

НАСТАВНО-НАУЧНОМ ВЕЋУ ФИЗИЧКОГ ФАКУЛТЕТА УНИВЕРЗИТЕТА У БЕОГРАДУ

Пошто смо на XI седници Изборног и Наставно-научног Већа Физичког факултета Универзитета у Београду, одржаној 24. септембра 2025. године, одређени за чланове Комисије за припрему извештаја по расписаном конкурс за избор једног ВАНРЕДНОГ ПРОФЕСОРА за ужу научну област ПРИМЕЊЕНА ФИЗИКА на Физичком факултету у Београду подносимо следећи

ИЗВЕШТАЈ

На конкурс за избор једног ВАНРЕДНОГ ПРОФЕСОРА за ужу научну област ПРИМЕЊЕНА ФИЗИКА на Физичком факултету у Београду, који је објављен у листу "Послови" дана 15. октобра 2025. године, пријавио се само један кандидат, др Ненад Тадић, доцент на Физичком факултету Универзитета у Београду.

БИОГРАФИЈА, НАСТАВНА И НАУЧНА АКТИВНОСТ ДР НЕНАДА ТАДИЋА

1 Основни биографски подаци

Ненад Тадић је рођен 03.11.1987. године у Лозници. Завршио је средњу техничку школу у Лозници 2006. године. Основне студије уписао је 2006. године на Физичком факултету Универзитета у Београду, смер Примењена физика и информатика, а завршио их је 2011. године са просечном оценом 9,07. На истом факултету завршио је мастер студије на смеру Примењена и компјутерска физика 2012. године са просечном оценом 10, одбранивши мастер рад са темом "Фотокаталитичке особине оксидних слојева добијених на титанијуму методом плазма електролитичке оксидације", под менторством проф. др Стевана Стојадиновића. Докторске студије физике на Физичком факултету Универзитета у Београду, ужа научна област Примењена физика, уписао је 2012. године. Одбранивши докторску дисертацију са називом "Структурна и оптичка карактеризација фотокатализатора на бази TiO_2 и ZnO прахова добијених плазменом електролитичком оксидацијом", под менторством проф. др Стевана Стојадиновића, у фебруару 2017. године завршио је докторске студије са просечном оценом 10.

Од новембра 2012. године запослен је на Физичком факултету Универзитета у Београду најпре као истраживач приправник, а потом од 2015. године као истраживач сарадник. У звање научни сарадник изабран је 28.02.2018. године, а унапређен је у звање виши научни сарадник 24.04.2023. године. У звање доцента за ужу научну област Примењена физика је изабран 17.03.2021. године на Физичком Факултету.

2 Наставна активност

Ненад Тадић од академске 2013/2014 године учествује у извођењу наставе студентима Физичког факултета Универзитета у Београду. Током последњих дванаест година држао је рачунске и експерименталне вежбе из више предмета. Држао је експерименталне вежбе на предметима Основи електронике студентима А смера, Физичка електроника студентима Б и Ц

смера, Метрологија студентима Б смера и Метрологија и стандардизација студентима Ц смера. Такође, држао је рачунске вежбе из предмета Електрична мерења студентима Ц смера.

Након избора у звање доцента, кандидат је држао предавања из предмета Основи електронике и Електрична мерења. Тренутно држи предавања и рачунске вежбе из предмета Електрична мерења студентима Ц смера. Поред овог предмета кандидат је тренутно ангажован за извођење експерименталних вежби из предмета Физичка електроника студентима Б и Ц смера, које у континуитету држи последњих једанаест година.

Студенти су у анонимним анкетама досадашњи наставни рад кандидата у звању доцента, од летњег семестра школске 2021/2022. године закључно са летњим семестром 2023/2024. године, оценили средњом оценом 4,485 (у четири анкете).

Кандидат је био ментор једног завршног рада и једног мастер рада одбрањених на Физичком факултету Универзитета у Београду. Осим тога, био је члан комисија за одбрану седам мастер радова и једне докторске дисертације одбрањених на Физичком факултету. Био је члан у комисијама за избор у научна звања више других кандидата.

