Study on minority-carrier lifetime in ultrananocrystalline diamond/hydrogenated amorphous carbon composite films

○(M1)N. Nishikawa[1], (D)S. Takeichi[1], (D)T. Hanada[1], (M1)S. Tategami[2], (M1)A. Iwamoto[2], (M1)H. Takeda[2], A. Fukuyama[2], and T. Yoshitake[2]
[1]*Dept. of Appl. Sci. for Electr. & Mat., Kyushu Univ., 6-1 Kasuga, Fukuoka, 816-8580, Japan*
[2]*Dept. of Eng., Univ. of Miyazaki, 1-1 Gakuenkibanadainishi Miyazaki, Miyazaki, 889-2155, Japan*
E-mail: naofumi_nishikawa@kyudai.jp

1. Introduction: Ultrananocrystalline diamond (UNCD)/hydrogenated amorphous carbon (a-C:H) composite (UNCD/a-C:H) films comprise a large number of grains with diameters of less than 10 nm and an a-C:H matrix [1,2]. Owing to the specific structure, some energy levels generates between the bandgap of diamond [1]. The absorption coefficient in the visible-ultraviolet ranges [3], UNCD/a-C:H is a new candidate semiconductor for photovoltaics. We experimentally succeeded in controlling the conduction type of UNCD/a-C:H by doping nitrogen and boron [4,5] in our previous research. In addition, based on these results, we fabricated pn-junctions by means of the deposition of nitrogen and boron-doped UNCD/a-C:H films on p-type Si and n-type Si substrates, respectively [6-8], and demonstrated the rectifying action and photodetection in the heterojunctions. On the other hand, the minority carrier lifetime, which is one of the most important factors in the photovoltaic action, has not been investigated for UNCD/a-C:H yet. In this work, the minority-carrier lifetimes of typical samples were measured by employing a μ-PCD apparatus.

2. Experimental: All samples were prepared on insulating Si substrate by coaxial arc plasma deposition (CAPD) with a graphite target. The minority-carrier lifetimes of undoped UNCD/nonhydrogenated amorphous carbon (a-C)(sample A), undoped UNCD/a-C:H (sample B), nitrogen-doped UNCD/a-C:H (sample C), and boron-doped UNCD/a-C:H (sample D) were measured by μ-PCD produced by Kobelco Research Institute, Inc.

3. Results: Figure 1 shows the time-dependence of the microwave reflectivity in voltage for the samples. There are obvious differences in the decay curve among the samples. The minority-carrier life times, estimated using the following equation, are displayed in Table 1.

$$\rho_{p,n,i} = \rho_{p,n,i}(0)\exp\left(-\frac{t}{\tau_{n,p}}\right) + \rho_{p0,n0} \qquad \text{when the film is intrinsic, } \rho_{p0,n0} = 0$$

Hydrogenation lengthens the lifetime evidently, which implies that dangling bonds that acts as trap centers are terminated by atomic hydrogen. Nitrogen and hydrogen doping slightly shortened the life time. The details will be reported at the conference.

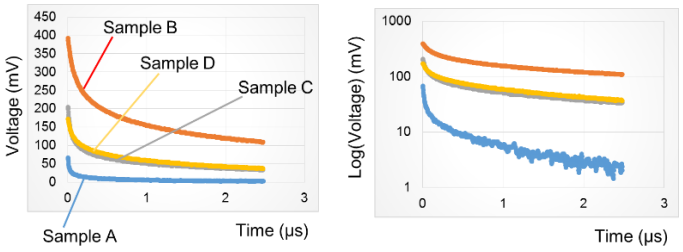

Fig. 1. (a) Time-dependence of the microwave reflectivity in voltage, and (b) the plots in log scale.

Sample name	sample	Life time (μs)
Sample A	UNCD/a-C	0.0062
Sample B	UNCD/a-C:H	1.58
Sample C	UNCD/a-C:H (N 4at.%)	0.40
Sample D	UNCD/a-C:H (B 0.5at.%)	1.08

Table.1 Minority-carrier life times in typical samples

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