

**Komitet za termodinamiku  
i fazne dijagrame Srbije**

*u saradnji sa:*

**Fakultetom tehničkih nauka u Kosovskoj Mitrovici,  
Tehničkim fakultetom u Boru i  
Associated Phase Diagram and Thermodynamics Committee  
(Poland, Czech Republic, Hungary, Bulgaria, Slovenia, Serbia,  
Montenegro, Romania, Croatia, Bosnia and Herzegovina)**

**Jedanaesti simpozijum o  
TERMODINAMICI  
I FAZNIM  
DIJAGRAMIMA**

**sa međunarodnim  
učesćem**



*Zbornik izvoda radova*

**Kosovska Mitrovica,  
23 - 24. jun 2023.**

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## **JEDANAESTI SIMPOZIJUM O TERMODINAMICI I FAZNIM DIJAGRAMIMA**

*sa međunarodnim učešćem*



## **ZBORNIK IZVODA RADOVA**

**Kosovska Mitrovica,  
23-24. jun 2023. god.**

# Jedanaesti simpozijum o termodinamici i faznim dijagramima

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## **O AKTIVNOSTIMA KOMITETA ZA TERMODINAMIKU I FAZNE DIJAGRAME SRBIJE U PROTEKLOM PERIODU**

**Dragan Manasijević<sup>1</sup>, Duško Minić<sup>2</sup>**

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<sup>2</sup>*Univerzitet u Prištini sa privremenim sedištem u Kosovskoj Mitrovici, Fakultet tehničkih nauka u Kosovskoj Mitrovici, Srbija*

Ovogodišnji simpozijum predstavlja 11. Simpozijum o termodinamici i faznim dijagramima u organizaciji Komiteta za termodinamiku i fazne dijagrame Srbije, Fakulteta tehničkih nauka u Kosovskoj Mitrovici Univerziteta u Prištini i Tehničkog fakulteta u Boru Univerziteta u Beogradu.

Simpozijum o termodinamici i faznim dijagramima ima za cilj promociju istraživanja u oblastima termodinamike i faznih dijagrama metalnih i drugih materijala, povezivanje i unapređenje saradnje istraživača sa različitih naučnih institucija u Srbiji koji se bave ovim naučnim disciplinama.

Termodinamika i fazni dijagrami predstavljaju osnov nauke o materijalima. Poznavanje termodinamike i faznih ravnoteža čine polaznu tačku za izučavanje mnogih drugih fenomena i procesa.

Više od dvadeset godina istraživači sa različitih naučnih institucija u Srbiji, kao i kolege iz inostranstva, koji se u svom naučnom radu bave termodinamikom i faznim dijagramima razmenjuju svoja znanja i iskustva i prave planove dalje saradnje na simpozijumu koji se tradicionalno održava svake druge godine.

Komiteta za termodinamiku i fazne dijagrame Srbije, koji je deo Associated Phase Diagram and Thermodynamics Committee (Poland, Czech Republic, Slovakia, Hungary, Bulgaria, Serbia and Montenegro) (skraćeno: APDTC) i organizator Simpozijuma, zvanično počinje sa radom 1999. god. i okuplja grupu istraživača u oblasti termodinamike, ispitivanja faznih dijagrama stanja, karakterizacije materijala, termijske analize i sl.

Osniivač i predsednik našeg Komiteta bila je prof. Dragana Živković. Usledile su i prve značajnije aktivnosti našeg Komiteta - organizacija Prvog simpozijuma o termodinamici i faznim dijagramima, juna 2001. godine na Borskom jezeru, kao i posebno izdanje časopisa Journal of Mining and Metallurgy Section B Metallurgy posvećeno ovom skupu.

Tokom 2002. godine, Komitet je organizovao Okrugli sto "THERPHAD" (THERmodynamics and PHAse Diagrams) u okviru 34. Oktobarskog savetovanja rudara i metalurga i okupio veliki broj značajnijih svetskih imena u ovoj oblasti.

Juna 2003. godine, organizovan je i Drugi simpozijum o termodinamici i faznim dijagramima SCG u okviru VI Savetovanja "Primena naučnih istraživanja i projektnih rešenja u metalurgiji" u Arandelovcu.



