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4

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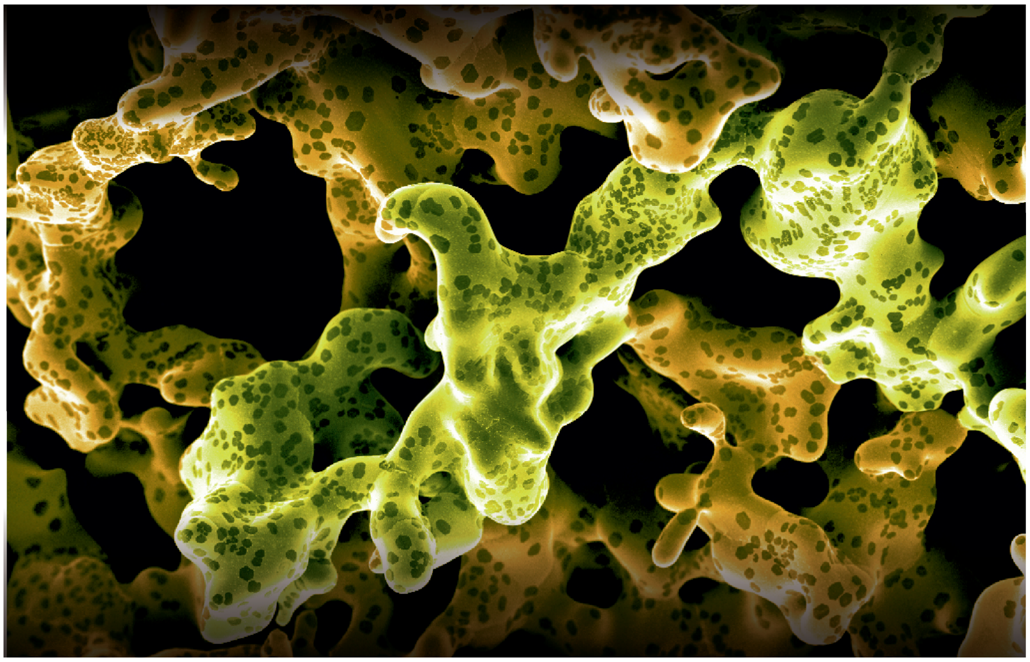

INSTYTUT TECHNOLOGII MATERIAŁÓW ELEKTRONICZNYCH
INSTITUTE OF ELECTRONIC MATERIALS TECHNOLOGY

Institute of Electronic
Materials Technology

Department of Epitaxy

WE OFFER:

Silicon epitaxial wafers
with parameters:
2 - 10 µm ± 4% / 0.005 – 5 Ωcm ± 10%
10 - 50 µm ± 5% / 5 – 100 Ωcm ± 15%
50 - 100 µm ± 8% / 100 – 300 Ωcm ± 20%

and also:

Measurements of the resistivity profile (carrier concentration) using the spreading resistance method in a point contact on a bevelled sample.

Measurements of the properties of defect centres in semiconductor materials, using the DLTS, HRPITS and EPR methods.

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INSTITUTE OF ELECTRONIC MATERIALS TECHNOLOGY

MATERIAŁY ELEKTRONICZNE

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WARSAW ITME 2016

MATERIAŁY
ELEKTRONICZNE
ELECTRONIC MATERIALS

Vol. 44 No. 4 2016

CONTENTS

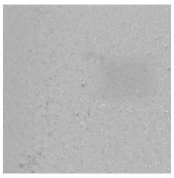
4 Viscosity sensor with shear-horizontal acoustic plate mode on BT-cut quartz and surface acoustic wave filter for mode selection

W. Soluch,
T. Wróbel

Shear horizontal acoustic plate mode (SHAPM) liquid viscosity sensor with the surface acoustic wave (SAW) filter for a chosen SHAPM selection was developed. A turnover temperature and a quadratic temperature coefficient of frequency of about 0°C and −25 ppb/(°C)^2, respectively, were obtained for a delay line on BT-cut quartz (−50.5°YX90°), with gold electrodes. An acoustically coupled resonator filter for a SHAPM selection was designed and fabricatedon the 38°YX cut quartz. With inductive coils of about 0.5 µH connected in series with a 50 Ω load, the measured IL of about 2 dB at a center frequency of about 100.4 MHz was obtained for the filter. For a SHAPM delay line with the filter, insertion loss, turnover temperature, and quadratic temperature coefficient of frequency of about 12 dB, 5°C, and −30 ppb/(°C)^2, respectively, were obtained. Insertion loss and frequency changes against product of mass density and viscosity were measured, using water and glycerin solutions. Insertion loss, and frequency changes of about 14 dB, and −18 kHz, respectively, were obtained, in a viscosity range from about 1 mPa·s to 1000 mPa·s.

