

# **New Insight into Fluorescent Polymeric Carbon Dots for Solid-State Laser Device**

Barun Kumar Barman,<sup>1\*</sup> David Hernández-Pinilla,<sup>1\*</sup> Ovidiu Cretu,<sup>3</sup> Riichiro Ohta,<sup>4\*</sup> Keiko Okano,<sup>1</sup>  
Toshifumi Shiroya,<sup>4</sup> Jun Sasai,<sup>4</sup> Koji Kimoto,<sup>3</sup> and Tadaaki Nagao<sup>1,2\*</sup>

<sup>1</sup>International Center for Materials Nanoarchitectonics (WPI-MANA), National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0044, Japan

<sup>2</sup>Department of Condensed Matter Physics Graduate School of Science, Hokkaido University, Kita-10 Nishi-8 Kita-ku, Sapporo 060-0810, Japan

<sup>3</sup>Electron Microscopy Group, National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0044, Japan

<sup>4</sup>L'Oréal Research and Innovation, KSP R&D, 3-2-1 Sakado, Takatsu-ku, Kawasaki, Kanagawa 213-0012, Japan

\*Correspondences

Email: [BARMAN.Kumarbarun@nims.go.jp](mailto:BARMAN.Kumarbarun@nims.go.jp) (B.K.B.)

[mayphys87@gmail.com](mailto:mayphys87@gmail.com) (D.-H. P)

[riichiro.ohta@loreal.com](mailto:riichiro.ohta@loreal.com) (R.O)

[NAGAO.Tadaaki@nims.go.jp](mailto:NAGAO.Tadaaki@nims.go.jp) (T.N)

Supporting information includes:

Total number of pages:11

Total number of figures:15

Total number of tables:2

Sample (1H,DMSO)

