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Near surface Langmuir probe characterization of silver reduction via plasma irradiation

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Metal catalyst preparation can be realized by plasma technology. These catalysts can be widely used for environmental treatment and energy production applications.[1] Studies on the reduction of metal ions using plasma began with the utilization of hydrogen (H_2) as the carrier gas, as it was believed that the highly reactive H_2 plasma could produce species required for the reduction process to occur.[2] With time, more studies on different plasmas for the reduction of noble metals from noble metal precursors were explored and it became apparent that the plasma reduction process is also possible with the use of other inert gases such as argon (Ar) and helium (He). Different types of plasmas and plasma devices have been reported for the reduction of metal NPs.[1-3]

Plasma contains many active species. Electrons, positive ions, negative ions, neutrals, and radicals present in the plasma may lead to a rapid reduction of metal compounds. Due to its complex and dynamic nature, there is difficulty in determining which species in the plasma are influential, hence the mechanism of plasma-based reduction reactions remains unclear.[4]

Langmuir probe is one of the simplest but the most straightforward method for *in situ* characterization of the local plasma.[5] In this study, the temporal evolution of the plasma characteristics near the surface holding Ag compound during plasma-induced reduction of Ag was investigated.

Prior to plasma exposure, $AgNO_{3(aq)}$ was pipetted on silicon (Si) substrates. The system was evacuated to base pressure (5×10^{-3} Pa) to allow solvent evaporation and retain the Ag precursor on the substrate. 1.0 Pa Ar was then introduced into the system. A tungsten (W) wire (l = 50 mm, d = 0.30 mm) was resistively heated to produce a discharge via electron impact ionization. The discharge current (I_d) and voltage (V_d) were set to 50 mA and 100 V, respectively. To measure the plasma density (n_0), ion saturation current (I_{sat}), electron temperature (T_e), and plasma potential (V_p) during the plasma reduction of Ag, an electrostatic probe was positioned 10 mm away from the sample surface. The probe was swept from -40 to 20 V and *I-V* traces were obtained at 5-min intervals for 30 mins.

Figure 1(a-d) show the trends of the plasma parameters as a function of time at varying substrate bias, while Fig. 1(e) shows the X-ray diffractograms of the samples after 30 mins of plasma exposure. The plasma characteristics can be correlated with the structure and properties of the plasma-reduced Ag.

References
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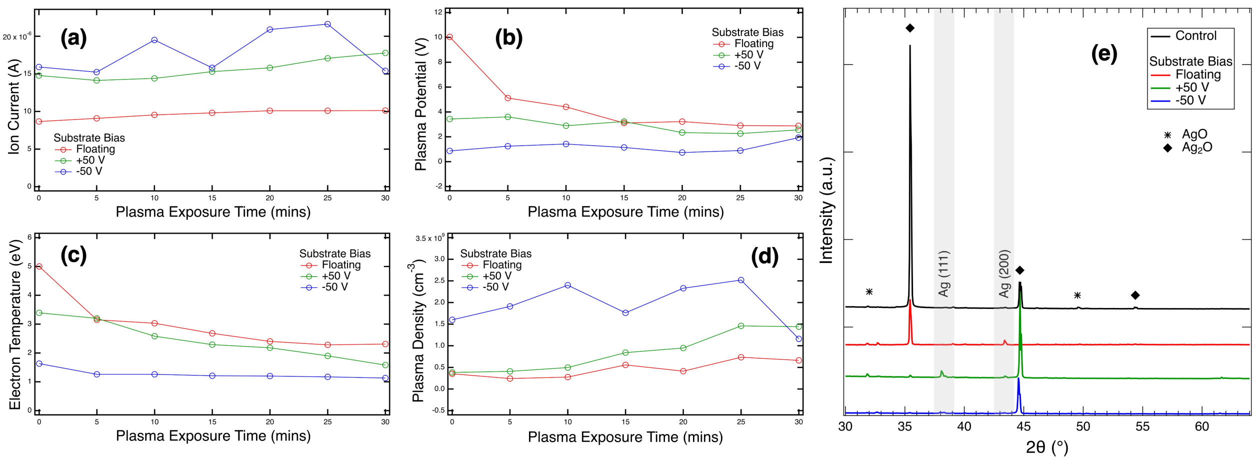

Figure 1. Trends of (a) I_{sat}, (b) V_p, (c) T_e, and (d) n_0 as a function of plasma exposure time at varying substrate bias and (e) X-ray diffractograms of the samples exposed to plasma for 30 mins at varying substrate bias.