8 Mechanical strength and fracture toughness of brittle monocrystalline and ceramic materials

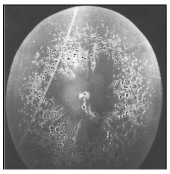
M. Boniecki,
P. Kamiński,
W. Wesołowski,
K. Krzyżak



The article compares the mechanical properties of a n-type silicon single crystal with an orientation <100> and resistivity ~ 2000 Ωcm, obtained by the floating zone (FZ) method, with the mechanical properties of Y_2O_3 ceramics. Both materials are characterized by a high value of transmission coefficient of electromagnetic radiation in the wavelength range from 2 µm to 8 µm and they can be used as optical windows in a near infrared range. However, the choice of a material type for the specific applications may depend on their mechanical properties. These properties have been determined both at room temperature and at elevated temperature, i.e. 700°C for Si and 800°C for Y_2O_3 ceramics. We have found that at room temperature the fracture toughness of the Si single crystal K_{Ic} = 1.3 ± 0.1 MPam$^{1/2}$ and the four-point bending strength σ_c = 289 ± 61 MPa. For Y_2O_3 ceramics these parameters are 1.8 ± 0.2 MPam$^{1/2}$ and 184 ± 20 MPa, respectively. At 700°C the mechanical parameters for the Si single crystal are: K_{Ic} = 20 ± 3 MPam$^{1/2}$ and σ_c = 592 ± 86 MPa. For Y_2O_3 ceramics at 800°C, K_{Ic} = 1.7 ± 0.1 MPam$^{1/2}$ and σ_c = 230 ± 23 MPa. The presented data show that at elevated temperatures both fracture toughness and bending strength of the Si single crystal are significantly greater than the values of those parameters found for Y_2O_3 ceramics.

17 Investigation of oxide crystals by means of synchrotron and conventional X-ray diffraction topography

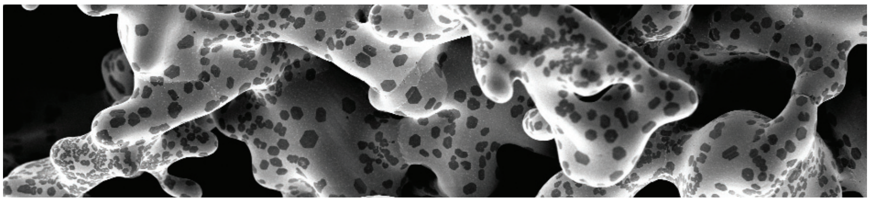
W. Wierzchowski,
A. Malinowska,
K. Wieteska,
E. Wierzbicka,
K. Mazur,
et al.



X-ray diffraction topography, exploring both conventional and synchrotron sources of X-rays, has been widely used for the investigation of the structural defects in crystals of oxides. The majority of bulk oxide crystals have been grown by the Czochralski method from a melted mixture of high purity oxides. Some important oxide crystals like quartz and ZnO have been obtained by the hydrothermal method. In the case of crystals grown by the first method, synchrotron diffraction topography can be and was used for studying individual dislocations and their complexes (e.g. glide bands, sub-grain boundaries), individual blocks, twinning, the domain structure and various segregation effects negatively affecting crystal properties. What is more, the topographical investigation can provide information concerning the reasons for the generation of the defects, which becomes useful for improving the growth technology. In the present paper the possibilities of the diffraction topography are discussed on the basis of several investigations of the oxide crystals, in particular garnets, orthovanadates, mixed calcium barium and strontium niobates as well as praseodymium lanthanum aluminates. The majority of the results refer to oxide crystals grown at the Institute of Electronic Materials Technology (ITME). The synchrotron investigations included in the paper were performed by the authors at the HASYLAB Synchrotron Laboratory in Hamburg.