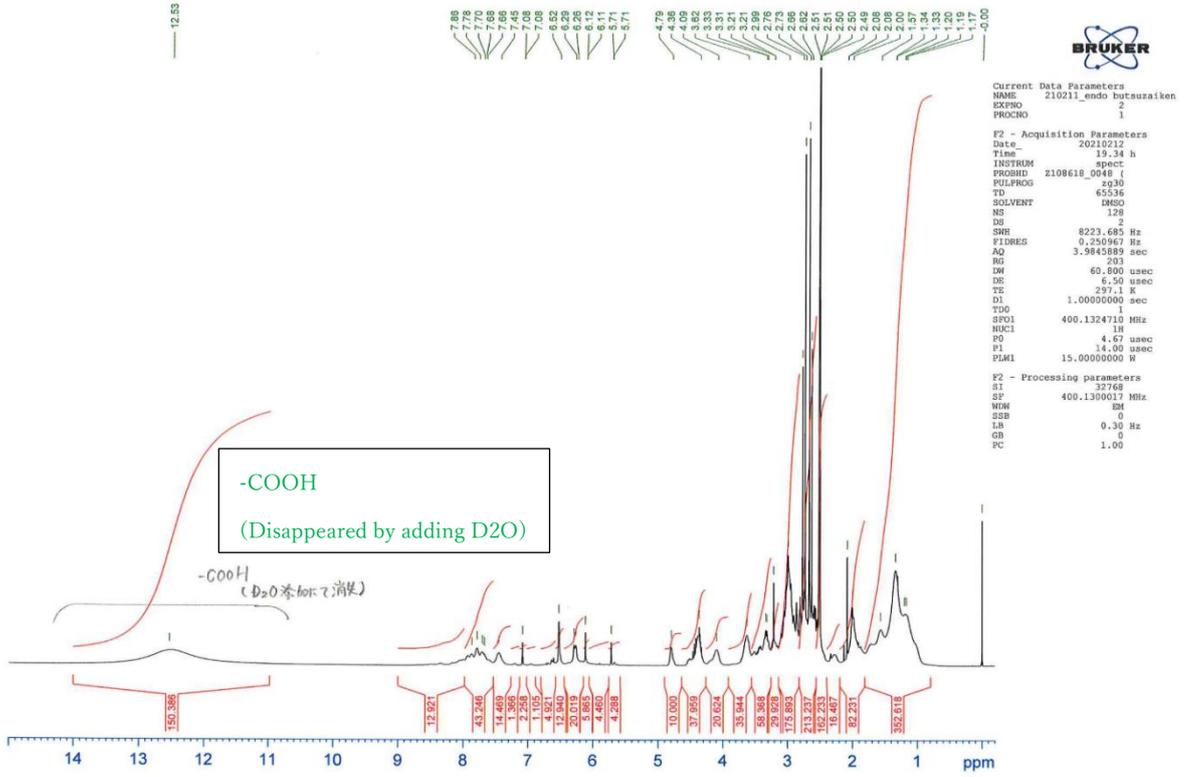


Figure S1. <sup>1</sup>H NMR spectrum of PCDs.

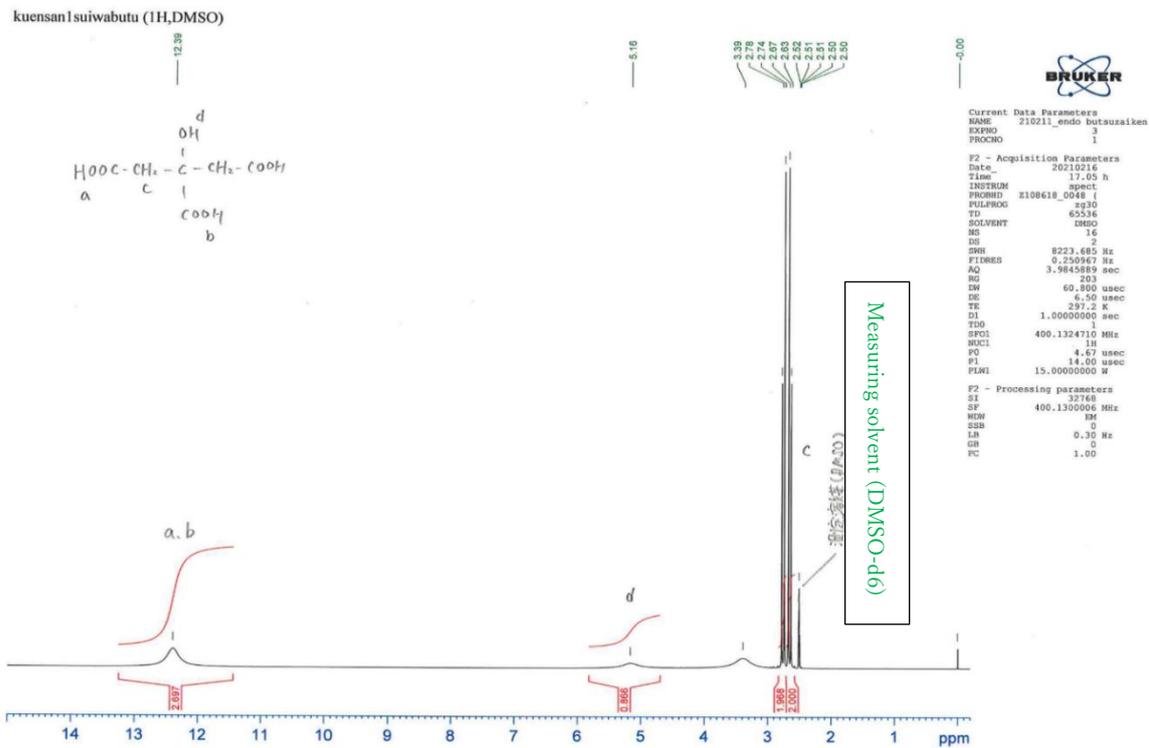


Figure S2. <sup>1</sup>H NMR spectrum of CA.

