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Atmospheric pressure plasma surface modification: from surface treatment to thin film deposition

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Atmospheric pressure plasmas (APP) are widely used in various application fields because of its simplicity, easy operation, low cost without vacuum equipment and fluency of active species [1]. Especially, APPs are favored in surface modification such as wettability control and thin layer deposition thank to the chemical functional groups and radicals generated in the plasma. Low gas temperature around room temperature of APPs is one of fascinating advantages for thermally-weak material treatment. For the reason, low frequency dielectric barrier discharge (DBD) plasma is intensively applied in this fields [2]. However, DBD has lower electron density due to its pulse discharge characteristics although it shows very low gas temperature. In addition, DBD easily transits to filamentary or streamer mode causing local damages on weak materials. In this work, therefore, we develop a robust APP source using radio-frequency (RF) to make continuous and higher electron density plasma for surface modifications as seen in Fig. 1 [3-5]. The RF-APP source is composed of cylindrical power electrode covered by dielectric tube to avoid arc generation. Side ground electrode is kept with 1 mm discharge gap to sustain low breakdown voltage. Bottom discharge gap is varied from 1 to 10 mm depending on treating materials. By moving substrate across the cylindrical electrode, large area surface can be treated by the plasma. Discharge gas chemistry is varied for the specific application target. For example, inert gases such as argon or helium gas is introduced to make hydrophilic or super-hydrophilic surface. The functional group such as O-, OH- can drastically increase the surface energy proved via very small water contact angle under 10 degree [1]. The super-hydrophilic surface is useful in surface adhesion between polymers and de-inking of used paper for paper recycling. On the other hand, the addition of CH4 and/or C4F8 gas to the plasma, the surface wettability changes into hydrophobic or super-hydrophobic surface showing larger water contact angle over 150 degree [3,4]. Especially, it is known that the super-hydrophobicity is the synergetic effect of chemistry due to low surface energy functional groups and physical morphology showing micro-nano structure on the surface [3]. This surface can be used in water-repellant application such as anti-icing, anti-biofouling, friction reduction and solar-panel maintenance. Interestingly, by combination of hydrophilic and hydrophobic surface through selective surface modification, the water-oil separation is effectively performed [4]. The effective surface treatment by RF-APP promises the possibility of thin film deposition through gas chemistry control. Therefore, we also deposit thin oxide and nitride films with high deposition rates. By introducing specific precursors such as titanium tetraisopropoxide (TTIP) and hexamethyldisilazane (HMDS), titanium oxide and silicon nitride can be deposited, respectively [5]. Comparing to pure chemical vapor deposition (CVD) at atmospheric pressure, the plasma plays the important role for layer densification, hardness and low carbon concentration due to the interaction between oxygen radical from the plasma and carbon in the layer [5]. Low surface temperature also enables the deposition of thin films on thermally weak materials. Hence APP method via simple tuning of gas chemistries provides a fast surface treatment and deposition of thin film with low gas temperature in an open air.

References

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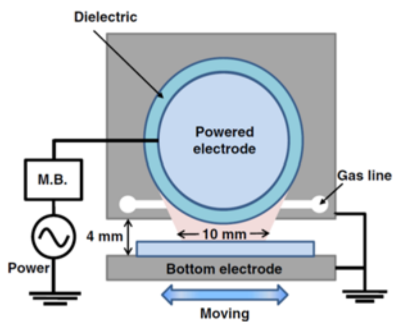

Figure 1. Schematic illustration of the experimental setup for atmospheric-pressure plasma generation