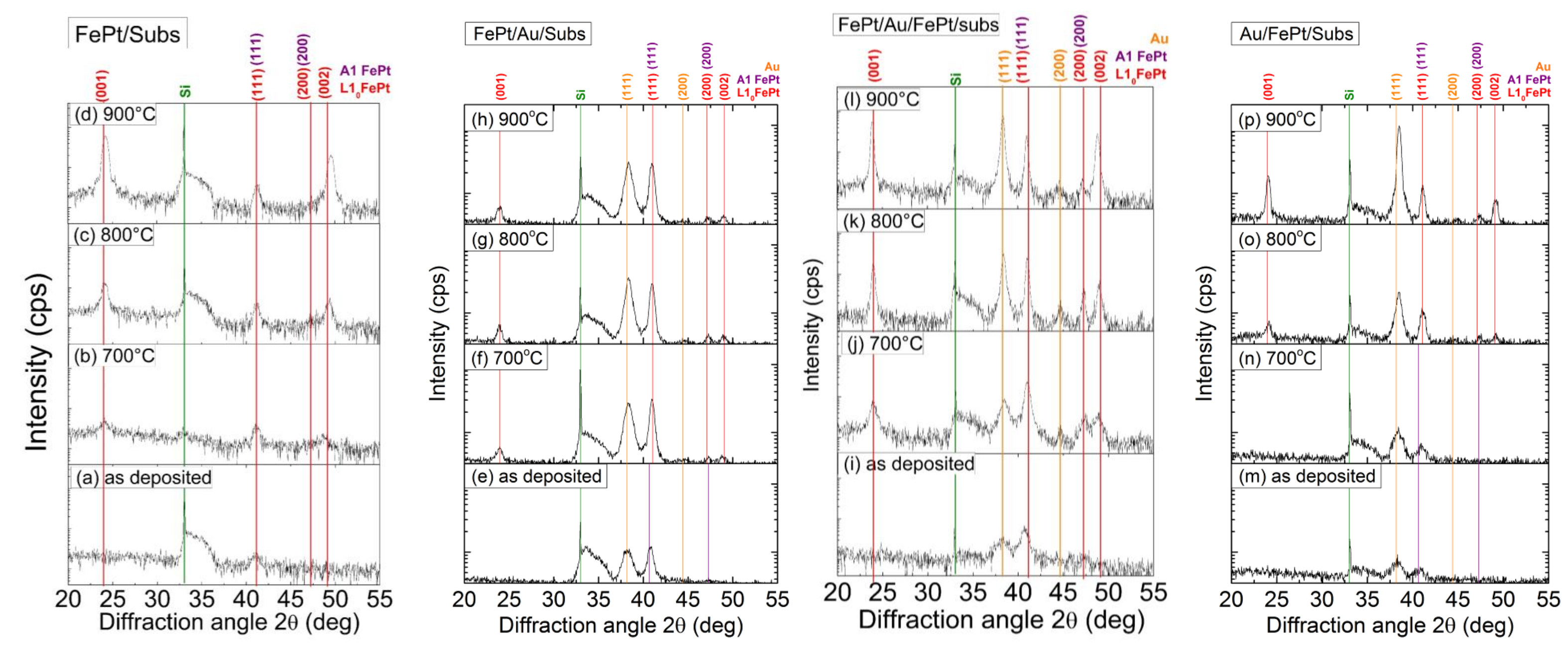
For the annealing set II, after films deposition on substrates, substrates were etched away in mixture of HNO_3 and HF acids. Films without substrates on a Cu grids were annealed in-situ by RHEED method in Electron diffraction unit EMR-100R. The phase composition and structure were investigated by TEM.