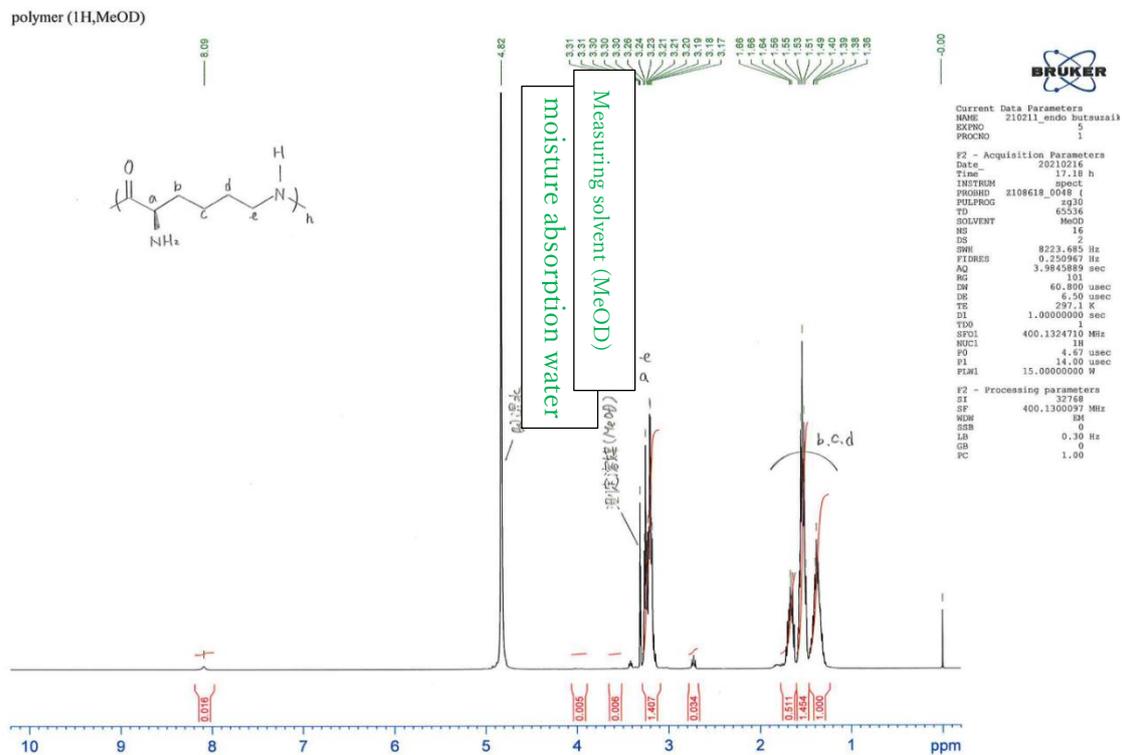


Figure S3. <sup>1</sup>H NMR spectrum of PLys.

