Program Overview

Room /Time	Jefferson 1 & Atrium
MoP	Poster Sessions

Advanced Characterization Techniques
Room Jefferson 1 & Atrium - Session AC-MoP
Advanced Characterization Techniques Poster Session

AC-MoP-1 Advanced Defect Characterization in b-Ga_2O_3 Without the Arrhenius Plot, *J. Li,* NCKU, Taiwan; ***Adam Neal,*** *S. Mou,* Air Force Research Laboratory, Materials and Manufacturing Directorate, USA; *M. Wong,* University of Massachusetts Lowell

Defect is one of the issues that limit the present performance of β-Ga_2O_3 devices. For example, several defects have been observed at 0.6, 0.8. and 1.1 eV below the conduction band edge of β-Ga_2O_3, which are considered to affect doping compensation, leakage current, and threshold stability in transistors. Conventional detection of β-Ga_2O_3 defects (in various forms such as Hall, conductivity, admittance spectroscopy, and deep-level transient spectroscopy (DLTS)) is accomplished by inspecting the electrical charge response, which is based on the Arrhenius behavior of the carrier emission rate from a defect determined by the activation energy E_a and the attempt-to-escape frequency ν_0. All thermally activated electrical charge response measurements are conventionally analyzed by the Arrhenius plot procedure, where one fits the Arrhenius plot of ln(ν) versus T^{-1} to a line and extract E_a from the slope and ν_0 from theintercept. Improvement of the measurement expediency for extracting E_a and ν_0 is desirable to understanding their physiochemical origins and devising mitigation strategies in β-Ga_2O_3 material and device engineering.

We investigate a ~0.8 eV defect in β-Ga_2O_3 using a technique that offers substantial improvement over the conventional DLTS technique, specifically in the analytical processing of electrical signal and the extraction of E_a and ν_0. The technique bypasses both the rate-window treatment and the Arrhenius plot. First, only the raw capacitance transients in the time domain are needed, which can be readily acquired by general-purpose instruments such as impedance analyzers and lock-in amplifiers. Next, the capacitance transients are projected between the temperature and time domains, as well as to the E_a and ν_0 domains. Extraction of E_a and ν_0 is accomplished by matching the projected and experimental capacitance transients to each other. The efficient utilization of information from the 2D temperature-time domain allows operation in a smaller temperature/voltage range and extraction of the temperature and electric-field dependence of E_a and ν_0.

AC-MoP-2 Infrared-Active Phonon Modes and Static Dielectric Constants of Orthorhombic $LiGaO_2$, ***Teresa Gramer,*** *M. Stokey, R. Korlacki, M. Schubert,* University of Nebraska - Lincoln

Li_2O-Ga_2O_3 is an oxide system of broader interest. $LiGaO_2$ (LGO) and multiple phases of Ga_2O_3 (GO) are ultra-wide bandgap metal oxides for future electronic and optoelectronic applications [1], and both LGO, which is orthorhombic, and the orthorhombic phase of GO are expected to be piezoelectric due to the lack of inversion symmetry [1]. While both GO and LGO have recently been identified to most likely trap holes which makes the achievement of sufficient p-type conductivity difficult [2], LGO is particularly promising as a substrate for heteroepitaxial growth of GaN due to very small lattice mismatch (<1%), and a composite LGO/β-GO substrate has also been demonstrated [3]. Here, we provide a thorough study of the fundamental optical and phonon mode properties of high-quality single-crystals of LGO using generalized spectroscopic ellipsometry in combination with hybrid-level density functional theory calculations to investigate the optical properties in the mid- to far-infrared spectral range. From this, all 33 infrared-active pairs of transverse and longitudinal optical phonon modes are observed. We derive the anisotropic midband gap indices of refraction and static dielectric constants.