RESULTS

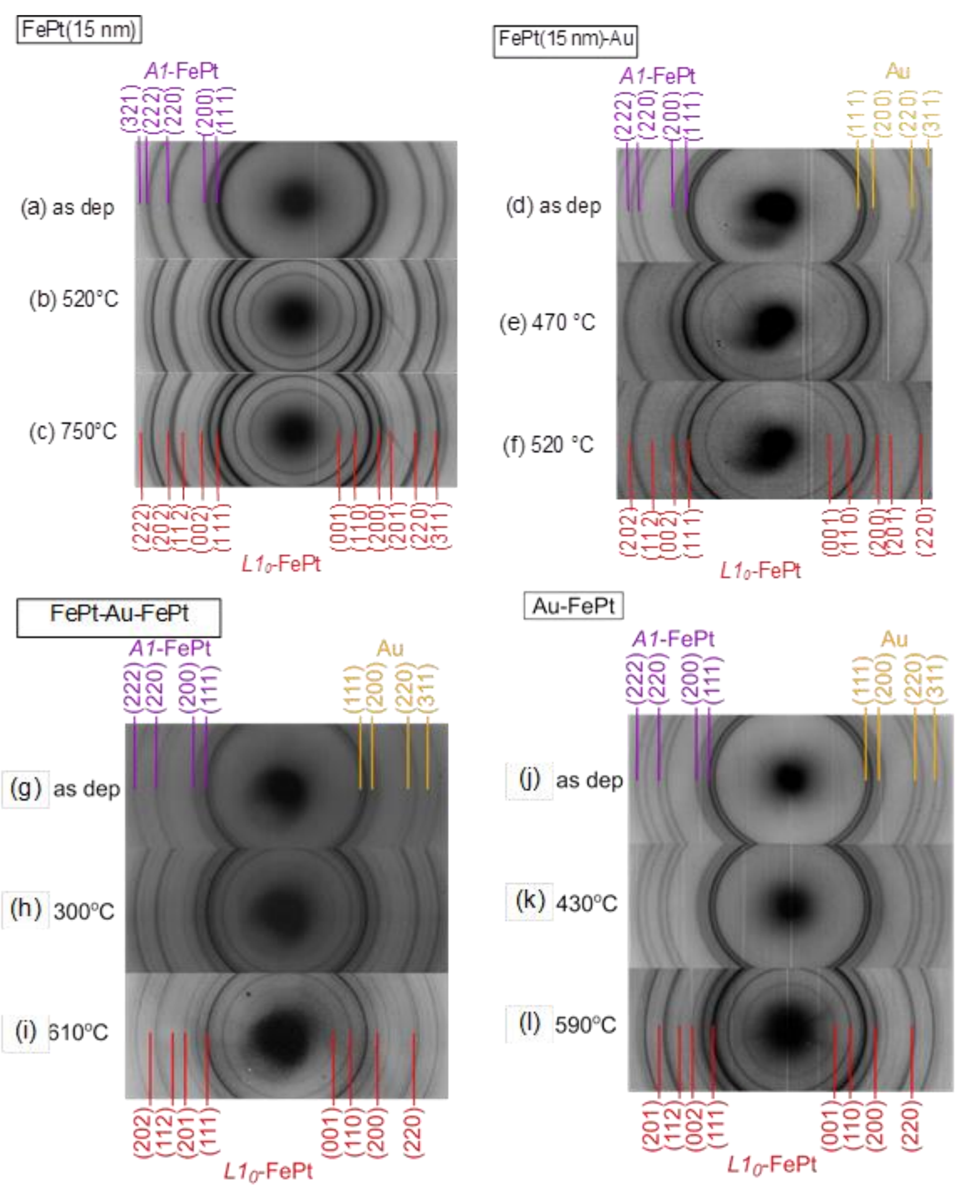
Schematic view of two orthogonal cross-sections of the FePt/Au/FePt/Sub. film annealed at 900°C and representing inhomogeneous stress fields at the Au-FePt GBs, which lead to the ordering and the formation of $L1_0$ FePt.



