

ELECTRONICS MATERIALS, PACKAGING AND RELIABILITY TECHNIQUES (EMPART)

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The EMPART research group is a multidisciplinary research unit. Its main activities lie in the electronics materials and devices, and nanotechnology focus areas of the University of Oulu. The group is a key player in the Center of Microscopy and Nanotechnology of the University of Oulu, where our overall target is to integrate nanostructures enabling novel functionality of electronic, telecommunication, bio/medical and energy/environmental devices.

The group comprises of specialists in microelectronic and nanoelectronic materials, mechanical engineering, measuring techniques, and also in chemistry and physics. The personnel consists of six professors, twelve post-doctoral researchers and 20 doctoral students.

The group was funded in 2013 by the University of Oulu, a European Research Council Advanced Grant to Professor Heli Jantunen, Tekes, the EU, the Academy of Finland, ERA.Net, and by domestic and foreign industry. Global research co-operation is a characteristic feature of the EMPART group, having key roles in several EU and other international projects.

In accordance with the long term research targets, we have continued the integration of interdisciplinary topics towards future advanced device and component implementations. In addition, a wide range of application areas utilizing the generic materials knowledge of the group have been of great importance from the application point of view. In 2013, the group leader Professor Jantunen was appointed as a Member of the World Academy of Ceramics (WAC) in recognition of her eminence in promoting progress in the field of ceramics science and technology.

The group co-operated in 2013 with other Infotech Oulu research groups as a partner in PrintoCent (Printed Electronics and Optical Measurements Innovation Center) having a printed electronics laboratory. National and international research co-operation included common projects and publications, and student, researcher and lecturer exchanges. The group also acknowledges Finnish and foreign industrial partners for their active participation in research projects.

Materials, components and technologies developed by the group are widely applied in the electronics industry, especially in wireless telecommunication, sensors/actuators and hybrid microelectronics technology. LTCC micro modules and printed electronics devices are important examples of present exploitation, together with recent scientific achievements in nanotechnology with applications. Novel materials, as well as our progress in fabrication have

been utilized in antennas, sensors, ceramic/polymer integrations, filters, micro-pumps, lens and mirror positioning systems, energy harvesters etc. The number of scientific refereed journal publications was about 45.

Personnel

professors, doctors	20
doctoral students	20
others	3
total	43
person years	13

External Funding

Source	EUR
Academy of Finland	125 000
Ministry of Education and Culture	120 000
Tekes	994 000
domestic private	439 000
international	893 000
total	2 571 000

Doctoral Theses

Kukkola J (2013) Gas sensors based on nanostructured tungsten oxides. Acta Universitatis Ouluensis. Technica C 462.

Halonen N (2013) Synthesis and applications of macroscopic well-aligned multi-walled carbon nanotube films. Acta Universitatis Ouluensis. Technica C 467.

Selected Publications

Trunina NA, Darvin ME, Kordás K, Sarkar A, Mikkola J-P, Lademann J, Meinke MC, Myllylä R, Tuchin VV & Popov AP (2013) Monitoring of TiO₂ and ZnO nanoparticle penetration into enamel and dentine of human tooth in vitro and assessment of their photocatalytic ability. IEEE Journal on Selected Topics in Quantum Electronics 20(3): 7300108.

Myllymäki S (2013) Incorporation of continuous student assessment into lectures in engineering education. European Journal of Engineering Education 38(4): 385-393.

Gemo N, Biasi P, Canu P, Menegazzo F, Pinna F, Samikannu A, Kordás K, Salmi TO & Mikkola J-P (2013) Reactivity aspects of SBA15-based doped supported catalysts: H₂O₂ direct synthesis and disproportionation reactions. Topics in Catalysis 56(9-10): 540-549.