[1] A review of band structure and material properties of transparent conducting and semiconducting oxides: Ga_2O_3, Al_2O_3, In_2O_3, ZnO, SnO_2, CdO, NiO, CuO, and Sc_2O_3, Joseph A. Spencer, Alyssa L. Mock, Alan G. Jacobs, Mathias Schubert, Yuhao Zhang, and Marko J. Tadjer , Applied Physics Reviews 9, 011315 (2022)

[2] Self-trapped holes and polaronic acceptors in ultrawide-bandgap oxides, John L. Lyons, Journal of Applied Physics 131, 025701 (2022)

[3] Composite substrate $LiGaO_2$ (0 0 1) β-Ga_2O_3 (1 0 0) fabricated by vapor transport equilibration, Jungang Zhang, Changtai Xia, Shuzhi Li, Xiaodong Xu, Feng Wu, Guangqing Pei, Jun Xu, Shengming Zhou, Qun Deng, Wusheng Xu, Hongsheng Shi, Mater. Lett. 60. 3073-3075. (2006)

AC-MoP-3 Spectroscopic Ellipsometry Optical Analysis of Zinc Gallate at Elevated Temperatures, ***Emma Williams,*** University of Nebraska-Lincoln, USA; *M. Hilfiker, U. Kilic, Y. Traouli, N. Koeppe, J. Rivera, A. Abakar, M. Stokey, R. Korlacki,* University of Nebraska - Lincoln; *Z. Galazka,* Leibniz-Institut für Kristallzüchtung, Germany; *M. Schubert,* University of Nebraska - Lincoln

Zinc gallate ($ZnGa_2O_4$) is shown to be a promising alternative to gallium oxide. This is due to the material's larger bandgap of 5.27(3) eV, compared to that of β-Ga_2O_3 (5.04 eV), which is linked to a higher Baliga's figure of merit. [1,2] $ZnGa_2O_4$ also contains an isotropic structure, which is advantageous compared to both the monoclinic β-phase and uniaxial α-phase of Ga_2O_3 in simplifying device design. [2,5] Additionally, $ZnGa_2O_4$ growth has rapidly developed to where bulk single crystals can be melt-grown with controllable n-type conductivity. [4]

In this work, the optical properties of $ZnGa_2O_4$ are modeled using a spectroscopic ellipsometry approach at temperatures between 22°C and 600°C, where material properties drastically change in elevated temperatures. At each 50°C interval a Cauchy dispersion equation is applied to the transparent region of the data where the refractive index and high-frequency refractive index is derived. Furthermore, a critical point model is implemented across the spectral range of 1 eV to 6.5 eV. This allows for the determination of the bandgap, which is found to red-shift linearly with temperature with a slope of -0.72(4) meV K^{-1}, resulting from the thermal expansion of the lattice. [3] The linear decrease in the bandgap energy when exposed to increasing elevated temperatures is in congruence with behavior shown by common wide bandgap metal oxides. In particular, the reduction of bandgap width as a function of temperature is comparable to that of the ultrawide bandgap material β-Ga_2O_3, further justifying $ZnGa_2O_4$ as a suitable high-power device material. [2,3]

References:

[1] M. Hilfiker *et al.* Appl. Phys. Lett. 118, 132102 (2021).

[2] A. Mock *et al.* Appl. Phys. Lett. 112, 041905 (2018).

[3] M. Hilfiker *et al.* Appl. Phys. Lett. 120, 132105 (2022).

[4] Z. Galazka *et al.* APL Materials 7, 022512 (2019).

[5] S. J. Pearton *et al.* Appl. Phys. Lett. 5, 011301 (2018).

AC-MoP-4 The Electron Spin Hamiltonian for Fe^{3+} in Monoclinic β-Ga_2O_3, *S. Richter,* Lund University, Sweden; *S. Knight, P. Kühne,* Linköping University, Sweden; ***Mathias Schubert,*** University of Nebraska - Lincoln; *V. Darakchieva,* Lund University, Sweden

Large interest in Ga_2O_3 originates from the possibility to build devices with high breakdown voltage. Understanding electronic defects is essential to utilize the material. As β-Ga_2O_3 is monoclinic, the effect of the low symmetry needs to be studied. Electron (paramagnetic) spin resonance (EPR) spectroscopy gives access to local site symmetry of spin-carrying defects. Deploying THz ellipsometry [1], we can measure high-field EPR at arbitrary variable frequency by reflection a free beam [2]. This allows true distinction of anisotropic g-factor and zero-field spin splitting, and hence examining the local site symmetry of electronic defects.