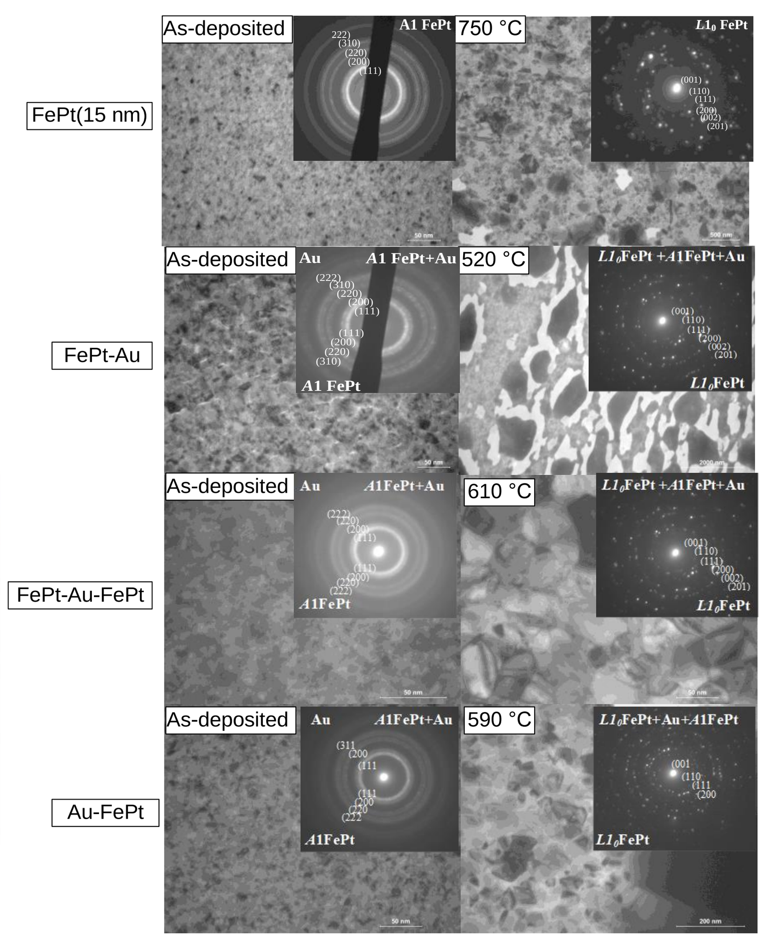
XRD (θ-2θ) scans of (a-d) FePt(15 nm), (e-h) FePt(15 nm)/Au(7.5 nm), (i-l) FePt(15 nm)/ Au(7.5 nm)/FePt(15 nm) and (m-p) Au(7.5 nm)/FePt(15 nm) films after deposition and annealing at different temperatures in the range of 700-900°C



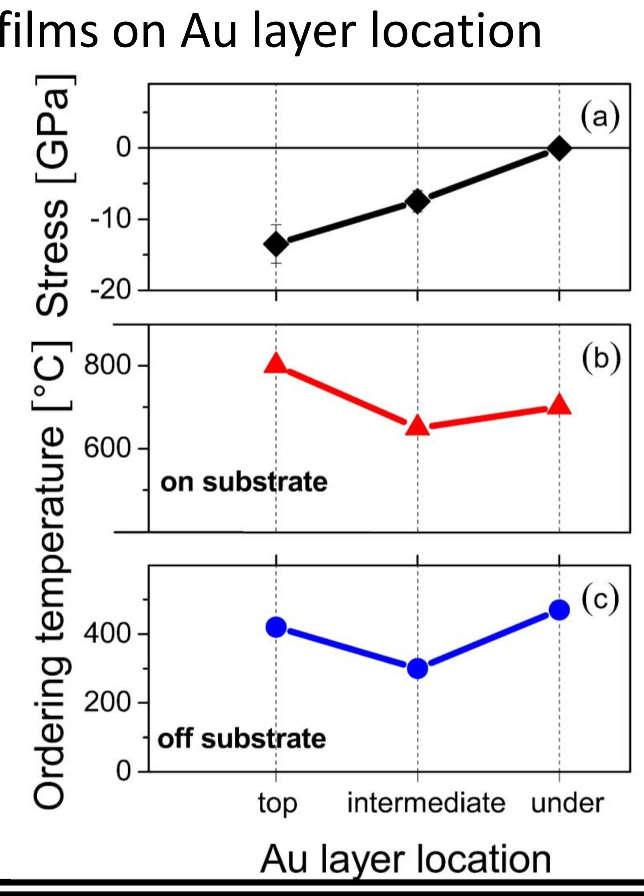
Electron diffraction patterns of film compositions separated from the substrate during *in-situ* annealing