Кандидат је са проф. др Стеваном Стојадиновићем написао универзитетски уџбеник „Електрична мерења“ [Б-1]. Наставно-научно веће Физичког факултета Универзитета у Београду је на седници одржаној 29.01.2025. године усвојило рецензију рукописа и донело одлуку да се он прихвати као уџбеник за предмет Електрична мерења.

Кандидат од 2016. године активно учествује у раду Лабораторије за метрологију Физичког факултета, која је од Акредитационог тела Србије акредитована као Лабораторија за еталонирање. Кандидат је дао значајан допринос унапређењу рада и побољшању система квалитета ове лабораторије.

Кандидат је учествовао у организацији такмичења из физике ученика основних школа. Од 2021. године повремено учествује у организацији промоција Физичког факултета. Члан је савета Физичког факултета, изабран из реда наставника за мандатни период 2023-2027 година.

3 Научна активност

Научна активност кандидата претежно је реализована експерименталним истраживањима у областима примењене физике и науке о материјалима. Ужа научна област истраживања кандидата је Примењена физика.

У току досадашњих истраживања кандидат је успоставио сарадњу са колегама из других научно истраживачких институција (Институт за мултидисциплинарна истраживања, Институт техничких наука САНУ, Институт за физику у Београду, Иновациони центар Технолошко-металуршког факултета у Београду, Институт за хемију, технологију и металургију, Департман за физику Природно-математичког факултета Универзитета у Новом Саду и Технички факултет у Бањој Луци).

Кандидат је дугогодишњи активни члан Српског керамичког друштва. Био један од чланова научног одбора конференције Advanced Ceramics and Application X - ACAX. Члан је организационог одбора конференције АСА.

За научно-истраживачки рад кандидат је добио годишњу награду Физичког факултета за младог истраживача 2015. године.

3.1 Публикације

Кандидат Ненад Тадић је коаутор 64 рада у међународним часописима, од чега 62 у водећим међународним часописима са импакт фактором већим од 1. Укупан импакт фактор ових радова је 232,014. Радови су до сада цитирани 1532 пута (без аутоцитата и цитата коаутора 1260 пута), док је Хиршов индекс кандидата 22 (подаци базе Scopus, 06.11.2025.). Осим тога, постигнути научни резултати су презентовани на више међународних и домаћих конференција.

Кандидат је рецензент у међународним часописима: *Nanomaterials*, *Journal of Alloys and Compounds*, *Science of Sintering*, *Research on Chemical Intermediates*, *Applied Physics A*.

3.2 Учешће на научним пројектима и међународна сарадња

Од 2012. до 2019. године кандидат је био ангажован на пројекту „Графитне и неорганске наноструктуре ниске димензионалности“, Министарства просвете, науке и технолошког развоја Републике Србије, евиденциони број ОН171035. Кандидат је био учесник међународног пројекта „Development and design of novel multiFUNctional PEO COATings“, FUNCOAT, Horizon2020-MSCA-RISE project No 823942 (2019-2024). У оквиру овог пројекта кандидат је руководио пројектним задатком „Морфолошка, хемијска и фазна карактеризација оксидних слојева на алуминијуму добијених плазменом електролитичком оксидацијом у волфраматном електролиту“. Такође, кандидат је био учесник билатералног пројекта реализованог између Србије и Белорусије „Добијање и испитивање нанокмполитних електричних изолационих слојева заснованих на порозној анодној алумини са апсорпцијом у инфрацрвеном региону за електронске компоненте са високим топлотним издвајањем“ (2018-2019). Кандидат је тренутно ангажован на пројекту „Functionalized PEO coatings with immobilized zeolites for photocatalytic applications - ZEOCOAT“, Фонда за науку Републике Србије, евиденциони број 7309 (од 2023. године).

4 Преглед научних резултата

Научноистраживачка активност кандидата припада областима примењене физике и науке о материјалима. Одвија се у неколико праваца и може се поделити у четири целине:

- Н1. Развој и испитивање полупроводничких фотокатализатора, оптичких и луминесцентних материјала синтетисаних плазменом електролитичком оксидацијом;
- Н2. Спектроскопско испитивање анодне и катодне плазмене електролитичке оксидације и карактеризација слојева добијених овим процесима;
- Н3. Унапређење и развој метода за синтезу и модификацију материјала посебних карактеристика погодних за различите апликације и њихово испитивање;
- Н4. Проучавање класичне анодизације метала и оксидних структура добијених овим процесом.

