Laser-induced-crystallization: a new perspective on single-crystal multi-element semiconductor films for versatile applications from electronics to photonics

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The use of excimer laser with a Gaussian-beam profile frequently adopted in attempts of crystallizing non-single-crystal (NSC) films is often referred to as laser-induced crystallization (LIC). Conventional LIC offers films made of single-element semiconductors (e.g., Si and Ge) for applications such as thin-film-transistor; however, it merely yields polycrystal films rather than single-crystal ones. While conventional LIC with single-element semiconductors continues to advance, harnessing LIC to extend its use to multi-element semiconductors will unlock applications currently not even conceivable, for instance, power devices and light emitting devices on flexible substrates with high thermal conductivity.
In this presentation, selective area crystallization of NSC copper(II) oxide (CuO) using distinctive LIC is described by illustrating a successful demonstration of producing single-crystal copper(I) oxide (Cu_2O). In the demonstration, a unique LIC system with diode laser, rather than excimer laser, and optics that produces a chevron beam-profile, rather than a Gaussian-beam profile, was used. The crystallization was verified by witnessing a transition from a NSC phase of CuO to a single-crystal phase of Cu_2O. The phase transition embraces several distinctive scenarios. For instance, a large number of crystallites that densely form grow independently and merge, and simultaneously, solid-state growth that takes place as the merging proceeds reduces the number of grain boundaries, and/or a small number of selected crystallites that sparsely form grow laterally, naturally limiting the number of grain boundaries. Provided with the experimental findings, a theoretical assessment based on a cellular automaton model, outfitted with the behaviors of localized recrystallization and stochastic nucleation, was developed. The theoretical assessment semi-quantitatively describes the dependence of vital crystallization features observed in the experiment on laser beam geometry. The theoretical assessment predicts that crystallinity primarily depends on a geometrical profile with which melting of non-single-crystal regions takes place along the laser scan direction. Concave-trailing profiles yield larger grains, leading to single-crystal, while convex-trailing profiles produce smaller grains, leading to polycrystal. Our study casts light on the fundamental question *Why does a chevron-beam profile succeed in producing single-crystal while a Gaussian-beam profile fails?* The project will be further extended to other materials including group III-V compound semiconductors in collaboration with Dr. Paola Prete (IMM-CNR, Lecce) and Prof. Nicola Lovergine (Uni-Salento).

Bio: Prof. Kobayashi joined UCSC in April 2008. Prior to UCSC, he was involved in developing electronic materials for ultra-high density resistive-switching devices to build memories and logic required for future computing systems at *Hewlett-Packard Laboratories*. He was also involved in semiconductor nanowire photonics for optical interconnect necessary for advanced computing systems. Prior to Hewlett-Packard Laboratories, Prof. Kobayashi worked at *Lawrence Livermore National Laboratory (LLNL)*, developing semiconductor materials for both ultra-high speed diagnosis systems required for the National Ignition Facility funded by the U.S. Department of Energy and the optical code division multiple access (optical-CDMA) funded by Defense Advanced Research Project Agency (DARPA). Prof. Kobayashi worked also at *Agilent Laboratories*, developing light emitting diodes, vertical cavity surface emitting lasers, and hetero bipolar transistors for both ultra-wide band fiber-optics and wireless communications. Nobby earned his Ph.D. degree in Materials Science from the University of Southern California in 1998.