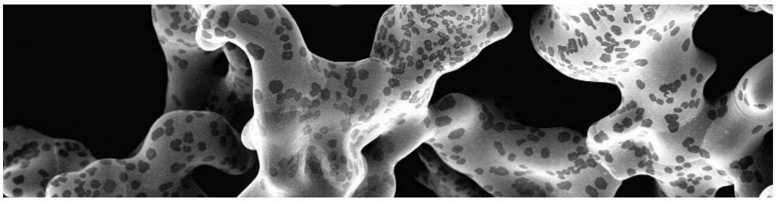
33 In memory

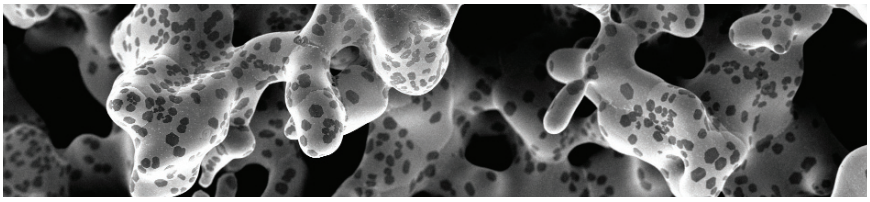
In memory of Elżbieta Nossarzewska - Orłowska PhD.



On the cover:
Copper powder covered with
graphene domains.

Author of the photo - Iwona Jóźwik.
Sample from Iwona Pasternak.





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In memory

It is with great sadness that we have learned of the death of **Dr. Eng. Elżbieta Nossarzewska - Orłowska**, who passed away after a long and serious illness on November 30, 2016. Dr. Eng. Nossarzewska-Orłowska in the years 1972-2007 was the Head of the Department of Epitaxy at the Institute of Electronic Materials Technology (ITME) in Warsaw. She was an outstanding scientist and engineer in the field of silicon epitaxy for the applications in the semiconductor electronics; a co-author of patents and a prize winner of the state awards for the technical achievements. Thanks to her knowledge and a great involvement in the professional activity, the quality of silicon epitaxial layers produced in ITME gained a wide recognition among the manufacturers of the semiconductor devices not only in Europe but also in the USA, Japan and China.

Elżbieta Nossarzewska-Orłowska graduated from the Faculty of Chemistry at Warsaw University of Technology in 1959. Soon after graduation she started to work at the Industrial Electronics Institute, where she spent twelve years carrying out research on the preparation and properties of the luminescent materials. In 1972 she received her PhD degree in chemical sciences at the Institute of Physical Chemistry of Polish Academy of Sciences, the subject of her doctorate thesis being the mechanism and kinetics of cathodoluminescence. In the same year, she started to work as the Head of the Department of Epitaxy at the Semiconductor Materials Science and Production Center, which was later transformed into the Institute of Electronic Materials Technology. She held this position continuously for thirty five years.

Dr. Eng. Elżbieta Nossarzewska-Orłowska created scientific and organizational bases for the development of the silicon epitaxy technology to be applied in the domestic industry of the semiconductor devices which at that time applied the epiplanar technology. It was under her supervision, that over a hundred scientific and research projects were carried out in the field of silicon epitaxial layers, most of which ended with the practical implementation in the production of the epitaxial layers of new properties. The originality of many technological solutions was reflected in a dozen of patents for the manufacturing method of the silicon wafers with an epitaxial layer. Dr. Eng. Nossarzewska - Orłowska was also an author or a co-author of a number of scientific papers published both in Polish and international journals. To appreciate her merits in the development of the semiconductor industry in Poland, Dr. Eng. Elżbieta Nossarzewska - Orłowska was awarded numerous distinctions and national awards.

CEMAT-Silicon is definitely on the list of her great achievements. After the reconstruction of CEMAT'70 in 1989 it become an employee-owned company and took over the production of silicon single crystals. Her great involvement in the ongoing changes in the ownership of the company, helped to maintain high standards of the advanced technology of the silicon production for the semiconductor devices.

Working for ITME in the years 1993-1996, Dr. Eng. Nossarzewska-Orłowska, contributed also to the elaboration of a technology used in the production of porous silicon layers for the applications in the optoelectronic integrated circuits. In 1997, she initiated the studies on silicon single crystal resistance to radiation which started in ITME, and were conducted as a part of a wide international cooperation coordinated by CERN. The research was supervised by Dr. Eng. Nossarzewska-Orłowska until she retired in 2007. The investigations, carried out in a cooperation with the University of Hamburg, helped to further elaborate the technology of the epitaxial layers production for high energy particle detectors and develop new research methods that enabled to determine the properties of the radiational defects in silicon single crystals. The research conducted in the cooperation with CERN have been continued until today and its results have been highly valued by the international scientific community.

For us, who work for the Department of Epitaxy, Madam Elżbieta - as she was called - will remain in our memory as a person who had a great impact not only on our professional work but also on our personal life. She expected us to be deeply involved in our professional duties, but at the same time she was our friend who often helped us solve our private problems. The funeral of Madam Elżbieta took place on December 7, 2016. We paid our last tribute grieving her and her warm smile will always stay in our memory.

