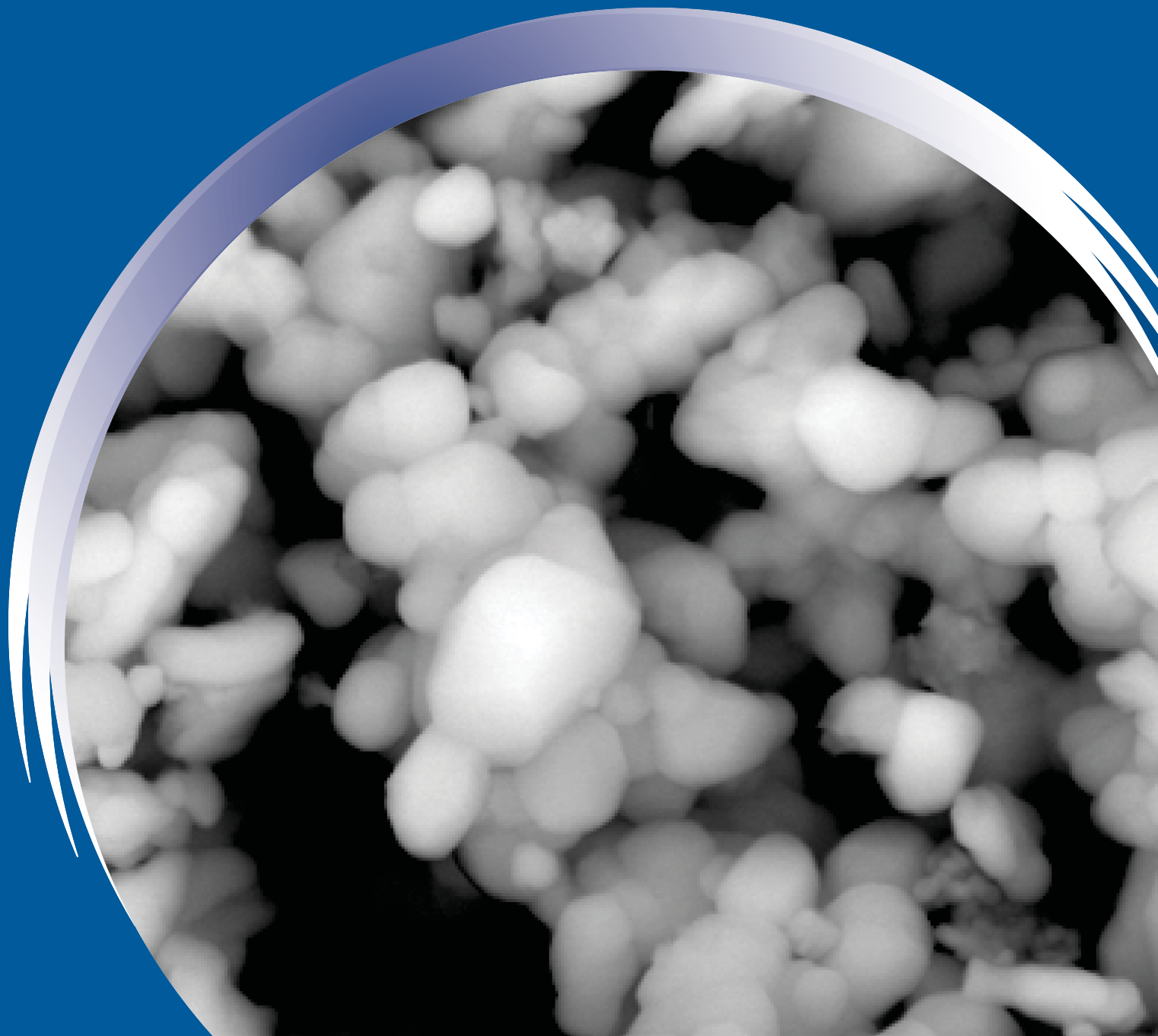


ISSN 0352-9045

Informacije MIDEM

*Journal of Microelectronics,
Electronic Components and Materials*
Vol. 52, No. 4(2022), December 2022

*Revija za mikroelektroniko,
elektronske sestavne dele in materiale*
letnik 52, številka 4(2022), December 2022



Informacije MIDEM 4-2022

Journal of Microelectronics, Electronic Components and Materials

VOLUME 52, NO. 4(184), LJUBLJANA, DECEMBER 2022 | LETNIK 52, NO. 4(184), LJUBLJANA, DECEMBER 2022

Published quarterly (March, June, September, December) by Society for Microelectronics, Electronic Components and Materials - MIDEM.
Copyright © 2022. All rights reserved. | Revija izhaja trimesečno (marec, junij, september, december). Izdaja Strokovno društvo za mikroelektroniko, elektronske sestavne dele in materiale – Društvo MIDEM. Copyright © 2022. Vse pravice pridržane.