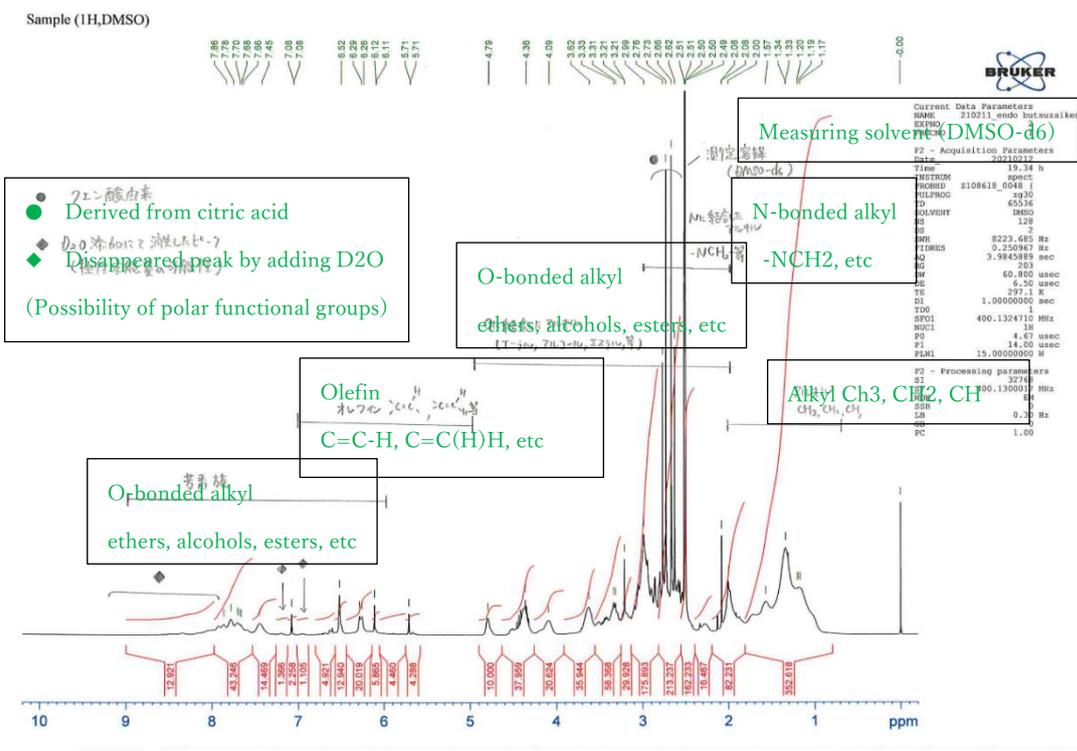
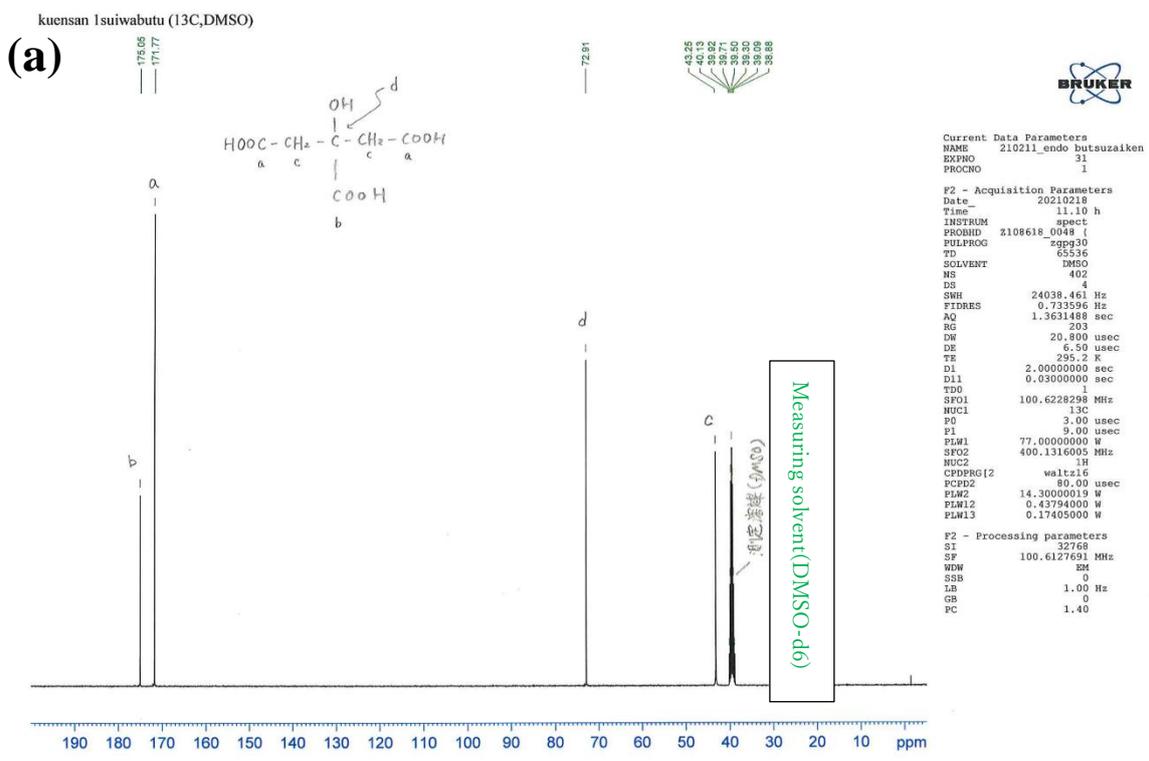


