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Multiple Ion Plasma FIB Application for Editing Laser Chips to Enable Live Monitoring of the Semiconductor Material Failure.

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Most dramatic changes in the internal structure of the semiconductor materials occur when the materials are energized, or high current passes through the device. It is a big challenge though to observe the gradual degradation directly. For understanding the failure mechanism and making better devices it is important to know when and at what sequence the chain of events, leading to the failure of the entire device starts.

There are many well established direct and indirect performance control techniques, which are used by the R&D and Quality Assurance Engineers for producing high quality laser chips and bars. For failed and/or aged chips and bars there are many post-failure analysis and cross-sectioning methods, which consist of isolating specific areas and analyzing then for the structural changes, compositional deviations, mechanical integrity, etc. [1].

Direct observation of the processes inside the semiconductor material while it transforms the electricity into the light helps to witness the failure precisely at the moment when it happened. In this paper we present the results of our recent experiment on modifying the fully functioning lasers by the plasma FIB and testing them directly under the electroluminescence surveillance camera.

In order to add the direct access point to our laser testing process we have added the process for opening the windows on otherwise blanked sections of the functioning laser chips for the direct observation of the electroluminescence changes in operating life test mode. Prior to that experimental approach we had our life test system registering all optical and electrical parameters until they fail. After the failure the post-mortem Electroluminescence was performed on the delaminated devices and used just to confirm the failure mode. Adding the Multiple Ion Plasma FIB (Thermo Scientific™ Helios Hydra DualBeam) capability for editing laser chips and bars allows us to literally witness the failure while our devices are energized.

Such experiments were demonstrated by another lab, which was making the laser chips with the lithographically defined windows. [2, 3] Focused plasma became available for editing relatively large areas with high precision became available only recently [4] and we have utilized it for that work. Our development [5] allows to take any laser chip or laser bar and cut the window on the n-side contact.
All devices were made and tested at our production facility. For opening windows, we were using the equipment at the University of Oregon.

Figure 1 demonstrates the resulting laser bar with the window for monitoring Electroluminescence. As a reference we are using non-edited devices from the same batch.

The method opens the possibilities for deep study of the processes inside the laser, visualization of the degradation and catastrophic failures. On **Figure 2** we show the series of Electroluminescence micrograph's series, taken every half a second during the active failure event [6].

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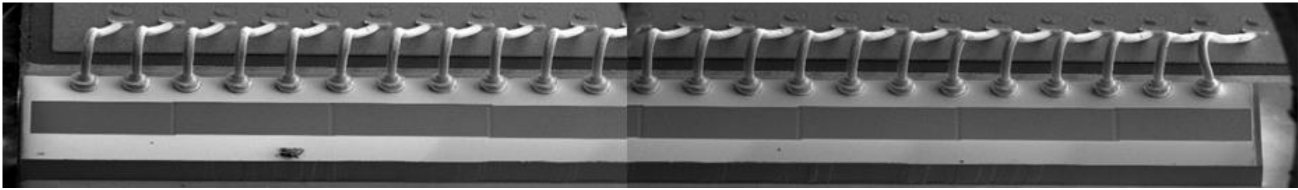

Figure 1. Laser chip with the window opened by the Plasma FIB to allow access for the EL camera

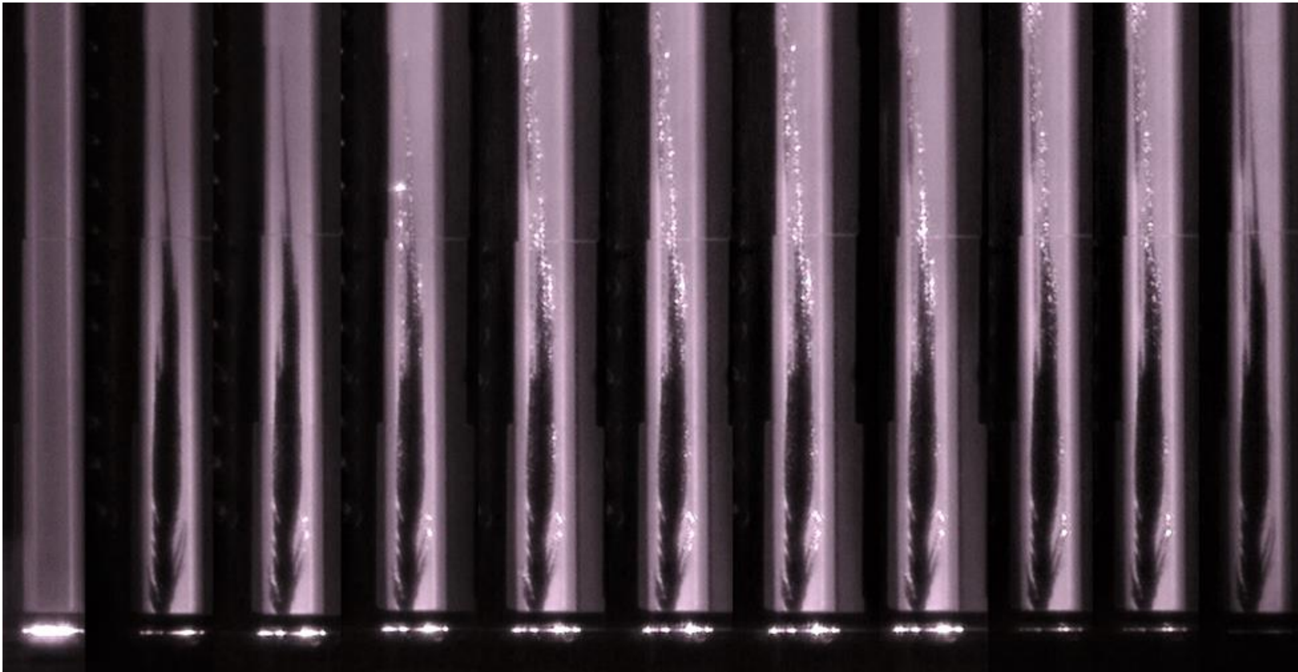

Figure 2. Sequence of the failure development imaged at half a second time lapse.

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[6] Authors acknowledge CAMCOR lab at the University of Oregon for providing the opportunity on using the Ion Plasma FIB and keeping us as the users. Special thank you to the FIB manager Valerie Brogden for her assistance in remote access sessions on the FIB.

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