Editor in Chief | Glavni in odgovorni urednik

Marko Topič, University of Ljubljana (UL), Faculty of Electrical Engineering, Slovenia

Editor of Electronic Edition | Urednik elektronske izdaje

Kristijan Brecl, UL, Faculty of Electrical Engineering, Slovenia

Associate Editors | Odgovorni področni uredniki

Vanja Ambrožič, UL, Faculty of Electrical Engineering, Slovenia

Arpad Bürmen, UL, Faculty of Electrical Engineering, Slovenia

Danjela Kuščer Hrovatin, Jožef Stefan Institute, Slovenia

Matija Pirc, UL, Faculty of Electrical Engineering, Slovenia

Franc Smole, UL, Faculty of Electrical Engineering, Slovenia

Matjaž Vidmar, UL, Faculty of Electrical Engineering, Slovenia

Editorial Board | Uredniški odbor

Mohamed Akil, ESIEE PARIS, France

Giuseppe Buja, University of Padova, Italy

Gian-Franco Dalla Betta, University of Trento, Italy

Martyn Fice, University College London, United Kingdom

Ciprian Iliescu, Institute of Bioengineering and Nanotechnology, A*STAR, Singapore

Marc Lethiecq, University of Tours, France

Teresa Orłowska-Kowalska, Wrocław University of Technology, Poland

Luca Palmieri, University of Padova, Italy

Goran Stojanović, University of Novi Sad, Serbia

International Advisory Board | Časopisni svet

Janez Trontelj, UL, Faculty of Electrical Engineering, Slovenia - Chairman

Cor Claeys, IMEC, Leuven, Belgium

Denis Donlagić, University of Maribor, Faculty of Elec. Eng. and Computer Science, Slovenia

Zvonko Fazarinc, CIS, Stanford University, Stanford, USA

Leszek J. Golonka, Technical University Wrocław, Wrocław, Poland

Jean-Marie Haussonne, EIC-LUSAC, Octeville, France

Barbara Malič, Jožef Stefan Institute, Slovenia

Miran Mozetič, Jožef Stefan Institute, Slovenia

Stane Pejovnik, UL, Faculty of Chemistry and Chemical Technology, Slovenia

Giorgio Pignatelli, University of Perugia, Italy

Giovanni Soncini, University of Trento, Trento, Italy

Iztok Šorli, MIKROIKS d.o.o., Ljubljana, Slovenia

Hong Wang, Xi'an Jiaotong University, China

Headquarters | Naslov uredništva

Uredništvo Informacije MIDEM

MIDEM pri MIKROIKS

Stegne 11, 1521 Ljubljana, Slovenia

T. +386 (0)1 513 37 68

F. + 386 (0)1 513 37 71

E. info@midem-drustvo.si

www.midem-drustvo.si

Annual subscription rate is 160 EUR, separate issue is 40 EUR. MIDEM members and Society sponsors receive current issues for free. Scientific Council for Technical Sciences of Slovenian Research Agency has recognized Informacije MIDEM as scientific Journal for microelectronics, electronic components and materials. Publishing of the Journal is cofinanced by Slovenian Research Agency and by Society sponsors. Scientific and professional papers published in the journal are indexed and abstracted in COBISS and INSPEC databases. The Journal is indexed by ISI® for Sci Search®, Research Alert® and Material Science Citation Index™. |

Letna naročnina je 160 EUR, cena posamezne številke pa 40 EUR. Člani in sponzorji MIDEM prejema posamezne številke brezplačno. Znanstveni svet za tehnične vede je podal pozitivno mnenje o reviji kot znanstveno-strokovni reviji za mikroelektroniko, elektronske sestavne dele in materiale. Izdajo revije sofinancirajo ARRS in sponzorji društva. Znanstveno-strokovne prispevke objavljene v Informacijah MIDEM zajemamo v podatkovne baze COBISS in INSPEC. Prispevke iz revije zajema ISI® v naslednje svoje produkte: Sci Search®, Research Alert® in Materials Science Citation Index™.