Figure S4. <sup>1</sup>H spectrum of PCDs in DMSO and D<sub>2</sub>O solvents.



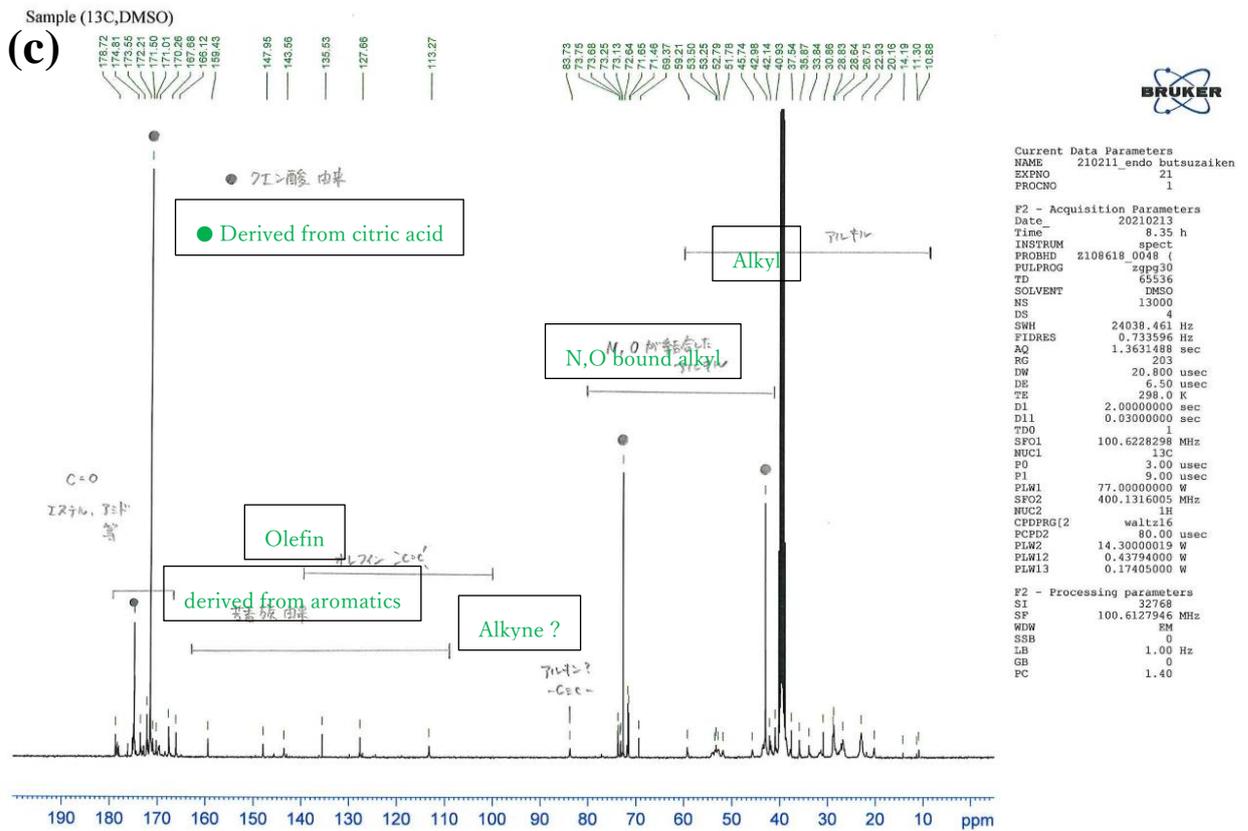