Iron incorporated on gallium sites can act as compensating acceptor and facilitate semi-insulating material. Here, we investigate the spin Hamiltonian of the neutral Fe^{3+} state with spin s=5/2. It is characterized by large zero-field splitting that differs for Fe on octahedral Ga_{ii} site (preferential) and Fe on tetrahedral Ga_i site. Different, partially incorrect, reports exist about the nature of the spin Hamiltonian [3,4]. In contrast to standard EPR measurements at X or Q band with limited access to allowed spin transitions, we obtain EPR scans in the frequency range 110-170GHz at magnetic field between 3 and 7T that capture all five resonances for each Fe site at the same time. Modeling the spin Hamiltonian reveals a slight anisotropy of the g-factor and shows that zero-field splitting up to fourth order is relevant. We will discuss how the monoclinic s=5/2 spin Hamiltonian differs from orthorhombic and/or s=3/2 approximations.

[1] P. Kühne *et al.*, IEEE Trans. Terahertz Sci. Technol. **8**(3), 257 (2018).
[2] S. Schubert *et al.*, Appl. Phys Lett. **120**, 102101 (2022).
[3] R. Büscher *et al.*, Z. Naturforsch. **42a**, 67 (1987).
[4] M. L. Meil'man, Sov. Phys. Sol. State **11**(6), 1403 (1969).

The supplemental material features exemplary experimental data and the form of the spin Hamiltonian.

AC-MoP-5 Characterization of (010) β-Ga_2O_3 to Support Fabrication, Wafer Size Scaleup, and Epi Development, ***David Snyder***, Penn State Applied Research Laboratory

Efficient wafer size scaleup of quality (010) β-Ga_2O_3 substrates and epi development require extensive materials characterization. Over the past two years, the Applied Research Laboratory (ARL) Electronic Materials and Devices Department (EMDD) has partnered with Northrop Grumman's SYNOPTICS division in support of the Air Force Research Laboratory (AFRL)'s initiative to produce 2-inch epi-ready (010) β-Ga_2O_3 substrates via the Czochralski (Cz) method. As part of this effort, ARL has developed a multitude of techniques specifically for characterizing β-Ga_2O_3 substrates at various stages of processing. In this poster, we highlight these techniques and describe the rapid feedback loop that ARL enables between those working on crystal growth, substrate fabrication, epi growth, and device processing within the expanding β-Ga_2O_3 community.

This poster covers defect mapping and identification, surface metrology, and x-ray characterization. Each of these areas provide essential information about the quality of β-Ga_2O_3 substrates for subsequent epi growth and ultimately device fabrication. We show how etch pit analysis is used to automatically map defects in up to 2-inch wafers in conjunction with the focused ion beam (FIB) approach to prepare cross-sections for imaging the defect structures, including nanopipes. White light interferometry/profilometry and atomic force microscopy (AFM) provide three-dimensional topography information about the wafers, i.e., after polishing, thermal annealing, or free etching. This poster also describes our method for in-situ high-resolution x-ray characterization during fabrication in which a decrease in full-width at half-maximum (FWHM) was correlated with removal amount to optimize β-Ga_2O_3 polishing. Finally, we discuss how x-ray characterization provides information about curvature and substrate/epi layer quality with grazing incidence x-ray diffraction (GIXRD) being utilized to provide extremely surface-sensitive monitoring.

AC-MoP-6 Photoluminescence Spectroscopy of Cr^{3+} in β-Ga_2O_3 and $(Al_{0.1}Ga_{0.9})_2O_3$, ***Cassandra Remple***, *J. Jesenovec, B. Dutton, J. McCloy, M. McCluskey,* Washington State University

Alloying β-Ga_2O_3 with Al_2O_3 to create $(Al_xGa_{1-x})_2O_3$ enables ultra-wide band gap material deep into the UV. Here, photoluminescence (PL) spectra of Cr^{3+} dopant is compared between monoclinic single crystals β-Ga_2O_3, and 10 mol.% Al_2O_3 alloyed with β-Ga_2O_3, denoted β-$(Al_{0.1}Ga_{0.9})_2O_3$ or AGO. Temperature dependent PL properties were studied for Cr^{3+} in AGO and β-Ga_2O_3 from 285 to 16 K. For β-Ga_2O_3at room temperature, the red-line emission doublet R_1 and R_2 occurs at 696 nm (1.78 eV) and 690 nm (1.80 eV) respectively along with a broad emission band at 709 nm (1.75 eV). For both AGO and β-Ga_2O_3 the R_1 line increases in intensity with decreasing temperature. This can be explained by the thermal depopulation effect of the R_1 state, which occurs with increasing temperature. The R_1 and R_2 lines of both materials were observed to blue-shift with decreasing temperature. Additional emission lines emerge at lower temperatures, with β-Ga_2O_3 showing more peaks than AGO. R_1 and R_2 peak parameters such as energy, intensity, width, and splitting were studied as a function of temperature, with significant differences between the two materials.

