IMEC's AttoLab adaptation of ultrafast pump probe spectroscopy and lensless imaging techniques to study nanodevice fabrication and high energy radiolysis of photoresists

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Information transfer by exposure of photoresist to form temporary masks of circuitry for pattern transfer into an underlying substrate is the cornerstone of the entire semiconductor industry. As device circuitry became smaller the actinic wavelength became smaller and more energetic. Today, semiconductor lithography is introducing 13.5 nm, extreme-ultraviolet lithography to print features at the nanometer scale in high volume manufacturing. In 2019 imec announced plans at SPIE Advanced Lithography to build the AttoLab with joint development partners KMLabs and SPECS. This lab is the first industrial laboratory capable of watching, in real time, the ultrafast dynamics of photoresists following 13.5 nm, EUV exposure, and for emulating high-numerical-aperture (high-NA) exposure on 300-mm wafers using two-beam EUV interference. First light, at imec, occurred in February 2020 and first imaging using a Lloyd's Mirror interference lithography (LMIL) apparatus on the AttoLab low-intensity spectroscopy beamline began in December 2020, with successful interference imaging of 20 nm pitch lines and spaces in early January 2021. These results were reached with an estimated 3 femtosecond temporal coherence, and we showed that we have sufficient beam pointing stability and mode quality, with low vibration-induced image blur even during protracted exposure times exceeding 300 seconds. These attributes enable not just lithography but also spectroscopy for studying ultrafast exposure dynamics that influence final resist chemistry and characterization methods such as EUV radiometry and coherent diffractive imaging. With these unique tools, we can help material suppliers develop better resists and masks for high-NA imaging and supply benchmark experiments for next generation lithography modeling for process and optical proximity correction (OPC) design. Finally, with the lessons learned with the LMIL, we have paved the way for printing pitches below 22 nm on full wafers using our high-intensity lithography beamline that is currently under construction with expected first light in May/June 2021.