中性子反射率法による細胞親和性窒素含有 DLC の膜構造評価

Neutron reflectometry analysis of nitrogen-containing DLC film structure for cell compatibility

東京電機大学 [1]，CROSS 中性子センター[2] ○(B)ファウズィア カマリナ [1]，多積 直之 [1]，宮田 登 [2]，宮崎 司 [2]，矢口 俊之 [1]，本間 章彦 [1]，平栗 健二 [1]，大越 康晴 [1]

Tokyo Denki Univ. [1], CROSS, Neutron Science and Technology Center [2], °Fauziyyah Qamarina[1], Naoyuki Tatsumi[1], Noboru Miyata[2], Tsukasa Miyazaki [2], Toshiyuki Yaguchi[1], Akihiko Homma[1], Kenji Hirakuri[1], Yasuharu Ohgoe[1]

E-mail: 16rt652@ms.dendai.ac.jp

1. Introduction

Diamond-like carbon (DLC) is form of materials that structurally amorphous in nature with sp^2 and sp^3 bonded carbon and hydrogen atom [1]. Additionally, DLC film has been well-known as biocompatible coating on medical applications, the knowledge of surface properties of DLC film include the interest in terms of biocompatibility and the structural analysis of the film that causes the enhancement to the properties of DLC film [2]. In our previous work, it was observed that the nitrogen-containing DLC film enhanced cell adhesion. However, the relationship between the surface functionality with the nitrogen-containing and the cell affinity has not been cleared yet. Biological response on DLC films are influenced by surface conditions associated with film structure. Therefore, it is important to obtain information on the hydrogen content over a depth profile of the DLC film. Neutron reflectometry is a nondestructive analytical technique with high sensitivity to light elements such as hydrogen. The objective of this research is to evaluate the structure of nitrogen-containing DLC film by neutron reflectometry method for cell compatibilities.

2. Experimental

Nitrogen-containing DLC films were deposited on Si substrate (Ø: 2 inch, thickness: 5 mm) by using 13.56 MHz RF plasma discharge (RF CVD) at 100 W. The film was deposited by using a mixture of CH_4 and N_2 gas (N_2 flow rate: 0, 40, 60 %) as the source gases at 30 Pa of gas pressure. The film thickness was kept around 100 nm. As for the neutron reflectometry measurement, polarized neutron reflectometer, “Sharaku” (J-PARC MLF High-Intensity Proton Accelerator Facility, BL17) was used to analyze the nitrogen-containing DLC at depth direction. For investigation of cell affinity of the nitrogen-containing DLC film, NIH-3T3 cells were used for cell proliferation on the DLC films. The cells were prepared in D-MEM solution (0.5×10^3 cell/cm^2) and incubated at 37 °C on the nitrogen-containing DLC film surface in an atmosphere for 3 days (air: 95 %, CO_2: 5 %, humidity: 100 %).

3. Results and Discussion

Figure 1 shows SLD depth profile of nitrogen-containing DLC which the parameter was obtained by mathematically fitting the neutron reflectivity measurement result. In Fig. 1, the SLD of the surface layer was increased by nitrogen containing. It is expected that the surface composition of the DLC film was changed due to hydrogen was replaced with nitrogen during the film deposition. In case of 40 % N_2 flow rate, the SLD was higher than 0 and 60 % N_2 flow rate. The film structure was influenced on N_2 flow rate during the film deposition. On the other hand, without nitrogen containing DLC film was uniformity in the SLD of the whole film. Moreover, the nitrogen-containing decreased the SLD of the bulk layer of the DLC film.

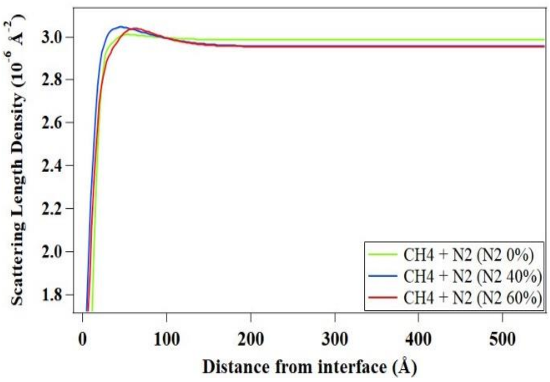

Fig. 1 SLD depth profile of nitrogen-containing DLC

Additionally, from the observation of cell affinity on the DLC films, the cell proliferation on the DLC films was inhibited and enhanced with increasing of nitrogen-containing in the DLC films of 40% and 60% flow rate respectively. The cell proliferation of the DLC films was influenced with nitrogen content. As a result, the surface layer of the DLC film was also affected, and it was observed that the nitrogen containing of the DLC film showed high influence to the cell proliferation with hydrogen content.

4. Conclusion

The nitrogen-containing DLC film was deposited on Si substrates by RF CVD technique with mixture of CH_4 and N_2 gas (N_2 flow rate: 0, 40, 60 %). During the film deposition, hydrogen was replaced with nitrogen and modified the surface layer of the DLC film for cell proliferation. The results indicated that the nitrogen containing effected on hydrogen containing and cell proliferation of the DLC film.

Reference

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