Kumar N, Mäki-Arvela P, Díaz SF, Aho A, Demidova Y, Linden

- J, Shepidchenko A, Tenhu M, Salonen J, Laukkanen P, Lashkul A, Dahl J, Sinev I & Leino A-R (2013) Isomerization of α -pinene oxide over iron-modified zeolites. *Topics in Catalysis* 56(9-10): 696–713.
- Bawuaha P, Silfsten P, Sarkar A, Kordás K, Mikko J-P & Peiponen K-E (2013) On the complex refractive index of N-doped TiO₂ nanospheres and nanowires in the terahertz spectral region. *Vibrational Spectroscopy* 68: 241–245.
- Leino E, Kumar N, Mäki-Arvela P, Aho A, Kordás K, Leino A-R, Shchukarev A, Murzin DY & Mikkola J-P (2013) Influence of the synthesis parameters on the physico-chemical and catalytic properties of cerium oxide for application in the synthesis of diethyl carbonate. *Materials Chemistry and Physics* 143(1): 65–75.
- Puustinen J, Lappalainen J, Hiltunen J & Hiltunen M (2013) Surface nanostructure effects on optical properties of Pb(Zr_xTi_{1-x})O₃ thin films. *Applied Physics A: Materials Science & Processing* DOI: 10.1007/s00339-013-8138-9.
- Kordás K, Kukkola J, Tóth G, Jantunen H, Szabó M, Sági A, Kukovec A, Kónya Z & Mikkola J-P (2013) Nanoparticle dispersions. In: *Springer Handbook of Nanomaterials*, 1st ed. (Ed. Robert Vajtai) Springer-Verlag, 729–776.
- Mohl M & Kordás K (2013) Nanostructures of common metals. In: *Springer Handbook of Nanomaterials*, 1st ed. (Ed. Robert Vajtai) Springer-Verlag, 389–408.
- Myllymäki S, Putaala J, Hannu J, Jantunen H, Mäntysalo M & Kunnari E (2013) Failure mode characterization in inkjet-printed CPW lines utilizing a high-frequency network analyzer and post-processed TDR analysis. *Progress In Electromagnetics Research C* 43: 1–14.
- Lynnyk A, Chvostova D, Pacherova O, Kocourek T, Jelinek M, Dejnek A & Tyunina M (2013) Optical properties of epitaxial relaxor ferroelectric PbSc_{0.5}Nb_{0.5}O₃ films. *Applied Physics Letters* 103: 132901.
- Peräntie J, Taylor HN, Hagberg J, Jantunen H & Ye Z-G (2013) Electrocaloric properties in relaxor ferroelectric (1-x)Pb(Mg_{1/3}Nb_{2/3})O₃-xPbTiO₃ system. *Journal of Applied Physics* 114(17): 174105.
- Huotari J, Lappalainen J, Puustinen J & Lloyd Spetz A (2013) Gas sensing properties of pulsed laser deposited vanadium oxide thin films with various crystal structures. *Sensors and Actuators B: Chemical* 187: 386–394.
- Tuhkala M, Juuti J & Jantunen H (2013) Use of an open-ended coaxial cavity method to characterize powdery substances exposed to humidity. *Applied Physics Letters* 103: 142907.
- Kukkola J, Mohl M, Leino A-R, Mäklin J, Halonen N, Shchukarev A, Konya Z, Jantunen H & Kordás K (2013) Room temperature hydrogen sensors based on metal decorated WO₃ nanowires. *Sensors and Actuators B: Chemical* 186: 90–95.
- Halonen N, Mäklin J, Rautio A-R, Kukkola J, Uusimäki A, Tóth G, Reddy LM, Vajtai R, Ajayan PM & Kordás K (2013) Thin micropatterned multi-walled carbon nanotube films for electrodes. *Chemical Physics Letters* 583(17): 87–91.
- Tuhkala M, Juuti J & Jantunen H (2013) Method to characterize dielectric properties of powdery substances. *Journal of Applied Physics* 114: 014108.
- Bukhanko N, Samikannu A, Larsson W, Shchukarev A, Leino A-R, Kordás K, Wärnå J & Mikkola J-P (2013) Continuous gas-phase synthesis of 1-ethyl chloride from ethyl alcohol and hydrochloric acid over Al₂O₃-based catalysts: the “green” route. *ACS Sustainable Chemistry & Engineering* 1(8): 883–893.