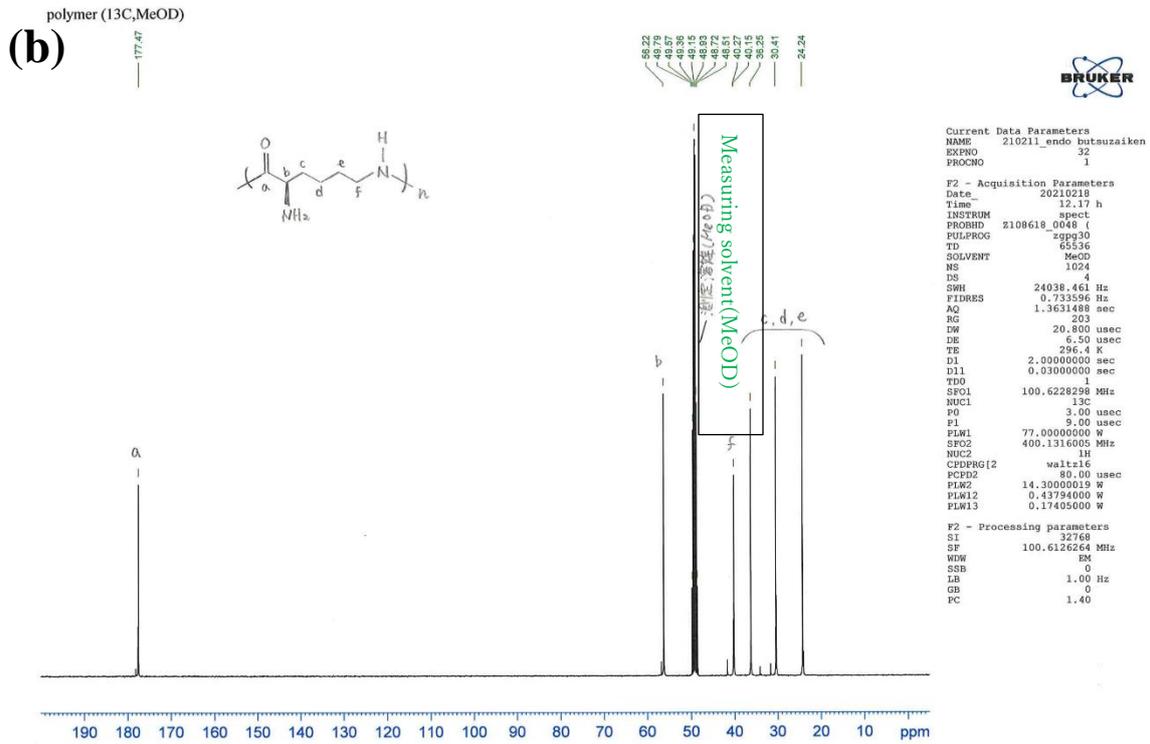


Figure S5. <sup>13</sup>C NMR spectra of (a) CA, (b) PLys, and (c) PCDs.

