

E-beam local heating with SEM: a new tool for e-beam nanopatterning.

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The heating induced by a SEM electron beam incident on a surface is a well-known phenomenon, which has already been studied, especially to account for possible sample damage. Under typical SEM measuring conditions (with beam current $< 10\text{ nA}$), the local rise in temperature (ΔK) is limited to few kelvins. However, under suitably arranged conditions, the local ΔK can readily reach the hundreds of kelvins range, and can be used to induce local phenomena even in a conventional SEM. These conditions include a suitable substrate with moderate thermal conductivity (oxides, chalcogenides, ...) and high electron beam current (I_b , typically $> 50\text{ nA}$). Regarding the e-beam energy (E_b), lower values result in higher ΔK (at unchanged I_b) and sharper heated area, due to the reduced interaction volume [1,2].

In this contribution, we present examples of systems in which a local modification has been produced by Focused E-Beam induced Heating (FEBH): melting of In nanoparticles, semiconductor-to-metal transition of V_2O_5 , etching of Bi_2Se_3 and Bi_2Te_3 . The effectiveness of the FEBH approach is enhanced when combined with a heating stage for in-situ tuning of the global substrate temperature (Assisted-FEBH, A-FEBH, Figure 1a). With A-FEBH it is possible to greatly extend the accessible temperature range and to optimize the patterning conditions. For example, while with FEBH it is possible to etch only the surface of thick Bi_2Se_3 crystals, and only for $E_b \geq 15\text{ keV}$, with A-FEBH this is also possible at 5 keV (Figure 1b), which enables also the etching of thin flakes and with higher resolution ($\sim 100\text{ nm}$, Figure 1c) [2].

Finally, to effectively drive FEBH (or A-FEBH) in the patterning process, it is necessary to correctly evaluate the locally induced temperature and develop a reliable and readily usable tool for temperature prediction. Despite several models already published (most recent in [3]), the topic is still under development. In this contribution we present our results obtained combining Monte Carlo simulations (CASINO) for e-beam energy deploy, and finite element calculations (COMSOL) for heat transport.

In summary, (A-)FEBH (which can be coupled with other techniques, e.g. EBID), establishes a new tool for e-beam nano-patterning, adding a “temperature axis” and enabling additional local phenomena.

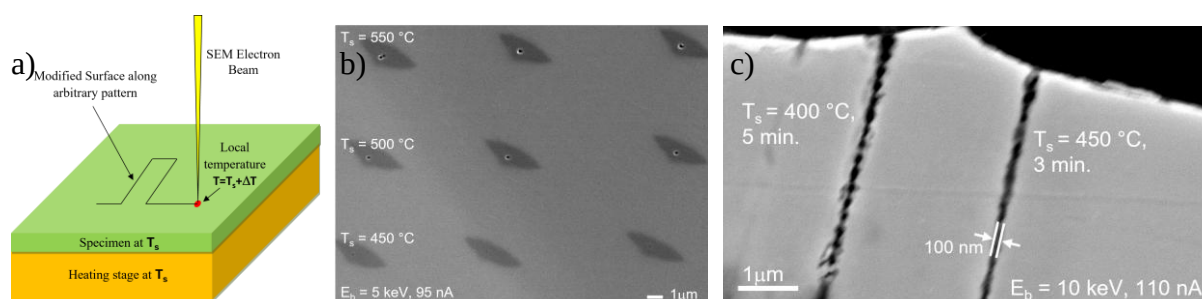


Figure 1. a) schematic of A-FEBH process. b) holes produced by A-FEBH on Bi_2Se_3 crystal surface (5 keV , 95 nA , 60 sec) at different heating stage temperatures T_s . c) trenches etched in a Bi_2Se_3 flake.

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References

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