AC-MoP-7 Surface Relaxation and Rumpling of Sn Doped B-ga2o3(010), ***Nick Barrett***, CEA Saclay, France*; A. Pancotti,* Universidade Federal de Jataí, Brazil*; T. Back,* AFRL*; W. Hamouda, M. Laccheb, C. Lubin, A. Boucly,* CEA Saclay, France*; P. Soukiassian,* Université Paris-Saclay, France*; J. Boeckl, D. Dorsey, S. Mou, T. Asel,* AFRL*; G. Geneste,* CEA, France

We have used X-ray Photoelectron Diffraction (XPD), low-energy electron diffraction (LEED), atomic force microscopy (AFM) and X-ray photoelectron spectroscopy (XPS) to determine the surface structure, chemistry and interplanar relaxation and rumpling in single crystal, Sn-doped b-Ga_2O_3 (010). XPD is a powerful technique, which combines information on local chemistry and atomic structure. By measuring the angular anisotropy of core level intensity one can, by comparison with simulations, deduce the local atomic and chemical environment around each type of emitting atom. The XPS measurements show typical spectra for stoichiometric Ga_2O_3(010). Annealing at 823 K yielded a well-ordered surface with sharp (1x1) low-energy electron diffraction (LEED) pattern. AFM shows unique surface termination with root mean square roughness of 0.1-0.15 nm. The XPD measurements were performed using a laboratory based setup with a monochromatic Al Ka (1486.7 eV) source and a high precision angular manipulator capable of scanning both polar (q) and azimuthal (f) angles. The XPD patterns collected for the Ga $2p_{3/2}$ and O 1s emission. Surface interlayer relaxation up to 8% of the bulk interplanar distance and 0.11–0.14 Å rumpling are observed at the β-Ga_2O_3(010) surface. At the surface, the oxygen atoms shift toward the vacuum with respect to the gallium atoms. The rumpling decreases to zero and and the interplanar distance reaches the bulk value of 1.52 Å by the sixth atomic layer. The surface structure agrees with that predicted by first-principles density functional theory calculations which, in addition, suggest a significant band gap narrowing of ≈1 eV in the surface layer, due to surface states spatially localized on surface oxygen atoms of O_{II} type.

A. Pancotti *et al. Phys. Rev. B***102**, 245306 (2020)

AC-MoP-8 Probing Vacancies and Hydrogen Related Defects in β-Ga_2O_3 with Positrons and FTIR, ***Corey Halverson***, *M. Weber, J. Jesenovec, B. Dutton, C. Remple, M. McCluskey, J. McCloy,* Washington State University

β-Ga_2O_3 is a promising material for power electronics. Ubiquitous hydrogen and vacancies strongly influence the electronic properties of these materials. Methods to detect and characterize them are desirable. Fourier Transform Infrared Spectroscopy (FTIR) and Positron Annihilation Spectroscopies (PAS) both have been use with success. Here, they are applied to investigate the hydrogen content in gallium vacancies particularly in the top 6 micrometers below the surface. A Czochralski grown bulk single crystal is explored before and after repeated annealing in vacuum with the main goal to remove hydrogen from the sample. The hydrogen reduction method was first applied with success on single crystal ZnO samples. β-Ga_2O_3 is sealed in an evacuated hydrogen-depleted quartz tube together with thin foils of titanium. Before sealing the ampoule, the quartz and the titanium are heated repeatedly to drive out trapped hydrogen. Then β-Ga_2O_3 is annealed at 850C to 900C for up to 8 days while maintaining the Ti-foil at the other end of the ampoule at room temperature. Depth resolved PAS Doppler broadening data reveal significant reduction in the effective positron diffusion length and small changes in the vacancy sensitive width of the annihilation line (S-parameter). These changes reversed by subsequent annealing in hydrogen. The positron data will be presented and correlated with bulk FTIR measurements on the same sample. This work generously supported by the Air Force Office of Scientific Research under award number FA9550-18-1-0507 monitored by Dr. Ali Sayir.