Vremenom su se i nacionalni komiteti drugih zemalja iz ovog dela Evrope priključivale u APDTC. Trenutno, APDTC uključuje 11 država članica: Poljska, Bosna i Hercegovina, Bugarska, Hrvatska, Češka, Mađarska, Crna Gora, Rumunija, Srbija, Slovačka i Slovenija.

Juna 2005. godine organizovan je Treći simpozijum o termodinamici i faznim dijagramima SCG u Boru, a jula 2006. godine naš Komitet je bio organizator godišnjeg sastanka APDTC u Zaječaru. U okviru ovog sastanka je organizovan i drugi okrugli sto THERPHAD, uz učešće najznačajnijih evropskih istraživača u ovoj oblasti, a saopšteni radovi su u celosti štampani u specijalnoj svesci Journal of Mining and Metallurgy Section B Metallurgy.

Jula 2009. godine održan je u Zaječaru i Četvrti simpozijum o termodinamici i faznim dijagramima. Peti simpozijum o termodinamici i faznim dijagramima održan je u Kladovu 13. oktobra 2011. godine. Šesti simpozijum o termodinamici i faznim dijagramima održan je na Borskom jezeru 19. oktobra 2013. godine.

Sedmi simpozijum o termodinamici i faznim dijagramima održan je 8. juna 2015. god. na Tehničkom fakultetu u Boru. Ovaj simpozijum se ističe po učešću značajnog broja priznatih istraživača iz inostranstva među kojima su: dr Yong Du, dr George Kaptay, dr Andrei Rotary, dr Lijun Zhang, dr Tamara Holjevac Grgurić, dr Jožef Medved, dr Maja Vončina, i dr.

Osmi simpozijum o termodinamici i faznim dijagramima održan je 19. i 20. juna 2017. god. na Fakultetu tehničkih nauka u Kosovskoj Mitrovici. Simpozijum je bio posvećen preminuloj prof. dr Dragani Živković, osnivaču i predsedniku Komiteta za termodinamiku i fazne dijagrame Srbije. Plenarno predavanje održao je prof. dr Yong Du sa Central South University, Changsha, China. Izloženo je 35 naučnih radova iz oblasti termodinamike i faznih dijagrama. Pored autora iz Srbije, učestvovali su i autori iz Kine i Hrvatske. Za predsednika i sekretara Komiteta za termodinamiku i fazne dijagrame Srbije izabrani su prof. dr Dragan Manasijević i doc. dr Milena Premović.

Deveti simpozijum o termodinamici i faznim dijagramima održan je 21. i 22. juna 2019. god. na Fakultetu tehničkih nauka u Kosovskoj Mitrovici. Plenarno predavanje održala je dr Nadežda M. Talijan, naučni savetnik Instituta za hemiju, tehnologiju i metalurgiju, (IHTM) i dopisni član Akademije inženjerskih nauka Srbije (AINS).

Izloženo je 21 naučnih radova iz oblasti termodinamike i faznih dijagrama. Pored autora iz Srbije, i ovom prilikom svoj naučni doprinos dali su autori iz Kine i Hrvatske. Takođe, za učesnike skupa organizovana je ekskurzija u okviru koje su posećeni jezero Gazivode kao i manastiri Crna Reka, Đurđevi Stupovi i Gradac.



## *Jedanaesti simpozijum o termodinamici i faznim dijagramima*

Jubilarni, deseti simpozijum o termodinamici i faznim dijagramima održan je 25. i 26. juna 2021. god. na Fakultetu tehničkih nauka u Kosovskoj Mitrovici. Plenarno predavanje pod nazivom Structural, thermodynamic and thermal aspects of silver based electrical contacts održao je dr Vladan Ćosović, naučni savetnik Instituta za hemiju, tehnologiju i metalurgiju Univerziteta u Beogradu. Izloženo je 29 naučnih radova iz oblasti termodinamike i faznih dijagrama.



*Fotografije sa Desetog simpozijuma održanog juna 2021. god.*



***Trenutni članovi Komiteta za  
termodinamiku i fazne dijagrame Srbije***

U narednoj tabeli je dat spisak naučnih institucija i istraživača koji su trenutno članovi Komiteta za termodinamiku i fazne dijagrame Srbije.