- Nelo M, Sloma M, Kelloniemi J, Puustinen J, Saikkonen T, Juuti J, Häkkinen J, Jakubowska M & Jantunen H (2013) Inkjet-printed memristor: printing process development. *Japanese Journal of Applied Physics* 52(5): UNSP 05DB21.
- Myllymäki S, Teirikangas M, Nelo M, Tulppo J, Sobocinski M, Juuti J, Jantunen H, Sloma M & Jakubowska M (2013) Radio frequency characteristics of printed meander inductors and interdigital capacitors. *Japanese Journal of Applied Physics* 52(5): UNSP 05DC08.
- Szabo M, Pusztai P, Leino A-R, Kordás K, Konya Z & Kukovec A (2013) Synthesis and characterization of WO₃ nanowires and metal nanoparticle-WO₃ nanowire composites. *Journal of Molecular Structure* 1044: 99–103.
- Leino E, Mäki-Arvela P, Eta V, Kumar N, Demoisson F, Samikannu A, Leino A-R, Shchukarev A, Murzin D-Y & Mikkola J-P (2013) The influence of various synthesis methods on the catalytic activity of cerium oxide in one-pot synthesis of diethyl carbonate starting from CO₂, ethanol and butylene oxide. *Catalysis Today* 210: 47–54.
- Tyunina M, Levoska J, Janolin P-E & Dejnek A (2013) Low-temperature relaxor state induced by epitaxial compression in PbSc_{0.5}Nb_{0.5}O₃ films. *Physical Review B* 87(22): 224107.
- Pitkänen O, Halonen N, Leino A-R, Mäklin J, Dombovari A, Lin J-H, Tóth G & Kordás K (2013) Low-temperature growth of carbon nanotubes on bi- and tri-metallic catalyst templates. *Topics in Catalysis* 56(9-10): 522–526.
- Pirilä M, Lenkkeri R, Goldmann WM, Kordás K, Huuhtanen M & Keiski RL (2013) Photocatalytic degradation of butanol in aqueous solutions by TiO₂ nanofibers. *Topics in Catalysis*, 56(9-10): 630–636.
- Leino A-R, Mohl M, Kukkola J, Mäki-Arvela P, Kokkonen T, Shchukarev A & Kordás K (2013) Low-temperature catalytic oxidation of multi-walled carbon nanotubes. *Carbon* 57: 99–107.
- Kähäri H, Juuti J, Myllymäki S & Jantunen H (2013) Preparation of alpha-MnMoO₄ at ultra-low temperature on an organic substrate. *Materials Research Bulletin* 48(6): 2403–2405.
- Ajaikumar S, Golets M, Larsson W, Shchukarev A, Kordás K, Leino A-R & Mikkola J-P (2013) Effective dispersion of Au and Au-M (M = Co, Ni, Cu and Zn) bimetallic nanoparticles over TiO₂ grafted SBA-15: their catalytic activity on dehydroisomerization of alpha-pinene. *Microporous and Mesoporous Materials* 173: 99–111.
- Hiltunen M, Heinonen E, Hiltunen J, Puustinen J, Lappalainen J & Karioja P (2013) Nanoimprint fabrication of slot waveguides. *IEEE Photonics Journal* 5(2): 2200808.
- Wu M-C, Liao H-C, Cho Y-C, Tóth G, Chen Y-F, Su W-F & Kordás K (2013) Photo-Kelvin probe force microscopy for photocatalytic performance characterization of single filament of TiO₂ nanofiber photocatalysts. *Journal of Materials Chemistry A* 1(18): 5715–5720.
- Tyunina M, Yao L, Plekh M, Levoska J & van Dijken S (2013) Epitaxial ferroelectric heterostructures with nanocolumn-enhanced dynamic properties. *Advanced Functional Materials* 23(4): 467–474.
- Sowpati AK, Nelo M, Palukuru VK, Juuti J & Jantunen H (2013) Miniaturisation of dual band monopole antennas loaded with screen printed cobalt nanoparticle ink. *IET Microwaves Antennas & Propagation* 7(3): 180–186.
- Tóth G, Halonen N, Mäklin J, Kukkola J & Kordás K (2013) Thermal management of micro hotspots in electric components with carbon nanotubes. *International Journal of Nanotechnology* 10(1-2): 57–62.
- Juntunen E, Tapaninen O, Sitomaniemi A & Heikkinen V (2013) Effect of phosphor encapsulant on the thermal resistance of a high-power COB LED module. *IEEE Transactions on Components, Packaging and Manufacturing Technology* 3(7): 1148–1154.