Главна истраживања кандидата су усмерена на проучавање процеса плазмене електролитичке оксидације (ПЕО) метала и оксидних структура које се добијају овим процесом. Посебну пажњу у својим истраживањима кандидат је посветио испитивању процеса добијања оксидних структура које садрже TiO_2 и ZnO и њихову примену у фотокатализи.

Поред ове (главне) теме значајан део резултата кандидата се односи на испитивање фотолуминесцентних особина оксидних слојева добијених плазменом електролитичком оксидацијом. Ова истраживања су дала велики допринос разумевању и развоју ПЕО процеса којим је омогућена његова оптимизација у циљу добијања материјала различитих функционалности. Додатно су испитиване могућности примене ових материјала у индустрији. Синтеза оксидних слојева анодним ПЕО процесом је знатно бржа у односу на друге методе, па је и ова тема посебно значајна и актуелна у областима примењене физике и науке о материјалима. Такође, до сада слабије истражена катодна плазмена електролитичка оксидација је у једном делу резултата спектроскопски испитивана, као и структуре које настају анодизацијом метала у овом процесу.

Поред ПЕО процеса, истраживања кандидата су делом посвећена унапређењу и оптимизацији других метода за синтезу материјала у облику танких превлака или наночестичних материјала у циљу добијања: високоактивних фотокатализатора, температурних сензора и сензора влажности. Додатно, део истраживања се односи на модификацију материјала погоних за различите апликације у индустрији.

На крају, један мањи део досадашњих резултата кандидата обухвата испитивања класичне анодизације метала, односно галвано и фотолуминесцентних особина насталих структура.

Н1. Развој и испитивање полупроводничких фотокатализатора, оптичких и луминесцентних материјала синтетисаних плазменом електролитичком оксидацијом [A4,A6-A8,A11-A14,A18-A25,A27,A29,A42-A44,A56]

У току досадашње истраживачке активности кандидат је дао значајан допринос разумевању и унапређењу ПЕО процеса на металима и легурама. Истраживања су рађена са циљем развоја и оптимизације комерцијално и еколошки прихватљиве методе за синтезу фотокаталитички активних и луминесцентних материјала. Иако су независни, ове процесе је погодно истраживати заједно имајући у виду да брзина рекомбинације наелектрисања значајно одређује и фотокаталитичке и фотолуминесцентне карактеристике полупроводних оксидних слојева.

Фотокатализа је изузетно актуелна област истраживања и бројни публиковани радови односе на развој метода за синтезу и унапређење карактеристика фотокатализатора. С обзиром на одличне фотокаталитичке особине TiO_2 и ZnO прахова, кандидат је посебну пажњу посветио истраживању могућности синтезе плазменом електролитичком оксидацијом фотокаталитички активних оксидних структура које садрже титанијум [A11,A14,A20,A23,A24,A42-A44] и цинк [A4,A8,A12,A13,A29]. У наведеним публикацијама извршена је оптимизација процеса у циљу добијања високе фотокаталитичке активности, а добијене структуре су детаљно окарактерисане. Фотокаталитичка активност је испитивана коришћењем моделног полутанта (органска боја метил оранж). Оно што додатно издваја истраживања је коришћење симулиране Сунчеве светлости у фотокаталитичким тестовима у циљу развоја комерцијално прихватљивих катализатора. Иако су TiO_2 и ZnO фотокаталитички високо активни полупроводници допирањем другим елементима могуће је побољшати њихове фотокаталитичке перформансе. Погодним допирањем може се успорити рекомбинација фотостворених наелектрисања и на тај начин значајно повећати фотокаталитичка активност. Примећено је успоравање рекомбинације код слојева који су допирани волфрамом [A8, A11], калајем [A14], тербијумом [A20], кадмијум сулфидом [A24], антимоном [A42], бизмутом [A43], манганом, никлом и кобалтом [A44]. Када се ради о допираном TiO_2 односно ZnO