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***Spisak objavljenih radova u časopisima međunarodnog značaja članova Komiteta za termodinamiku i fazne dijagrame Srbije u periodu 2021.-2023. godina***

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## **Plenarno predavanje**



**Vaso D. Manojlović**, Associate Professor at the Department of Metallurgical Engineering, Faculty of Technology and Metallurgy, University of Belgrade, was born on May 11, 1985, in Nikšić, Montenegro. His educational path began in Nikšić, where he accomplished his primary and high school education. Graduating in 2010, Manojlović completed his Metallurgical Engineering degree and defended his thesis on "Examination of the Possibilities of Magnesium Recycling by Vacuum Distillation". Advancing his academic endeavors, Manojlović initiated his doctoral studies in

the 2010/11 academic year, specializing in Metallurgical Engineering. By March 2017, his doctoral dissertation, titled "Metallothermic Reduction in Recycling Technologies Applied to Metallurgical By-products and Waste", was successfully defended, under the mentorship of Prof. Dr. Željko Kamberović.

Dr. Manojlović has a notable background of active participation in multiple projects relating to process engineering in metallurgy, with industry and science. He published over 20 articles in journals of category M20, more than 60 reviewed articles in international conferences and other journals, and one patent. Dr. Manojlović's research predominantly focuses on process metallurgy, particularly recycling technology, where he applied metallothermic reduction reactions to treat metallurgical waste and intermediate products, demonstrating possible synergy in the utilization of exothermic reactions. His significant contributions to the field also include optimizing metallurgical processes in recycling technologies, where he utilized machine learning to optimize steel waste recycling in an electric arc furnace, predicted electricity consumption and product mechanical properties based on numerous process parameters. Beginning in 2022, Dr. Manojlović initiated research alongside his PhD candidate, Gordana Marković. Their focus was on biocompatible Ti alloys used in medicine, which is also the theme of the presentation for this Symposium. They placed a strong emphasis on thermodynamic calculations and machine learning techniques for predicting the mechanical properties of these alloys.

In the period from 2011 to 2012, Vaso D. Manojlović was affiliated with the Technical Faculty "Mihajlo Pupin" in Zrenjanin, University of Novi Sad, serving as a Teaching Assistant. In May 2012, he transitioned to the Institute for Technology of Nuclear and Other Mineral Raw Materials in Belgrade, where he fulfilled the responsibilities of a Research Associate within the Center for Metallurgical Technologies. Following this, since 2017, Manojlović has been deploying his expertise as an Assistant Professor at the University of Belgrade, Faculty of Technology and Metallurgy, engaging in teaching various courses within the Department for Metallurgical Engineering. Concurrently, since 2016, he has been serving in the management for the journal "Metallurgical and Materials Engineering" under the publishment of the Serbian Association of Metallurgical Engineers. This distinguished journal has secured accreditation and is indexed in notable global databases, such as "DOAJ" (2016), Thomson Reuters emerging sources citation index (2017), and Scopus (2019).

Professor Manojlović demonstrates a dedication for innovation and has twice participated in the "Best Technological Innovation" competition held by the Republic of Serbia's Ministry of Education, Science, and Technological Development, and with his team earning a commendable second place in 2016.





## **Designing Biocompatible Titanium Alloys: Machine Learning Approach**

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### **Abstract**

Titanium and its various alloys have been used for decades as for numerous dental and orthopedic devices. What makes it suitable for these applications is the excellent combination of biocompatibility, corrosion resistance, low modulus of elasticity and specific strength. However, recent researches have linked some of the main alloying elements, aluminum and vanadium, and several other elements besides them, with a very harmful effect on the human body. Stress shielding is another possible side effect due to the still insufficiently matched elastic modulus of the alloy and bone. These issues have demanded the exploration for alternative alloys, characterized by non-toxic components and a low elastic modulus. The design of titanium alloys involves a variety of techniques, such as the Mo equivalent method, the electron-to-atom ratio (e/a) method, d electron-based alloy design, experimental techniques, and cutting-edge machine learning approaches. This study leverages the Extra Tree Regression method from machine learning to analyze the most influential parameters for the elastic modulus, identifying the specific heat and share of silicon in alloy as significant factors. Multi-component diagrams were subsequently constructed to guide the development of alloys with a low elastic modulus. Also, employing the developed model with the Monte Carlo experimental design method we found optimal compositions for high entropy alloys with a low Young's modulus. These findings provide a solid foundation for future experimental studies on biocompatible titanium alloys.

