Ultrafast growth of metallic deposits by focused ion beam irradiation under cryogenic conditions (Cryo-FIBID)

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Recently, a new technique named Focused Ion Beam Induced Deposition under cryogenic conditions (Cryo-FIBID) has been proposed and applied to grow metallic W-C deposits[1]. In this technique, sketched in Figure 1, a condensed precursor layer delivered through a gas-injection system (GIS) is condensed on a cold substrate. After irradiation with a focused ion beam and substrate heating up to room temperature, a deposit forms with the same shape as the scan performed. The main advantage of this technique is the enhancement of the growth speed up to three orders of magnitude when compared to standard FIBID processing carried out at room temperature[2]. In the present contribution, we will show the application of Cryo-FIBID to other precursors beyond $W(CO)_6$, with the aim of obtaining ultrafast growth of metallic deposits, and eventually additional functional properties. In particular, we will discuss the results obtained using the $(CH_3)_3Pt(CpCH_3)$ precursor, which is commonly found in commercial FIB equipment. As shown in Figure 2, a 30 nm-thick precursor condensed layer in combination with a 30 kV Ga FIB is suitable to create Pt-C deposits that exhibit quasi-metallic behavior. In Figure 3, the obtained results for Cryo-FIBID are put in perspective, comparing the required charge dose with other lithography techniques[3]. Remarkably, Cryo-FIBID is very convenient to grow deposits at the micro- and nano-scale, given its high growth rate and the minimized ion-induced damage. In the last part of the talk, we will introduce research in progress in which Cryo-FIBID is used to grow metallic deposits by condensing other precursors beyond $W(CO)_6$ and $(CH_3)_3Pt(CpCH_3)$.

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[1] R. Córdoba, P. Orús, S. Strohauer, T. Torres, J. M. De Teresa, Sci. Repts. **9**, 14076 (2019)
[2] J. M. De Teresa, P. Orús, R. Córdoba, P. Philipp, Micromachines **10**, 799 (2019)
[3] A. Salvador-Porroche, S. Sangiao, P. Philipp, P. Cea and J. M. De Teresa Nanomaterials **10**, 1906 (2020)

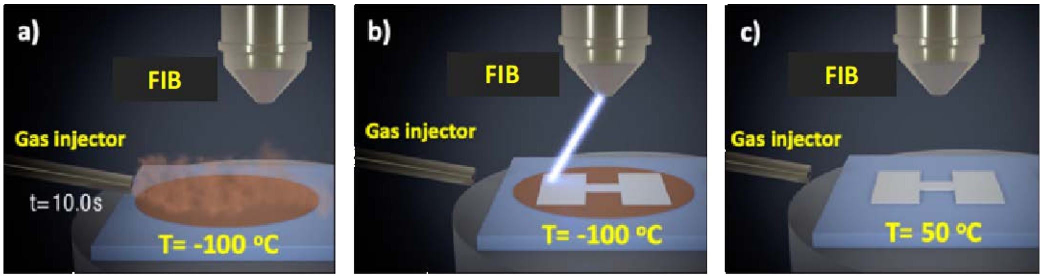

Figure 1: Sketch with the three steps of Cryo-FIBID growth: a) precursor condensation on a cold substrate; b) FIB irradiation; c) substrate heating

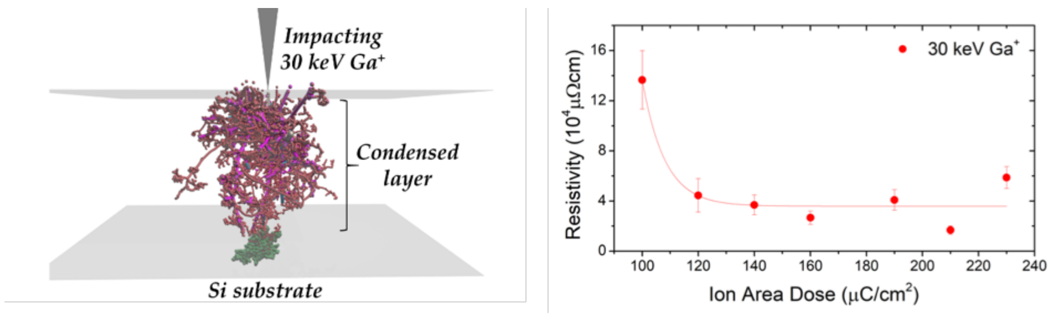

Figure 2: Left: SDTRIMSP simulations on the ion-induced decomposition of a 30 nm-thick $(CH_3)_3Pt(CpCH_3)$ condensed layer by a 30 kV Ga beam. *Right:* Resistivity as a function of ion dose for a 30 nm-thick $(CH_3)_3Pt(CpCH_3)$ condensed layer.

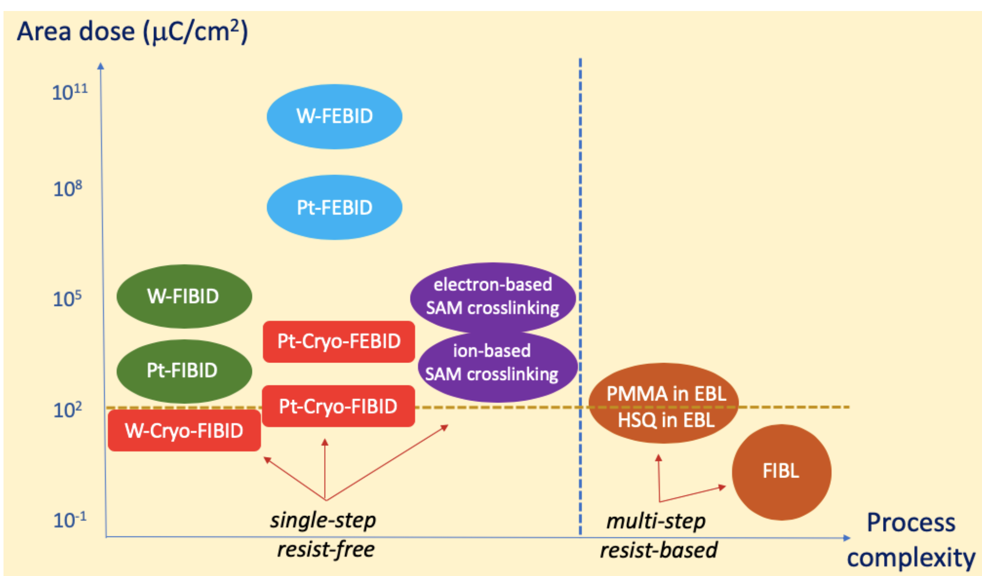

Figure 3: Comparison of charge-particle-based lithography techniques in terms of the required irradiation dose: The cryo-FIBID deposits are those that require the lower irradiation doses per area among the single-step techniques. SAM stands for self-assembled monolayer, PMMA and HSQ are two popular resists, and FIBL stands for focused ion beam lithography.