AC-MoP-9 Evolution of Anisotropy and Order of Band-to-Band Transitions, Excitons, Phonons, Static and High Frequency Dielectric Constants Including Strain Dependencies in Alpha and Beta Phase ($Al_xGa_{1-x})_2O_3$, ***Megan Stokey***, University of Nebraska-Lincoln*; R. Korlacki, M. Hilfiker, T. Gramer,* University of Nebraska - Lincoln*; J. Knudtson,* University of Nebraska-Lincoln*; S. Richter,* Lund University, Sweden*; S. Knight,* Linköping University, Sweden*; A. Mock,* Weber State University*; A. Mauze, Y. Zhang, J. Speck,* University of California Santa Barbara*; R. Jinno, Y. Cho, H. Xing, D. Jena,* Cornell University*; Y. Oshima,* National Institute for Materials Science, Japan*; E. Ahmadi,* University of Michigan*; V. Darakchieva,* Lund University, Sweden*; M. Schubert,* University of Nebraska - Lincoln

The rhombohedral alpha and monoclinic beta phases of gallium oxide both make promising candidates for ultra-wide bandgap semiconductor technology. Of particular interest are alloyed films and the evolution of anisotropic optical properties with respect to both alloy composition and strain induced effects. Here, we study alpha and beta phase $(Al_xGa_{1-x})_2O_3$ via a combined density functional theory and generalized spectroscopic ellipsometry approach across a range of alloying. Infrared-active phonon properties, static dielectric constants and midband gap indices of refraction are quantified.[1,2,3] Strain and alloying effects are shown and compared to previous theoretical works.[4] Band-to-band transitions, excitons, and high-frequency dielectric constants are also investigated in the visible to vacuum-ultra-violet (VUV) spectral range.[5,6,7,8] We identify a switch in band order where the lowest band-to-band transition occurs with polarization along the ordinary plane in α-Ga--$_2$O-$_3$ whereas for α-Al_2O_3 the lowest transition occurs with polarization in the extraordinary direction. With this, we present the most comprehensive picture of optical properties' evolution along composition and strain currently available.

[1] M. Stokey, *et al.,* Phys. Rev. Materials 6, 014601 (2022)

[2] M. Stokey, *et al.,* Appl. Phys. Lett. 120, 112202 (2022)

[3] The influence of strain and composition on the infrared active phonons in epitaxial β-(AlxGa1-x)2O3 deposited onto (010) β-Ga2O3; M. Stokey, *et al.*, *In Preparation*

[4] R. Korlacki, *et al.*, Rev. B 102, 180101(R) (2020)

[5] M. Hilfiker, *et al.,* Appl. Phys. Lett. 118, 062103 (2021)

[6]Anisotropic dielectric function, direction dependent bandgap energy, band order, and indirect to direct gap cross over in α-(AlxGa1-x)2O3 (0≤x≤1); M. Hilfiker, *et al.,* Appl. Phys. Lett. XX, XX (2022)

[7] M. Hilfiker, *et al.,* Appl. Phys. Lett. 119, 092103 (2021)

[8] M. Hilfiker, *et al.,* Phys. Lett. 114, 231901 (2019)

AC-MoP-10 Photoluminescence Mapping of Gallium Oxide and Aluminum Gallium Oxide Epitaxial Films, ***Jacqueline Cooke**, P. Ranga,* University of Utah*; J. Jesenovec, J. McCloy,* Washington State University*; S. Krishnamoorthy,* University of California at Santa Barbara*; M. Scarpulla, B. Sensale-Rodriguez,* University of Utah

The mechanisms generating photoluminescence (PL) emissions from gallium oxide (Ga_2O_3) and aluminum gallium oxide (AGO) have been under intense scrutiny. In general, spectrally-resolved PL is used to characterize the defects leading to radiative recombination processes within a specific material. In this regard, the PL spectra for β-Ga_2O_3 has generally been deconvoluted in three emission bands: UV, blue, and green. So far, the intense debate in defining the defects and phenomenological explanations of electronic processes that cause Ga_2O_3 and AGO emissions have only explored point defects as the potential source for the PL emission leaving out whether extended defects could affect PL. Because of the strong electron phonon coupling, emission peak shapes from any defect are expected to be very broad and not have a simple functional peak shape; these attributes make it challenging to fit spectra uniquely. Because of this, there is little chance of directly assigning PL spectral features unambiguously to specific β-Ga_2O_3 point defects from PL alone.