Design | Oblikovanje: Snežana Madič Lešnik; Printed by | tisk: Biro M, Ljubljana; Circulation | Naklada: 1000 issues | izvodov; Slovenia Taxe Percue | Poština plačana pri pošti 1102 Ljubljana

Content | Vsebina

Original scientific papers

Izvirni znanstveni članki

R. Fathima, S. Perumal, V. Muniyappan, M. Faseehuddin, W. Tangsrirat: Electronically Tunable Multifunction Current Mode Filter Employing Grounded Capacitors	205	R. Fathima, S. Perumal, V. Muniyappan, M. Faseehuddin, W. Tangsrirat: Elektronsko nastavljiv večfunkcijski filter v tokovnem načinu z ozemljenimi kondenzatorji
S. Bernik, N. Brguljan, M. Ercegovac, Z. Samardžija: Influence of Trace Elements on the Electrical Properties of ZnO-based Multilayer Varistors	215	S. Bernik, N. Brguljan, M. Ercegovac, Z. Samardžija: Vpliv elementov v sledovih na električne lastnosti večplastnih varistorjev na osnovi ZnO
R. Mishra, G. R. Mishra, M. Faseehuddin, J. Sampe: VD-EXCCII Based Mixed Mode Biquadratic Universal Filter Employing Grounded Capacitors	227	R. Mishra, G. R. Mishra, M. Faseehuddin, J. Sampe: VD-EXCCII na osnovi mešanega načina bikvadratičnega univerzalnega filtra, ki uporablja ozemljene kondenzatorje
D. Singh, S. K. Paul: Mixed-mode Universal Filter Using FD-CCCTA and its Extension as Shadow Filter	239	D. Singh, S. K. Paul: Univerzalni filter z mešanim načinom uporabe FD-CCCTA in njegova razširitev kot filter v senci
D. Palani, M. Arulraj: User Offloading using Hybrid NOMA in Next-generation Heterogeneous Network	263	D. Palani, M. Arulraj: Uporabniška razbremenitev z uporabo hibridnega NOMA v heterogenem omrežju naslednje generacije
Winners of Prestigious International Awards	271	Dobitnika uglednih mednarodnih nagrad
Announcement and Call for Papers: 58 th International Conference on Microelectronics, Devices and Materials With the Workshop on Chemical sensors: materials and applications	273	Napoved in vabilo k udeležbi: 58. mednarodna konferenca o mikroelektroniki, napravah in materialih z delavnico o kemičnih senzorjih: materialih in aplikacijah
Front page: SEM image showing typical morphology of the Cr ₂ O ₃ powders (S. Bernik et al.)		Naslovnica: SEM slika tipične morfologije praška Cr ₂ O ₃ (S. Bernik et al.)

Dobitnika uglednih mednarodnih nagrad

Winners of Prestigious International Awards

Profesorica dr. Barbara Malič, predsednica Društva MIDEM, in profesor dr. Marko Topič, častni predsednik Društva MIDEM, sta v letu 2022 prejela ugledni mednarodni nagradi za izjemne prispevke in vrhunske dosežke na strokovnih področjih, ki jih pokriva naše društvo.

V imenu Društva MIDEM jima iskreno čestitamo in želimo veliko novih raziskovalnih izzivov in uspehov!

prof. dr. Janez Krč
podpredsednik Društva MIDEM

*PROF. DR. BARBARA MALIČ, DOBITNICA
NAGRADE ZDRUŽENJA IEEE ZA PODROČJE
FEROELEKTRIKOV*

Vodja Odseka za elektronsko keramiko Instituta „Jožef Stefan“, prof. Barbara Malič, je dobitnica nagrade IEEE Ferroelectrics Recognition Award za leto 2022, ki jo podeljuje odbor za feroelektrike pri društvu Ultrasonics, Ferroelectrics and Frequency Control Society (UFFC-S) v okviru zveze IEEE za dosežke na področju raziskav feroelektrikov. Prof. Malič je nagrado prejela za izjemen prispevek k razjasnitvi odnosov med kemijskimi in fizikalnimi lastnostmi feroelektrične keramike. V raziskavah feroelektrične keramike na osnovi svinčevih perovskitov in okolju prijaznejših alkalijskih niobatov se je posvečala razumevanju kemijskih procesov, ki potekajo med sintezo in sintranjem keramike, in so osnova za načrtovanje mikrostrukture in posledično njihovih funkcijskih lastnosti. Nagrada je veliko priznanje raziskovalnemu delu prof. Malič in potrditev odličnosti raziskav feroelektrikov, ki Odsek za elektronsko keramiko že vrsto let uvrščajo med najpomembnejše raziskovalne skupine tega področja.

