Predictive insight based on grey box analysis of plasma process data

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Explosive growth of information society demands ultra-high performance CPU, ultra-high density memory with a high speed, and so on, which in turn leads to needs for extremely sophisticated plasma processing for the device fabrication. Plasma processing is based on plasma physics, plasma chemistry, and surface chemistry. These three are interacted in an awfully complex way in multiscale in the phase space of time, space, and velocity. The number of external tuning knobs such as pressure, power, substrate temperature is much less than that of internal parameters, and hence it is difficult to tune finely plasma processes. One possible solution to overcome such difficulties is application of machine learning and big data analytics to plasma processes. We are developing several approaches to extract hidden information from big data of plasma processes and film properties [1]. Here we exemplify such developments.

CVD plasma potentially contains nanoparticles which often modify properties of CVD films. We have investigated effects of plasma fluctuation on growth of nanoparticles in capacitively-coupled rf discharges with amplitude modulation [2] We deduced spatial profiles of fluctuations from 100 Hz component envelope of laser light scattering (LLS) intensity from nanoparticles and Ar I 750nm emission intensity, in such CVD plasmas, as shown in Fig. 1. These results extract from 32G byte movie file using statistical fluctuation analysis. Strong local fluctuations of LLS intensity are formed in the edge plasma regions of |r| = 25-35 mm, whereas weak and random fluctuations of Ar I emission intensity are observed in the whole plasma region. The difference in Fig. 1 is mainly originated from mass difference between nanoparticles and electrons.

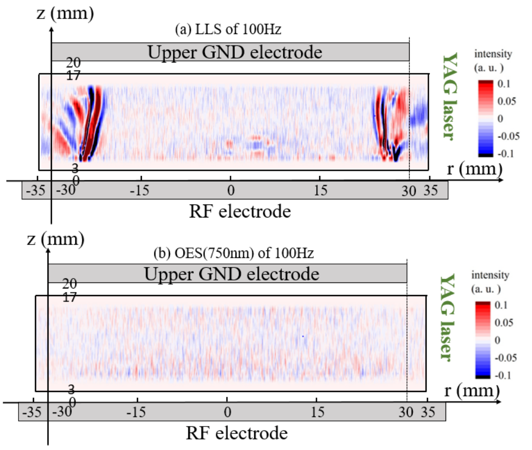

Fig. 1. Spatial profiles of fluctuation of 100 Hz component envelope of LLS intensity (above) and Ar I 750 emission intensity (below) in CVD plasma.

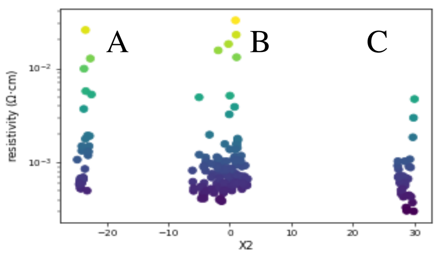

Fig. 2. t-SNE outputs as function of resistivity using 150 experimental data.

Next, we introduce another application to a sputter deposition process of TCO films. We identified key parameters to achieve low resistivity films using the t-distributed stochastic neighboring ensemble (t-SNE) method, which reduces the dimensionality. Figure 2 shows t-SNE outputs as a function of resistivity. The group C contains the lowest resistivity. Thus, the data analytics provides predictive insights.

[1] M. Shiratani, *et. al.*, Mater. Sci. Forum **879** (2017) 1772.
[2] K. Kamataki, *et al.*, Appl. Phys. Exp. **4** (2011) 105001.