фотокатализатору мање активним полупроводницима треба напоменути да се јављају два супротстављена ефекта. Први је повољан за процес фотокатализе и огледа се у могућности успоравања брзине рекомбинације наелектрисања, док је други смањење броја фотокаталитички активних центара односно њихово прекривање. Зато је у свим поменутих истраживањима одређена оптимална концентрација допанта. Иако је успоравање рекомбинације доминантно при побољшању карактеристика фотокатализатора допирањем, значајно повећање фотокаталитичке активности је могуће добити и повољном конверзијом апсорбоване светлости. Истраживање извршено на ZnO фотокатализатору показује да његова активност, уколико се побуђује светлошћу из средњег ултраљубичастог дела спектра, може значајно повећати допирањем церијумом [A29]. У студији рађеној на TiO₂ фотокатализатору допирањем гвожђем потврђена је могућност проширења апсорпционог спектра и на тај начин значајног повећања фотокаталитичке активности [A23]. Поред титанијума и цинка испитиване су могућности креирања фотокатализатора на бази других елемената [A6, A56]. Неки креирани системи су показали веома високе активности у фотокаталитичким тестовима, Al₂O₃:Ce³⁺/ZnO 74% конверзије [A29], Al₂O₃:W/ZnO 65% конверзије [A8], TiO₂:Fe 64% конверзије [A23] након шест сати зрачења симулираном сунчевом светлошћу.

Док је за фотокаталитичке перформансе полупроводника пожељно дуже време живота наелектрисања односно смањена брзина њихове рекомбинације, луминесценција полупроводника је већа уколико је већа стопа рекомбинације полупроводника. Стога се један део луминесцентних истраживања односи на испитивање стопе рекомбинације наелектрисања плазменом електролитичком оксидацијом синтетисаних фотокатализатора, док други правац истраживања кандидата представља развој луминесцентних материјала. Детаљно су испитиване фотолуминесцентне особине оксидних слојева добијених анодизацијом ниобијума [A6], цинка [A12] и хафнијума [A17]. У овим истраживањима је потврђен утицај структурних дефеката на интензитет луминесценције, која пре свега потиче од кисеоничних вакансија. Поред чистих оксида коришћењем наночестица цинка формиран су композитни оксиди Al₂O₃/ZnO [A8] и MgO/ZnO [A13] који имају изражене луминесцентне особине. Цинк је коришћен због јаке луминесценције цинк оксида у блиској ултраљубичастој области спектра на око 382 nm и “зелене” емисије на око 510 nm. Луминесценција у блиској ултраљубичастој области потиче од радијативне рекомбинације наелектрисања док је зелена луминесценција повезана са кисеониковим и цинковим вакансијама. Истраживања су показала да је код оваквих система луминесценција сложена и потиче како од ZnO тако и од оксида насталих од материјала аноде, при чему је доминанан утицај ZnO. Луминесценција Al₂O₃ и MgO потиче од F и F⁺ центара у овим слојевима. Посебану пажњу у истраживањима кандидат је посветио испитивању сложених луминесцентних система формираним употребом лантаноида самаријума [A7,A18], еуропијума [A19], тербијума [A21], ербијума [A22], ербијума и итербијума [A25], холмијума и итербијума [A27] и церијума [A56]. У свим наведеним публикацијама детаљно су проучени сложени фотолуминесцентни спектри настали услед комплексних механизма луминесценције лантаноида.

H2. Спектроскопско испитивање анодне и катодне плазмене електролитичке оксидације и карактеризација слојева добијених овим процесима [A3,A5,A6,A9,A12,A15,A17,A36,A41]

Поред одличних фотокаталитичких и оптичких особина оксидне превлаке формиране плазменом електролитичком оксидацијом имају изванредну отпорност на хабање, трење, корозију, добре термичке и електричне особине што чини ове површине погодним за примену

у текстилној индустрији, ваздухопловству, аутомобилској индустрији, биомедицинским уређајима итд. Карактеристике добијених материјала одређене су самим анодизационим процесом. Стога се један правац истраживања кандидата односи се на проучавање самих анодизационих процеса [A3,A5,A9,A12,A15,A17,A36], док други представља детаљно испитивање добијених оксидних слојева [A5, A12,A15,A17,A36,A41].