Professor Dr. Barbara Malič, President of the MIDEM Society, and Professor Dr. Marko Topič, Honorary President of the MIDEM Society, received in 2022 prestigious international awards for outstanding contributions and achievements in the fields of expertise covered by our Society.

On behalf of the MIDEM Society, we congratulate them and wish them many new research challenges and successes!

Prof. Dr. Janez Krč
Vice-President of the MIDEM Society

*PROF. DR. BARBARA MALIČ, WINNER OF THE
IEEE PRIZE FOR FERROELECTRICS*



Prof. Barbara Malič, head of the Electron Ceramics Department at the Jožef Stefan Institute, is the recipient of the 2022 IEEE Ferroelectrics Recognition Award, presented by the Ferroelectrics Committee of the Ultrasonics, Ferroelectrics and Frequency Control Society (UFFC-S) IEEE for achievements in the field of ferroelectrics research. Prof. Malič received the award for her outstanding contribution to elucidating

the relationships between the chemical and physical properties of ferroelectric ceramics. In her research on ferroelectric ceramics based on lead perovskites and the more environmentally friendly alkali niobates, she focused on understanding the chemical processes that occur during the synthesis and sintering of the ceramics and form the basis for the design of their microstructure and consequently their functional properties. The award is a great recognition of Prof. Malič's research work and a confirmation of the excellence of ferroelectrics research, which has made the Electron Ceramics Department one of the most important research groups in this field for many years.

*PROF. DR. MARKO TOPIČ, DOBITNIK EVROPSKE
BECQUERELOVE NAGRADE ZA PODROČJE
FOTOVOLTAIKE*

Profesor dr. Marko Topič s Fakultete za elektrotehniko Univerze v Ljubljani je letošnji dobitnik prestižne evropske nagrade "European Becquerel Prize for Outstanding Merits in Photovoltaics" za izjemne prispevke na področju fotovoltaike. Ti vključujejo njegovo akademsko in znanstvenoraziskovalno delo z razvojem številnih optičnih in električnih simulatorjev ter merilnih sistemov, ki jih uporabljajo številni laboratoriji in industrija, njegovo izjemno angažiranost pri oblikovanju močne fotovoltaične skupnosti v Evropi in po svetu ter njegovo delo v vlogi predsednika Evropske tehnološke in inovacijske platforme za fotovoltaiko (ETIP-PV.eu). Profesor Topič si ves čas svojega delovanja prizadeva za spodbujanje izmenjave znanja in ljudi, podpira prisotnost industrijskega PV-sektorja v EU ter zagotavlja pomoč številnim znanstvenikom in inženirjem, dejavnim tako v akademskih krogih kot v fotovoltaični industriji. Uradna podelitev nagrade je bila na 8. svetovni konferenci o fotovoltaični pretvorbi energije (WCPEC-8) 26. septembra 2022 v Milanu.



*PROF. DR. MARKO TOPIČ, WINNER OF
THE EUROPEAN BECQUEREL PRIZE FOR
PHOTOVOLTAICS*

Professor Dr. Marko Topič from the Faculty of Electrical Engineering, University of Ljubljana, is this year's recipient of the prestigious "European Becquerel Prize for Outstanding Merits in Photovoltaics" for his exceptional contributions to the field of photovoltaics. These include his academic and research work in developing a number of optical and electrical simulators and measurement systems used by many laboratories and industries, his great commitment to building a strong community of photovoltaic researchers in Europe and worldwide, and his work as Chair of the European Technology and Innovation Platform for Photovoltaics (ETIP-PV.eu). The official award ceremony took place at the 8th World Conference on Photovoltaic Energy Conversion (WCPEC-8) on 26th September 2022 in Milan.

