

Tuesday Afternoon Poster Sessions

Advanced Surface Engineering Division
Room: East Exhibit Hall - Session SE-TuP

Advanced Surface Engineering Poster Session

SE-TuP2 Fabrication of Multilayer X-ray Gratings on Staircase Substrates, C. Liu, Argonne National Laboratory, S. Lynch, National Heart, Lung, and Blood Institute, L. Assoufid, Argonne National Laboratory, H. Wen, National Heart, Lung, and Blood Institute

Classical hard x-ray transmission gratings fabricated using lithography are limited by a small aspect ratio of less than 20 when the grating periods are smaller than 2 microns. State of the art X-ray phase contrast imaging techniques require high density transmission gratings with smaller periods and higher aspect ratio to cover larger energy range for thicker samples. This problem may be addressed with a sliced multilayer technique, similar to that used in multilayer Laue lenses and multilayer transmission mask gratings. To increase the acceptance area of the grating, it was proposed [1] to use a thin Si substrate that is asymmetrically etched to a staircase with each stair supporting a multilayer parallel to its surface. Using an X-ray beam shining through the layers at an oblique angle to the substrate and parallel to the layer surfaces, one hopes to have a large-area transmission grating with small multilayer periods. The first fabrication test is completed using W/Si multilayers with dc magnetron sputtering deposition. The layer thickness d is designed to be (stair height)/ $2N$, where $2N$ is the total number of layers. Preliminary results and challenges are presented.

[1] S. K. Lynch and H. H. Wen et al. "Multilayer-Coated Micro-Grating Array for X-Ray Phase-Contrast Imaging," SPIE Proceedings 2011, submitted.

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SE-TuP3 Investigations on Physical Processes for Low Temperature Plasma Activated Wafer Bonding, T. Thomas Plach, K. Hingerl, Johannes Kepler University, Austria, V. Dragoi, M. Wimplinger, EV Group, Austria

Direct wafer bonding is a straightforward method of directly connecting wafers, with suitable (in terms of micro-roughness, flatness and cleanliness) surfaces, permanently to each other, by bringing them into contact and subsequently annealing them or simply storing them. The conventional process for hydrophilic oxidized Silicon surfaces (native as well as thermal oxide) is well understood, and explained the following way [1]:

Up to 100°C the substrate surfaces are held together via van der Waals interaction which is mediated by a few monolayers of water. In the range of 100-200°C the water diffuses away from the interface both along the interface and through the oxide into the crystalline bulk, where it reacts with the silicon and forms oxide. The increase of the bond strength from 50% to 100% of Si bulk strength is usually attributed to a closing of gaps at the interface, which starts at the softening temperature of the thermal oxide at around 900-1000°C, depending on whether dry or wet oxide was used.

Low temperature plasma activated direct wafer bonding is a process that lowers the required annealing temperatures necessary for reaching high bond strength. One example for such an improvement is a pair of native oxide – thermal oxide wafers, where bulk strength can be realized by plasma activation with subsequent annealing at temperatures below 200°C. At this temperature conventional wafer bonding reaches half of Si bulk strength, and is limited by gaps at the bonding interface. The mechanism behind this improvement compared to the non activated process is still under discussion.

To clarify the mechanism for this commercially available process, different bonding experiments were performed to evaluate the lifetime of the surface activation and the achievable bond strength when varying some of the boundary conditions of the process (substrates with different orientations, various plasmas, and lowering the annealing temperature).

By partly covering wafers during plasma activation, comparisons between the activated and non-activated regions could be made on single wafers. Therefore the influence of the slightly different substrates could be eliminated. Such wafers were then analyzed by atomic force microscopy, by spectroscopic ellipsometry, by Auger analysis and by X-ray photoelectron spectroscopy.

Finally a model for the mechanism, which was derived from the model for the conventional bonding process, and which explains the experimental results will be presented.