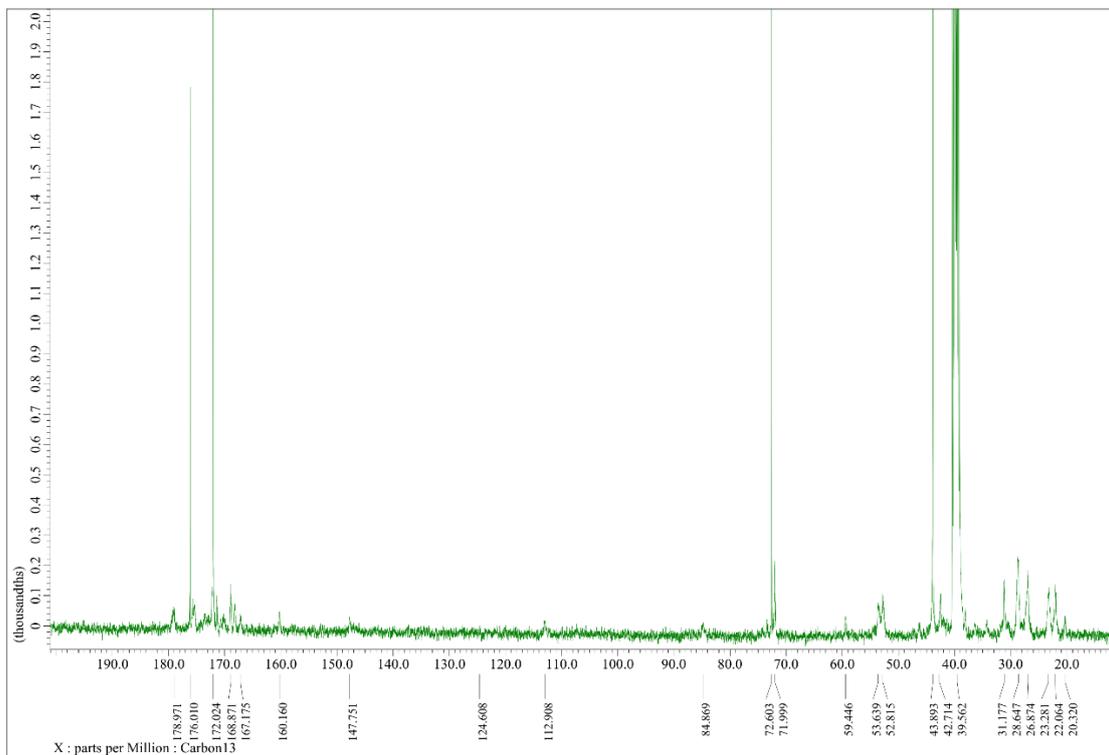


Figure S6.  $^{13}\text{C}$  NMR spectra of osmosis purified PCDs in  $\text{D}_2\text{O}$  solvent.

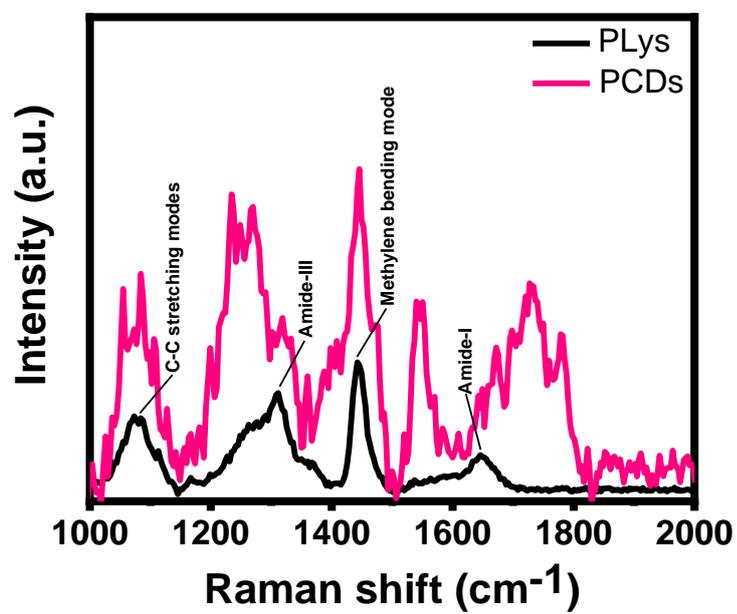


Figure S7. Comparison of Raman spectra of dried PLys and PCDs films on quartz substrate.