Colleagues from the Department of Epitaxy

INFORMATION FOR AUTHORS AND READERS

I. Submission rules

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b) The captions to the illustrations, both in Polish and in English, should also be provided as the separate files.

c) The following items should be present on first page of the article: the given name and family name of the author, degree, authors affiliation, postal address, e-mail, the article title, both in Polish and in English.

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The *Institute of Electronic Materials Technology* develops advanced innovative production technologies of materials characterized by a perfect crystallographic structure and excellent properties, as well as components based on these materials. The scope of R&D activities carried out covers the following areas:

Materials for next-generation components:

- graphene;
- topological insulators;
- materials for spintronics;
- self-organising materials;
- photonic crystals, including plasmonic materials and metamaterials.

Materials for energy generation, storage and transfer:

- wide gap semiconductors, including silicon carbide for GaN HEMT transistors;
- semiconductor-doped glass optical fibres for photovoltaics;
- eutectic materials for photovoltaics;
- SiC wafers and SiC epitaxial layers;
- glass-ceramic seals for fuel cells;
- thermoelectric materials;
- inert matrices for a safe storage of radioactive waste;
- electrode materials for lithium ion batteries;
- ceramic-metal composites and FGMs.

Materials for photonics:

- materials for III-V based semiconductor lasers (obtained using GaAsP, InGaP, AlGaAs, GaAs, GaSb and InP), wafers, epitaxial structures;
- GaN-based epitaxial structures;
- materials for solid state lasers, produced using strontium-calcium niobate;
- infrared photodetectors and UV photodetectors;
- oxide crystals for lasers, passive Q modulators, scintillators, electro-optical and piezoelectric devices, substrates for superconducting HTSc layers;
- glass and ceramics with carefully designed spectral characteristics, including transparent ceramics;
- diffractive optical elements and microlenses;
- nanostructured thin layers;
- luminescent nanopowders and nanocrystals;
- optical fibres and waveguides, including active and photonic fibres.

Materials for electronics:

- silicon monocrystals (standard Si wafers and Si wafers with special properties);
- porous silicon;
- silicon foils;
- epitaxial layers on silicon;
- SiC wafers and SiC epitaxial layers;
- nanopowders and polymer-based powders, pastes and inks for printed electronics;
- photosensitive pastes;
- piezoelectric crystals;
- ceramic-metal composites;
- super-pure metals.

Components:

ITME has elaborated a great number of innovative electronic components based on the manufactured materials, for instance:

- optical fibres (active and photonic), filters, diffractive lenses, two-dimensional photonic microstructures;
- passive elements on membranes (sensors);
- filters, resonators, sensors and actuators based on surface acoustic waves;
- semiconductor devices (lasers, transistors, photodetectors, Schottky diodes);
- solid state lasers and microlasers.

The manufacture of state of the art components is possible at ITME due to high-tech equipment enabling:

- design and manufacture of masks;
- deposition of dielectric thin films (SiO_2, Si_3N_4 , AlN);
- multilayer metallization;
- use of lithography: contact printing using deep UV, electron beam pattern generation;
- application of various etching techniques, including reactive ion etching and controlled sidewall etching.

Advanced methods of material properties investigation:

The characterization of materials is performed at ITME by the following methods:

- standard chemical analysis and spectral instrumental methods (flame atomie emission spectrometry, atomie absorption spectroscopy, ultraviolet to far-infrared spectroscopy);
- Mössbauer spectroscopy (conventional, conversion electron method, X radiation method and unique "rfMössbauer" method developed at ITME);
- X-ray powder diffraction using the Rietveld method, High Resolution X-ray diffraction, X-ray reflectometry and X-ray diffraction topography;
- scanning electron microscopy and a method based on synchrotron radiation;
- electron paramagnetic resonance;
- atomie force microscopy;
- standard thermal methods (high-temperature microscopy, thermogravimetry, differential thermal analysis, dilatometry, etc.) and X-ray methods;
- mechanical methods (testing resistance, friction, hardness, etc.);
- optical methods (microscopy, absorption, reflectometry).

Methods of electronic and photonic components investigation:

ITME tests optoelectronic, microelectronic and piezoelectric devices, using special techniques enabling the characterization of components, including:

- I-V and C-V measurements;
- deep level transient spectroscopy;
- impedance measurements and the measurements of scattering matrix elements up to the frequency of 20 Ghz;
- noise measurements;
- analysis of operational parametres of lasers and photodetectors.