Анализу анодне и катодне плазмене електролитичке анодизације у реалном времену могуће је извршити оптичком емисионом спектроскопијом, која представља погодну технику за карактеризацију плазме која настаје у току електролитичке оксидације. С обзиром на комплексност процеса, информације које се добијају у реалном времену значајне су за његово делимично контролисање. Истраживања показују да се у оптичким емисионим спектрима неизоставно јављају максимуми који потичу како од употребљеног анодног материјала, тако и од коришћеног раствора без обзира на процес. Поред података о присутности одређених атомских и молекулских врста рачунате су електронске концентрације и температуре плазме. Испитивањем анодизације цинка [A12], ниобијума [A6] и хафнијума [A17] коришћењем Балмерове линије H_{β} процењене су електронске концентрације, док је електронска температура плазме процењена при анодизацији цинка из односа $Zn\ I$ линија на 334.5 nm и 472.2 nm. Такође, мање коришћена катодна плазмена електролитичка оксидација је испитивана емисионом оптичком спектроскопијом [A3, A5, A9, A15]. Анализа водоничне алфа и бета линије при анодизацији волфрама указала је на постојање два региона унутар микропражњења, док је на основу релативног односа интензитета атомских линија волфрама процењена температура плазме [A3]. Слично, помоћу Балмерове бета линије водоника је израчуната одговарајућа електронска концентрација, а температура је процењена мерењем интензитета атомских линија молибдена при његовој катодној плазменој оксидацији [A5]. При анализи катодне плазмене електролизе рефракторских метала (Zr, Ti, Ta) развијена је процедура фитовања заснована на три међусобно померена профила спектралних линија да би се анализирали сложени облици спектралних линије $Na\ I$ на 568.64 nm и 615.86 nm [A9]. Резултати су указали да постоје три зоне микро пражњења са различитим електронским густинама. У истраживању катодне плазмене оксидације челика поред детаљне карактеризације саме плазме анализиране су наночестице гвожђа које настају као производ процеса [A15]. Имајући у виду релативно малу истраженост катодне ПЕО, истраживања у овој области представљају значајан допринос у разумевању самог процеса.

Детаљно су испитиване особине структура креираних плазменом електролитичком оксидацијом у циљу њихових могућих апликација. Одређени су морфологија, хемијски односно фазни састав, оптичке фотолуминесцентне особине и дебљине слојева насталих анодном ПЕО цинка [A12] и хафнијума [A17]. Испитивање цитотоксичности импланата титанијума [A41] је показало да се ПЕО може користити за синтезу биоматеријала. Карактеризација слојева насталих катодном ПЕО молибдена [A5] је показала да та техника није погодна за формирање полупроводничких слојева, већ се може користити за припрему површина, односно њихово чишћење, као и за синтезу наночестица [A15].

Поред бројних резултата везаних за галваностатски једносмерни режим ПЕО различитих метала, истражен је и импулсни режим са ултра кратким циклусима на алуминијуму [A36]. Сам процес је окарактерисан оптичком емисионом спектроскопијом, а посебно је испитан утицај времена трајања импулса на добијене Al-W структуре.

Н3. Унапређење и развој метода за синтезу и модификацију материјала посебних карактеристика погодних за различите апликације и њихово испитивање [A2,A10,A16,A26,A28,A30-A35,A37-A40,A45-A55,A57-A64]

Значајан део истраживања кандидата односи се на испитивање физичких и физичко-хемијских карактеристика материјала својствених функционалности и развој метода којим се они могу синтетисати. Део истраживања обухвата испитивање потенцијалних апликација синтетисаних материјала унапређених карактеристика погодних за израду фотокатализатора [A31,A33,A35,A48,A51,A61], сензора влажности [A26,A30,A34,A37,A39], сензора температуре [A37,A39], сензора кисеоника [A49], сензора глифосата [A58], као и материјала са антиоксидативним и/или антибактеријским својствима погодним за израду активне амбалаже [A32,A46,A51,A52,A39].