[1] Q.-Y. Tong, U. Gösele, Semiconductor Wafer Bonding: Science and Technology, Wiley, (1998)

SE-TuP4 Crystalline Thin Film Materials with Ultra-Low Thermal Conductivity, C. Muratore, V. Varshney, A. Reed, J. Hu, J. Bultman, T. Smith, A.A. Voevodin, Air Force Research Laboratory

Transition metal dichalcogenide (TMD) crystals are characterized by their distinct layered atomic structures, with strong covalent bonds comprising each layer, but weak van der Waals forces holding the layers together. The relationship between chemical bonding in a material and its thermal conductivity (k) is well-known, however the thermal properties of TMD thin films with such highly anisotropic chemical bonds have only recently been investigated with remarkable results, such as ultra-low k_z . Materials with very low thermal conductivity in the z-axis, but higher k_x and k_y have potential as next-generation thermal barrier or heat spreading materials. Molecular dynamics (MD) simulations predicted $k_x=k_y=4k_z$ for perfect TMD crystals (MoS₂ in this case). Experiments to determine $k_{x,y}$ and k_z were conducted by developing processes to grow crystalline TMD thin film materials with strong (002) (basal planes parallel to surface) or (100) (perpendicular basal planes) preferred orientation. Initially, no correlation between structure and thermal conductivity was apparent, as water intercalation and reactivity to ambient air resulted in a thermal "short-circuit" across basal planes, such that the time between deposition and k measurement had a stronger impact on thermal conductivity than film orientation. Experiments to measure intrinsic thermal conductivity of MoS₂ revealed values approximately one order of magnitude lower than those predicted using MD simulations, however, measurement of $k_x=k_y=4k_z$ was consistent with simulation results. Simulations to evaluate the dependence of thermal conductivity on grain size were evaluated, which correlated well to measured values. Comparison of measured k values for MoS₂, WS₂, WSe₂ and other materials with analogous crystal structures are discussed in the context of the Slack Law, which accounts for intrinsic physical properties of the crystal, but not film microstructure. Alternatives to TMDs, with less environmental sensitivity, will also be illustrated.

SE-TuP5 Investigation on the Nanoindentation Research Trend in the Surfacing and Joining Technologies, H.T. Kim, S.C. Kil, Korea Institute of Science and Technology Information, Republic of Korea

The research trend on the nanoindentation testing in the surfacing and joining/welding technologies has been reviewed. The increasing interest in the mechanical properties of modern surfacing and joining/ welding structures is placing stringent demands on the manufacturing techniques and performance requirements, and the manufacture employs the high quality and efficiency testing devices to produce best quality products. Nanoindentation testing which enables to evaluate hardness, yield/tensile strength, and residual stress plays an important role in measuring the mechanical properties for relatively small and local volumes, so that it is very useful in obtaining profiles or maps of mechanical properties in the narrow zone of coating and HAZ of weldment. This has led to an increasing attention to the field of surfacing and joining/welding structures. This paper covers recent technical trends of nanoindentation testing technologies of surfacing and joining/welding including the COMPENDEX DB analysis of published papers, research subject and research institutes.

Authors Index

Bold page numbers indicate the presenter

— A —

Assoufid, L.: SE-TuP2, 1

— B —

Bultman, J.: SE-TuP4, 1

— D —

Dragoi, V.: SE-TuP3, 1

— H —

Hingerl, K.: SE-TuP3, 1

Hu, J.: SE-TuP4, 1

— K —

Kil, S.C.: SE-TuP5, 1

Kim, H.T.: SE-TuP5, **1**

— L —

Liu, C.: SE-TuP2, **1**

Lynch, S.: SE-TuP2, 1

— M —

Muratore, C.: SE-TuP4, **1**

— R —

Reed, A.: SE-TuP4, 1

— S —

Smith, T.: SE-TuP4, 1

— T —

Thomas Plach, T.: SE-TuP3, **1**

— V —

Varshney, V.: SE-TuP4, 1

Voevodin, A.A.: SE-TuP4, 1

— W —

Wen, H.: SE-TuP2, 1

Wimplinger, M.: SE-TuP3, 1