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Laser irradiation-induced phase transition in titanium dioxide films

Rimantas Knizikevičius *

Department of Physics, Kaunas University of Technology, 73 K. Donelaičio St., LT-44249 Kaunas, Lithuania

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ABSTRACT

The oxidation of titanium substrates in the air under laser irradiation is investigated. The experimental dependence of TiO_2 layer thickness on the number of laser pulses is subjected to the comprehensive analysis. The prevailing chemical and physical processes on the substrate surface and in the near-surface layer are determined. It is found that the laser irradiation drives the surface-energy induced mixing in the near-surface layer of titanium substrates. The mixing rate sharply depends on temperature. This allowed to detect the exothermic phase transition from anatase to rutile in the titanium dioxide films using ex-situ experimental measurements.

Video and Presentation to this article can be found online at https://doi.org/10.1016/j.sctalk.2023.100187.

Figures

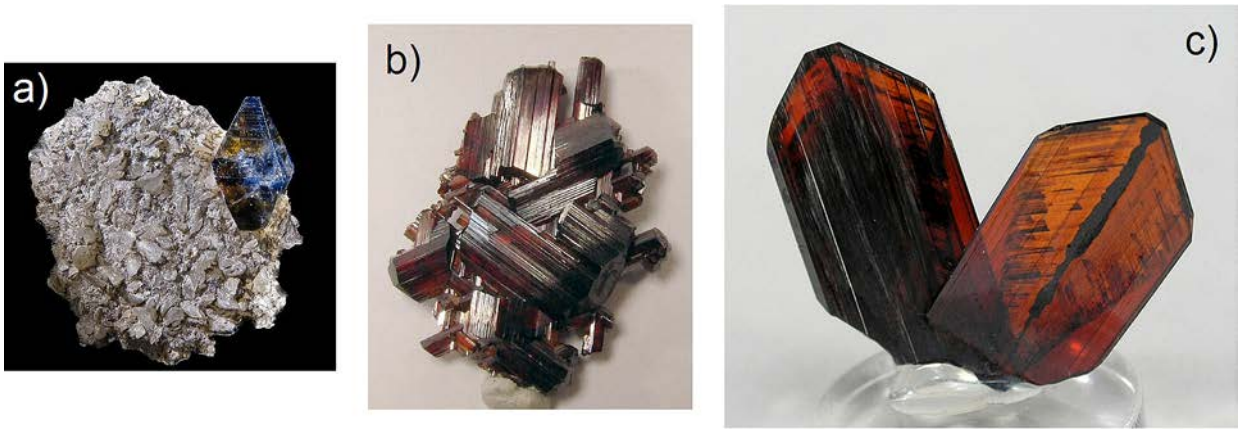

Fig. 1. At standard conditions, titanium dioxide is found in three different phases: a) anatase; b) rutile; c) brookite. Magnification is the same.

* Corresponding author.
E-mail address: Rimantas.Knizikevicius@ktu.lt.

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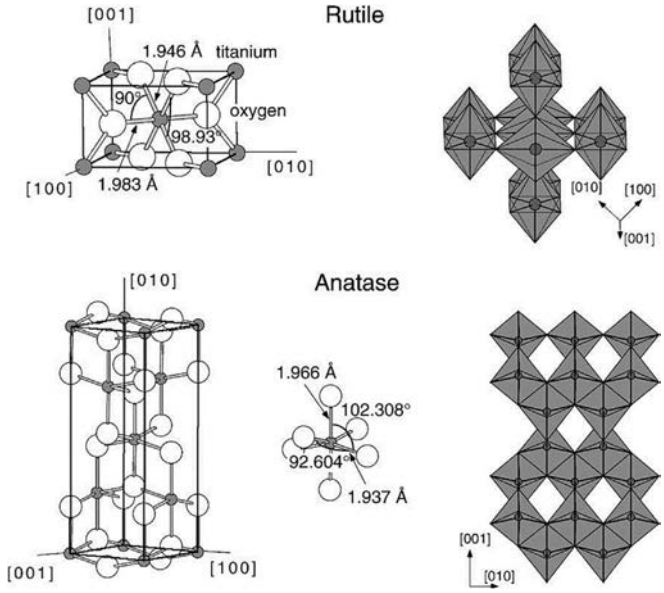

Fig. 2. The structures of rutile and anatase crystals [1]. The tetragonal bulk unit cell of rutile has the dimensions, $a = b = 4.587$ Å, $c = 2.953$ Å, and the one of anatase $a = b = 3.782$ Å, $c = 9.502$ Å.