У овим истраживањима је коришћено више различитих метода синтеза материјала. Сол-гел методом синтетисани су BiFeO_3 [A10], Fe_2TiO_5 [A31], FeMnO_3 [A32], $\text{Co}_x\text{Mg}_{1-x}\text{Fe}_2\text{O}_4$ [A35], NiMn_2O_4 [A39], Fe_2TiO_5 [A46] и тербијумом допиран BiFeO_3 [A60]. Електроспининг методом синтетисани су нановлакна NiMn_2O_4 [A37], Fe_2TiO_5 [A40], TiO_2 допиран никлом [A54] и самаријумом и цирконијумом [A48]. Спреј пиролизом формиран је фотокаталитички активан филм рутила допиран церијумом [A33]. Додатно значајна су истраживања везана за развој еколошки чистих „зелених“ метода којима су синтетисане наночестице ZnO [A51,A52,A58], Fe_2TiO_5 [A52] и $\text{SrFe}_{12}\text{O}_{19}$ [A57] различитих функционалности.

Детаљна испитивања електричних својстава су урађена за бизмут ферит [A10], тербијумом допиран бизмут ферит [A60], чист и неодимијумом допиран церијум диоксид [A2]. Утицај допирања на диелектричне особине је испитан за стронцијум титанат допиран манганом [A55] и бентонит допиран натријумом, бакром и цинком [A59]. Такође, за стронцијум титанат је испитан утицај механичке активације на микроструктуру и диелектричне особине [A47], као и утицај температуре на диелектричне особине стронцијум хексаферита [A57].

У свим истраживањима из ове области добијене структуре су детаљно окарактерисане.

Н4. Проучавање класичне анодизације метала и добијених оксидних структура овим процесом [A1, A6]

Мањи део истраживачког рада кандидат је посветио испитивању класичне анодизације метала. Истраживања публикована у раду [A1] испитују луминесценцију тантала при анодизацији у режиму константне струје у воденим растворима фосфорне и оксалне киселине. Слаба анодна луминесценција у току анодизације је повезана са постојањем дефеката у формираним оксидним слојевима. Показано је да интензитет луминесценције расте са порастом концентрације дефеката на анодизованим узорцима тантала, повећаном густином струје и температуром електролита. Испитивање луминесцентних спектра је указало на постојање широких луминесцентних трака у видљивој и блиској инфрацрвеној области спектра. Интензитет луминесценције значајно расте са појавом диелектричног пробоја оксидног слоја и у овим спектрима су детектоване линије које одговарају електронским прелазима у атомима кисеоника и водоника.

Слично као код тантала, постојање дефеката у формираном баријерном оксидном слоју доводи до појаве слабе анодне луминесценције при класичној анодизацији ниобијума [A6]. Испитивање оксидних слојева добијених пре пробоја показује да су они аморфни, а до њихове делимичне кристализације долази тек након диелектричног пробоја и они се углавном састоје од хексагоналне фазе ниобијум-пентоксида.

5 Списак публикација

A. Радови у међународним часописима

Радови у водећим међународним часописима (Импакт фактор > 1)

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ЗАКЉУЧАК

Комисија констатује да се на конкурс за избор једног ванредног професора за ужу научну област **Примењена физика** јавио један кандидат чији резултати значајно превазилазе минималне услове за избор у звање ванредног професора прописане Законом о високом образовању, Статутом Универзитета у Београду и Статутом и Правилником за изборе у звања Физичког факултета. Кандидат Ненад Тадић је до сада објавио 62 рада у међународним часописима са импакт фактором већим од 1 и укупним импакт фактором тих радова 232,014 који су цитирани преко 1200 пута (без самоцитата и цитата коаутора). Поред тога, кандидат је коаутор једног универзитетског уџбеника који је се користи на Физичком факултету Универзитета у Београду.

У досадашњем наставном раду кандидат је показао способност да развија и унапређује курсеве на свим нивоима студија, а његов педагошки рад је одлично оцењен од стране студената. Кандидат је био ментор једног завршног и једног мастер рада на Физичком факултету.

На основу свега наведеног Комисија сматра да кандидат др Ненад Тадић одговара специфичним захтевима уже научне области Примењена физика, те предлаже Изборном већу Физичког факултета да усвоји овај Извештај и изабере др Ненада Тадића у звање ванредног професора Физичког факултета за ужу научну област Примењена физика.

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