Here, a systematic PL study on multiple series of β-Ga_2O_3 and AGO epitaxial thin films and bulk single crystals is performed. Spectrally-resolved PL, PL intensity mapping, scanning electron microscopy (SEM), atomic force microscopy (AFM), and transmission electron microscopy (TEM) were used along with literature to show that extended structural defects largely determine the PL emission from many samples of β-Ga_2O_3 and AGO. Homogeneous films with no extended defects or stacking faults and bulk crystals yield PL emission with a dominant UV peak, while samples of lesser crystalline quality exhibiting stacking faults, rotation domain boundaries, and other such extended defects do not exhibit a UV emission but rather exhibit blue.

Si-doped homoepitaxial (010) β-Ga_2O_3 samples yield homogeneous crystalline films with a low density of extended defects and an unshifting dominant UV emission in PL. A bulk (-201) β-Ga_2O_3 sample shows a dominant UV emission while heteroepitaxial and homoepitaxial (-201) β-Ga_2O_3 films show dominant blue PL emission (due to the films' poor quality as seen in PL mapping, AFM and SEM). An AGO series shows consistent blue centered PL for AGO grown on both sapphire and β-Ga_2O_3 (also due to the films' poor quality as seen in TEM, PL mapping, AFM and SEM). Lastly, an improved (reduced number of extended defects) 10% AGO film grown on (010) bulk β-Ga_2O_3 show a shift in the PL spectrum with a now UV dominant emission. PL mapping shows that areas of extended defects emit blue PL while the crystal film emits UV PL within the sample.

AC-MoP-12 Non-Destructive Characterization of Annealed Si-Implanted Thin Film β-Ga_2O_3, ***Aine Connolly**, K. Gann,* Cornell University*; S. Tetlak,* Air Force Research Laboratory*; V. Protasenko,* Cornell University*; M. Slocum, S. Mou,* Air Force Research Laboratory*; M. Thompson,* Cornell University

Selective doping by ion implantation is critical for small-scale device fabrication in wide-bandgap materials such as β-Ga_2O_3, requiring understanding of both lattice damage due to implantation and subsequent lattice recovery during thermal annealing. Carrier activation, mobility, and diffusion are known to be critically coupled to annealing temperature, time and ambient as well as intrinsic and extrinsic film properties. Electrical measurements provide one measure of annealing behavior, but are limited due to the need for direct metal contacts, the intrinsic spatial averaging, and the inability to directly measure lattice recovery or observe associated defects. To address these limitations, we present Raman spectroscopy and photoluminescence (PL) measurements of β-Ga_2O_3 implanted and annealed samples, evaluating their ability to local carrier activation and lattice recovery non-destructively.

Recent studies of bulk doped β-Ga_2O_3 [1] have identified additional Raman peaks in samples with carrier concentrations above the Mott criterion. To determine if these peaks are directly linked to carrier activation, we examined a wide range of Si-implanted ($5x10^{19}$ cm^{-3}) and annealed samples using a laterally localized Raman probe. A peak at 285 cm^{-1} was observed above the noise floor in several samples, with the intensity increasingly linearly with sheet carrier density (N_s). The effect of the lattice quality (recovery) on the relative intensities of other Raman peaks was also analyzed.

Previous β-Ga_2O_3 studies suggest that an increase in activated dopants decreases the total PL, due to the higher defect density and the resultant probability of electrons reaching non-radiative recombination centers [2]. PL behavior of the Si-implanted samples was thus measured as a function of lattice recovery with (N_2 ambient) and without (O_2 ambient) carrier activation. The Pl signal decreased dramatically after implantation, with partial recovery after thermal anneals and lattice damage recovery. Negative correlation was observed between the PL intensity and carrier activation. Correlations between PL and cathodoluminescence were also measured.

[1] Fiedler, A., Ramsteiner, M., Galazka, Z., and K. Irmscher. Raman scattering in heavily donor doped B-Ga2O3. *Appl. Phys. Lett.* 117, 152107 (2020)

[2] Shimamura, K., Villora, E.G., Ujiie, T., and K. Aoki. Excitation and photoluminescence of pure and Si-doped B-Ga2O3 single crystals. *Appl. Phys. Lett.* 92, 201914 (2008).

Author Index

Bold page numbers indicate presenter