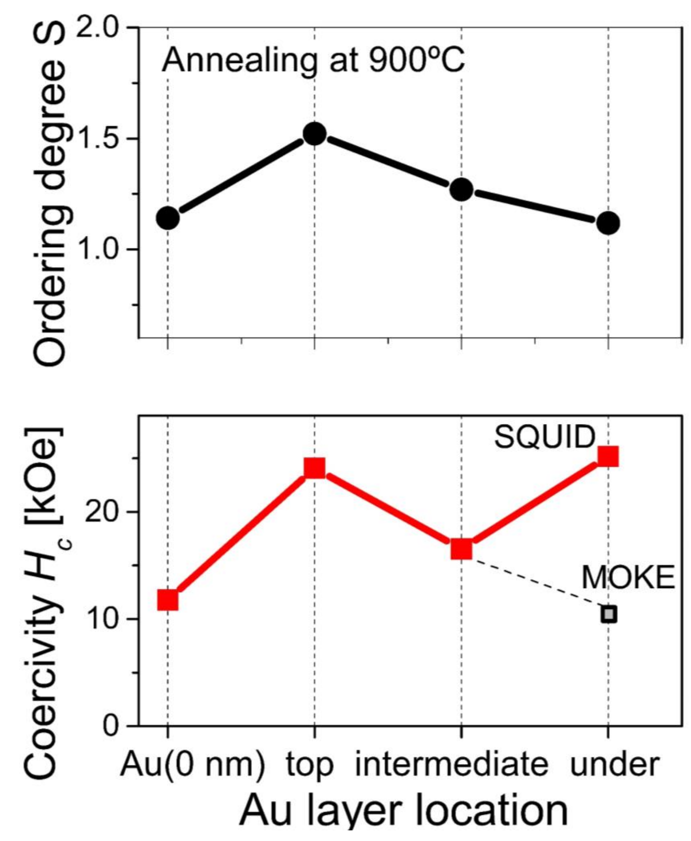
TEM image and electron diffraction patterns of as-deposited and after annealing in situ films



The dependence of:
(a) the residual mechanical stress in the FePt layer after deposition;
(b) the FePt ordering temperature of films on the substrates on Au layer location
(c) the FePt ordering temperature of separated from substrates films on Au layer location



Dependence of the $L1_0$ FePt phase ordering degree and the coercivity after annealing at 900°C on the Au layer location



CONCLUSIONS

It was established that the location of the Au layer in the as-deposited film composition affects the parameters of its grain structure. Post-annealings activate the grain-boundary diffusion of Au and ordering processes that accompanied by the ordered $L1_0$ FePt phase formation. Depending on the grain size of the first deposited layer, these processes occur at different rates. The stresses caused by the difference in thermal expansion coefficients of $Fe_{50}Pt_{50}$ and Au are relaxed under the $A1$ FePt→$L1_0$ FePt transformation, which is accompanied by a decrease in volume of the unit cell. An increase in the Au concentration at the grain boundaries reduces the exchange interaction between them, which increases coercivity. In both compositions with smaller grains size of FePt films with an intermediate Au layer on the substrate and separated from it is observed the lowest temperature of the beginning of $L1_0$ phase formation

ACKNOWLEDGMENTS

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