MIDEM 2023

58th INTERNATIONAL CONFERENCE ON MICROELECTRONICS, DEVICES AND MATERIALS WITH THE WORKSHOP ON CHEMICAL SENSORS: MATERIALS AND APPLICATIONS

September 27th – September 29th, 2023
 Slovenia

Announcement and Call for Papers

Chairs:

Prof. Dr. Danjela Kuščer
Assist. Prof. Dr. Kristina Žagar
Soderžnik

IMPORTANT DATES

Abstract submission deadline:

May 15, 2023

Acceptance notification:

June 26, 2023

Full paper submission deadline:

July 31, 2023

Invited and accepted papers will be published in the Conference Proceedings.

Detailed and updated information about the MIDEM Conferences, as well as for paper preparation can be found on

<http://www.midem-drustvo.si//>

GENERAL INFORMATION

The 58th International Conference on Microelectronics, Devices and Materials with the Workshop on Chemical sensors: materials and applications continues a successful tradition of the annual international conferences organised by the MIDEM Society, the Society for Microelectronics, Electronic Components and Materials. The conference will be held from **SEPTEMBER 27th – 29th, 2023**.

Topics of interest include but are not limited to:

- Chemical sensors,
- Novel monolithic and hybrid circuit processing techniques
- New device and circuit design,
- Process and device modelling,
- Semiconductor physics,
- Sensors and actuators,
- Electromechanical devices, microsystems and nanosystems,
- Nanoelectronics,
- Optoelectronics,
- Photovoltaic devices,
- Electronic materials science and technology,
- New electronic materials and applications,
- Materials characterization techniques,
- Reliability and failure analysis,
- Education in microelectronics, devices and materials.

ORGANIZER:

MIDEM Society - Society for Microelectronics, Electronic Components and Materials, Slovenia

CO-ORGANIZER:

Republic of Slovenia, Ministry of Economic Development and Technology
 European Union, European Regional Development fund

CONFERENCE SPONSORS: UL FE, UL FS, IJS, IMAPS, Slovenia Chapter; IEEE, Slovenia Section



Boards of MIDEM Society | *Organi društva MIDEM*

MIDEM Executive Board | Izvršilni odbor MIDEM

President of the MIDEM Society | Predsednik društva MIDEM

Prof. Dr. Barbara Malič, Jožef Stefan Institute, Ljubljana, Slovenia

Vice-presidents | Podpredsednika

Prof. Dr. Janez Krč, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

Dr. Iztok Šorli, Mikroiks d.o.o., Ljubljana, Slovenia

Secretary | Tajnik

Olga Zakrajšek, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

MIDEM Executive Board Members | Člani izvršilnega odbora MIDEM

Prof. Dr. Slavko Bernik, Jožef Stefan Institute, Slovenia

Assoc. Prof. Dr. Miha Čekada, Jožef Stefan Institute, Ljubljana, Slovenia

Prof. DDr. Denis Donlagič, UM, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia

Prof. Dr. Leszek J. Golonka, Technical University, Wroclaw, Poljska

Prof. Dr. Vera Gradišnik, Tehnički fakultet Sveučilišta u Rijeci, Rijeka, Croatia

Mag. Leopold Knez, Iskra TELA, d.d., Ljubljana, Slovenia

Mag. Mitja Koprivšek, ETI Elektroelementi, Izlake, Slovenia

Asst. Prof. Dr. Gregor Primc, Jožef Stefan Institute, Ljubljana, Slovenia

Prof. Dr. Janez Trontelj, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

Asst. Prof. Dr. Hana Uršič Nemevšek, Jožef Stefan Institute, Ljubljana, Slovenia

Dr. Danilo Vrtačnik, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

Supervisory Board | Nadzorni odbor

Prof. Dr. Franc Smole, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

Prof. Dr. Drago Strle, UL, Faculty of Electrical Engineering, Ljubljana, Slovenia

Igor Pompe, retired

Court of honour | Častno razsodišče

Darko Belavič, Jožef Stefan Institute, Ljubljana, Slovenia

Dr. Miloš Komac, retired

Dr. Hana Uršič Nemevšek, Jožef Stefan Institute, Ljubljana, Slovenia

Informacije MIDE
Journal of Microelectronics, Electronic Components and Materials
ISSN 0352-9045

Publisher / Založnik:
MIDEM Society / Društvo MIDE
Society for Microelectronics, Electronic Components and Materials, Ljubljana, Slovenia
Strokovno društvo za mikroelektroniko, elektronske sestavne dele in materiale, Ljubljana, Slovenija

www.midem-drustvo.si