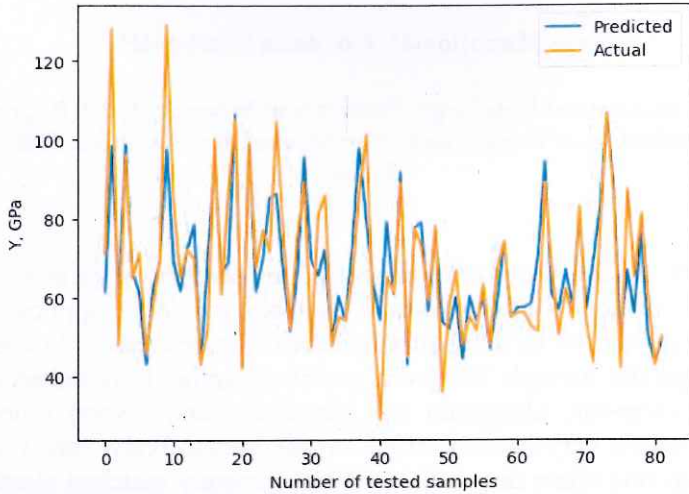
### **Acknowledgement**

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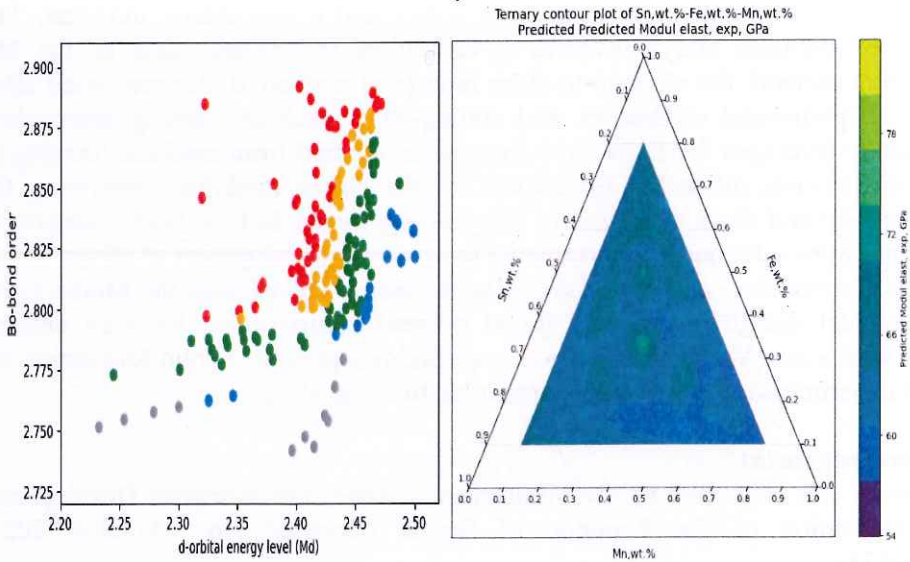
### **References**

1. V. Manojlović, G. Marković, *Metallurgical and Materials Data* 1, (2023) 1-6.
2. V. Manojlović, Ž. Kamberović, M. Korać, M. Dotlić, *Applied Energy*, 307 (2022) 118209.
3. A. Festas, A. Ramos, J. P. Davim, *Materials*, 236 (4) (2021) 8168–81883.

Graphical abstract:



a)



b)

c)

a) Predicted and actual values for the modulus of elasticity depending on the number of tested samples, b) Bo-Md dependence plot for modeled data, c) Three-component diagrams with mapped areas of low elastic modulus, depending on the mass ratios of the following alloying elements: Sn, Fe, Mn.