Poster

Rapid structural transformations in metals after sub-ps pulsed laser annealing

I. Jacyna[1,*], R.Sobierajski[1], P. Zalden[2], K. Sokolowski-Tinten[3], A. Olczak[4], C. Bressler[2], M. Chojnacki[1], P. Dziegielewski[4], G. Evangelakis[5], A.R. Fernandez[2], K. Fronc[1], W. Gawełda[2], K. Georgarakis[6], A.L. Greer[7], R. Kaminski[8], R.W.E. van de Kruijs[9], D. Khakhulin[2], D. Klinger[1], K. Kosyl[1], K. Kubicek[2], I. Milov[9], N. Panagiotopoulos[7], M. Sikora[10], P. Sun[11], H. Yousef[2] and J. Antonowicz[4]

[1]*Institute of Physics Polish Academy of Sciences, al. Lotników 32/46, 02-668 Warsaw, Poland,*

[2]*European XFEL, Holzkoppel 4, 22869 Schenefeld, Germany,*

[3]*Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany,*

[4]*Faculty of Physics, Warsaw University of Technology, Koszykowa 75, 00-662 Warsaw, Poland*

[5]*Department of Physics, University of Ioannina, Ioannina 45110, Greece*

School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, MK43 0AL, UK ,

[7]*Department of Materials Science & Metallurgy, University of Cambridge, Cambridge, CB3 0FS, UK,*

[8]*Department of Chemistry, University of Warsaw, Żwirki i Wigury 101, 02-089 Warsaw, Poland,*

[9]*Industrial Focus Group XUV Optics, MESA+ Institute for Nanotechnology, University of Twente, Drienerlolaan 5, 7522 NB Enschede, Netherlands,*

[10]*Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology, al. A. Mickiewicza 30, 30-059 Krakow, Poland,*

[11]*SLAC National Accelerator Laboratory, 2575 Sand Hill Rd, Menlo Park, CA 94025, USA*

*e-mail:yatsyna@ifpan.edu.pl

We have studied ultrafast solid-solid and solid-liquid phase transformations in laser-excited iron. Samples (30 nm thick layers deposited on 300 nm SiN membranes and caped with 300 nm SiO) were annealed at extremely high heating rates (up to ~10^15 K/s) by sub-picosecond laser pulses. By adjusting the irradiation fluence we have varied the maximum temperature from a ~1000 K up to approx. 3 times the complete melting threshold. The temporal evolution of samples' state was characterized using X-ray diffraction technique at the European XFEL facility[1]. The application of the ultrashort (fs) X-ray pulses allowed to directly probe the atomic structure of the sample with an unprecedentedly high temporal resolution of ~500 fs (relevant for the ultrafast rates of studied processes) at delay times in the range from before up to tens of ps after excitation with a pump pulse[2]. It enabled new insight into the atomic-level mechanisms and kinetics of ultrafast phase transitions. In particular, we have measured the characteristic time scales of the martensitic transformations and melting in Fe thin layer samples. The proposed experimental approach is matching the timescales of experimental and computational studies[3,4] of structural transformations, which for conventional annealing techniques combined with XRD characterisation differ by several orders of magnitude.

Acknowledgements: This work was supported by National Science Centre, Poland, grant agreement No 2017/27/B/ST3/02860,

References

1. W.Decking et al., Nature Photonics 14 (2020) 391–397
2. P. Zalden et al., Science 364 (2019) 1062
3. X. Ou, Materials Science and Technology 33 (2017) 822-835
4. Y.Shibuta, Chemical Physics Letters 445 (2007) 265-270