Fig. 3. Artist's impression of the surface-energy induced mixing at the macroscale.

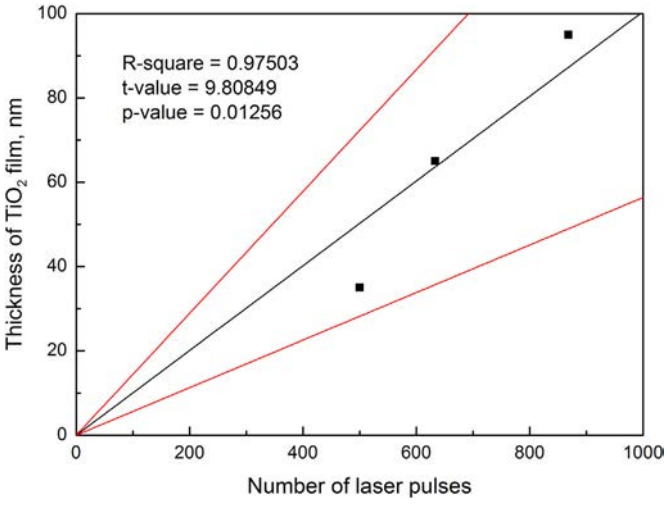

Fig. 4. The experimental [2] and theoretical dependences of TiO_2 film thickness on the number of laser pulses.

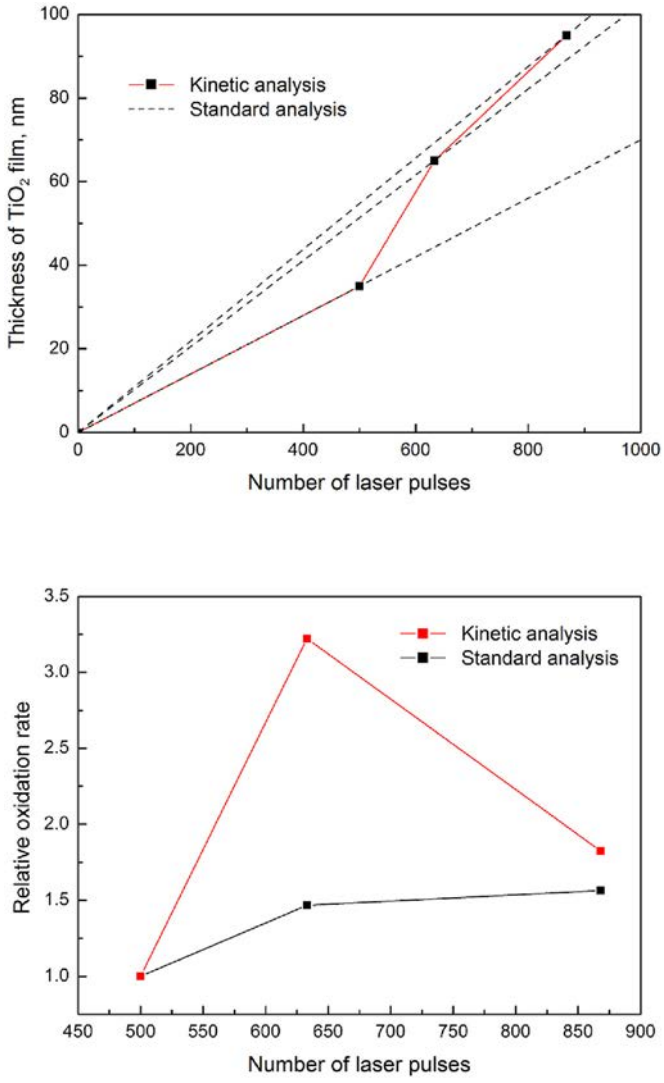

Fig. 5. The comparison of standard and kinetic analysis methods to calculate dependence of the relative oxidation rate on the number of laser pulses.

