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Advanced Low Temperature Processes at the University of Illinois

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Most contemporary applications of plasmas involve using a low temperature plasma to either deposit, remove or modify a surface. This means that plasma material interactions play an integral role in the modification and manufacturing of modern day components. For example, not only in the microchip processing industry but also in EUVL lithography and surface modification. The Center for Plasma Material Interactions (CPMI) at the University of Illinois Urbana-Champaign (UIUC) has been at the forefront of developing many of the plasma material processes that go into modifying surfaces. The next generation of lithography is here. EUV (13.5 nm) is now in high volume manufacturing, allowing patterns to be made on semiconductor wafers at the 10 and 7 nm nodes in one pass, as opposed to quadruple patterning (4 passes) with the standard 193nm light. This ushers in the potential beyond mere pattern shrinkage, for advance design rules which will even further increase the density and speed of integrated circuits. The major difficulty with the EUV sources is lifetime of the components, and therefore throughput of wafers which can be patterned. The EUV light is generated by 25kW of laser power hitting a 30-micron-diameter droplet of molten tin 50,000 times per second, creating a plasma of Sn+8 to Sn+12 ions which then radiate a few percent of the power into the EUV 13.5 nm band. This light is emitted in all directions, and some of it is incident on a multi-layer mirror which reflects the light toward an intermediate focus on the way to the chip. This mirror is quickly covered with errant Sn atoms from the droplets, and damaged by energetic Sn ions. Current mirrors at use in industry lose 50% of their reflectivity in only 3 months and need to be replaced. Research work at CPMI is centered on finding a way to continually clean the mirror surface, and therefore preserve the needed EUV reflectivity. Experiments have shown that it is possible to create a plasma-covered mirror which may never need to be replaced, saving the industry millions of dollars per replacement and doubling throughput. We are also investigating a plasma-enhanced, laser-induced surface conversion process for forming TiN on TiO$_2$ surfaces. This process uses a pulsed femtosecond laser to provide localized energy deposition at the Ti surface, along with a secondary plasma to supply reactive N species. Chemical based processes are often used to promote the adhesion and corrosion resistance of light weight metals used in the automotive industry. We have been able to show that an atmospheric plasmas system is capable of applying coatings to these materials and is capable of further improving the performance with a much smaller chemical footprint. Covetic materials, defined as carbon infused metals, are conveniently casted by thermal and electrical reactions1. Our new research focuses on the study of covetic-like materials using atmospheric pressure plasma that has similar properties to covetic materials. Chrome based galvanic barriers are often used on tactical vehicles and weapons to meet the rigorous performance requirements set by the Depart of Defense. However, the safe disposal of hazardous, and often carcinogenic, waste generated in the process puts a significant financial burden on the Department of Defense. The present work seeks to design and develop an alternative atmospheric pressure plasma based process with a much lower chemical footprint as an alternative to the current state of the art. Multi-layer zirconia-silica coatings have been deposited with the goal of utilizing zirconia as a passivation layer and silica as a adhesion promoter for the subsequent coatings. The experiments have shown that atmospheric pressure plasma jets are capable of depositing uniform coatings with of thickness of 100 - 200 nm with small carbon content. This presentation will describe some of the work and present results from these experiments.

References

[1] H. M. I. Jaim, *et. al,* Carbon, **111**, (2017) 309.