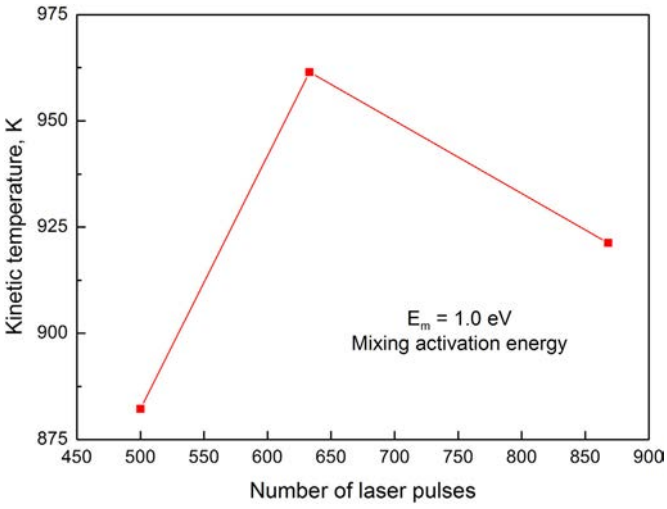

Fig. 6. The dependence of kinetic temperature of TiO_2 film on the number of laser pulses. The effective time of single pulse is 6 ns. The value of mixing activation energy is estimated from scanning tunneling microscopy measurements of the considered system [3].

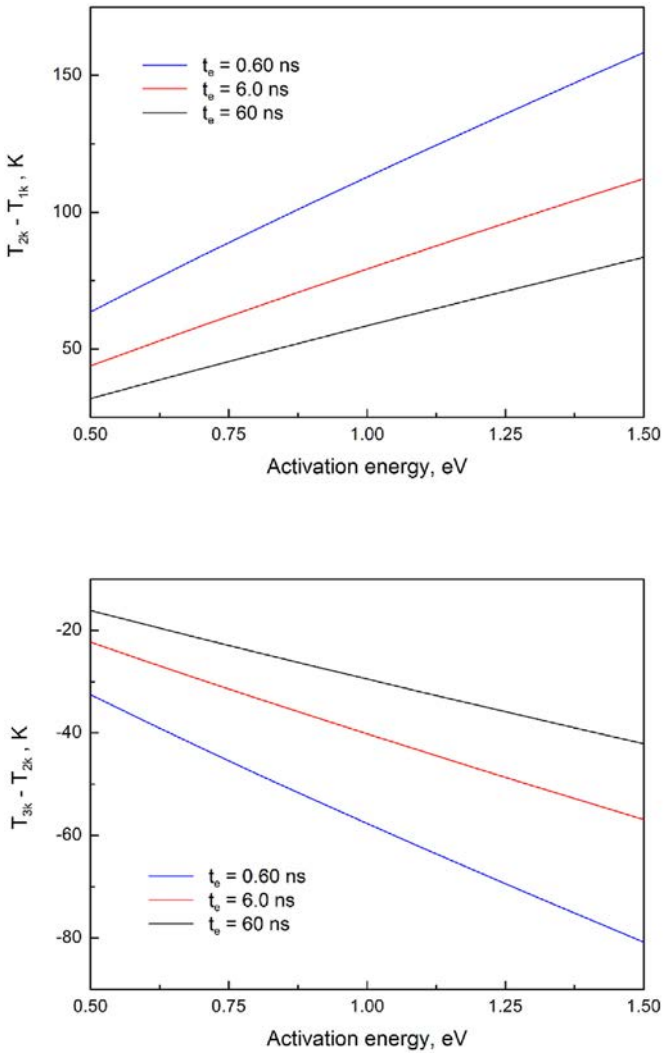

Fig. 7. The changes in kinetic temperature versus the mixing activation energy at three different effective times of single pulse.

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CRediT authorship contribution statement

Rimantas Knizikevičius: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Writing – review & editing.

Data availability

Data will be made available on request.

Declaration of interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further reading

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Rimantas Knizikevičius received PhD degree in Physics from Kaunas University of Technology in 2000. His research interests include dry etching processes and surface inhibition mechanisms. From 2002 until 2006 he appeared as a clear winner of The Young Scientists Research Competition organized by Kaunas University of Technology. In 2003, he won The Young Scientists Research Competition in the field of mathematics, physics, and chemistry organized by The Lithuanian Academy of Sciences. Afterwards, he served as the editor of Dataset Papers in Science, Hindawi Publishing Corporation. In 2019, he was granted a Latvian state research fellowship at Riga Technical University. As theoretical scientist, he has published over 30 articles in Web of Science journals without coauthors. Since receiving PhD degree, he is giving lectures in physics at Kaunas University of Technology, Lithuania.