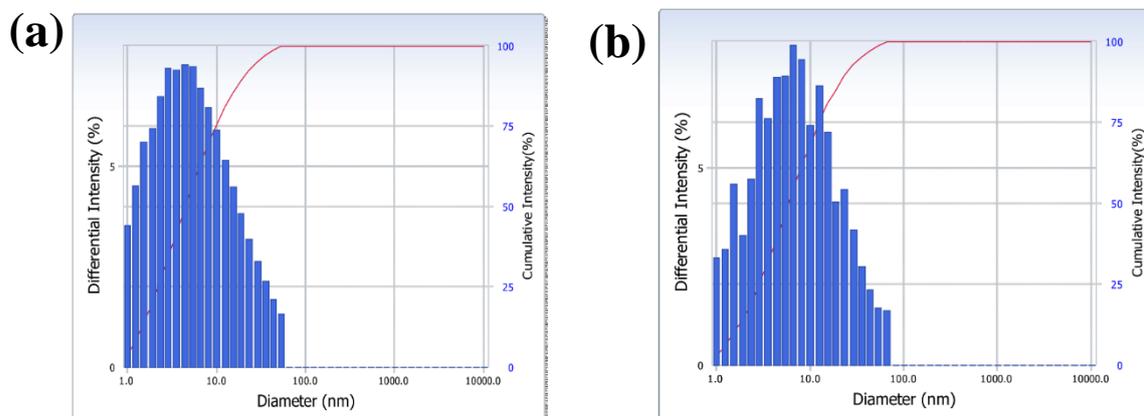


Figure S8. DLS spectra of PCDs synthesized at (a) 200 °C and (b) 220 °C.

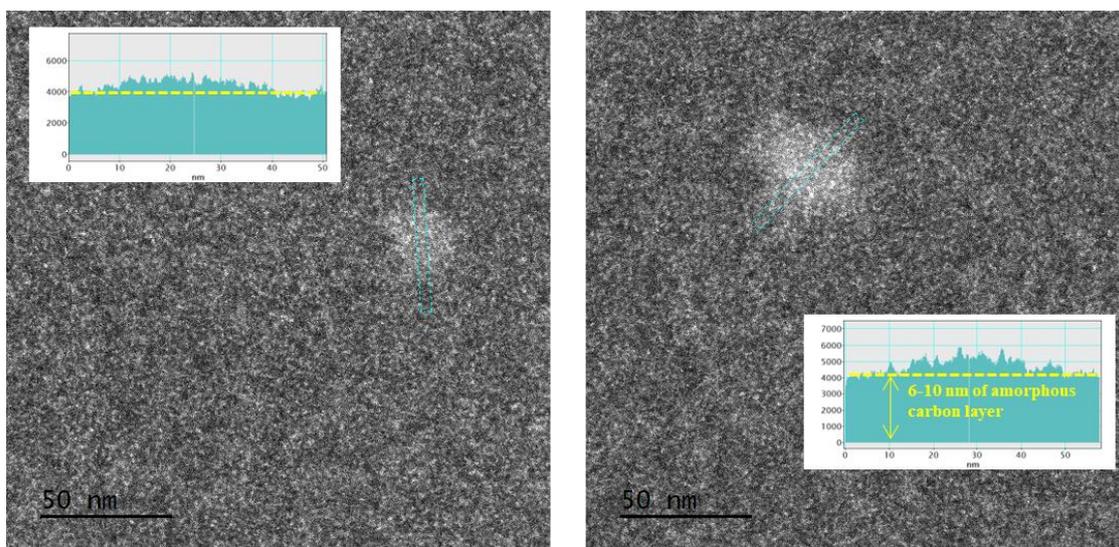


Figure S9. Typical TEM images of PCDs on superhigh resolution carbon coated Cu grid, where thickness of the carbon layer  $\sim$  6-10 nm, which hinder the observations soft PCDs in the size range of 5-10 nm.

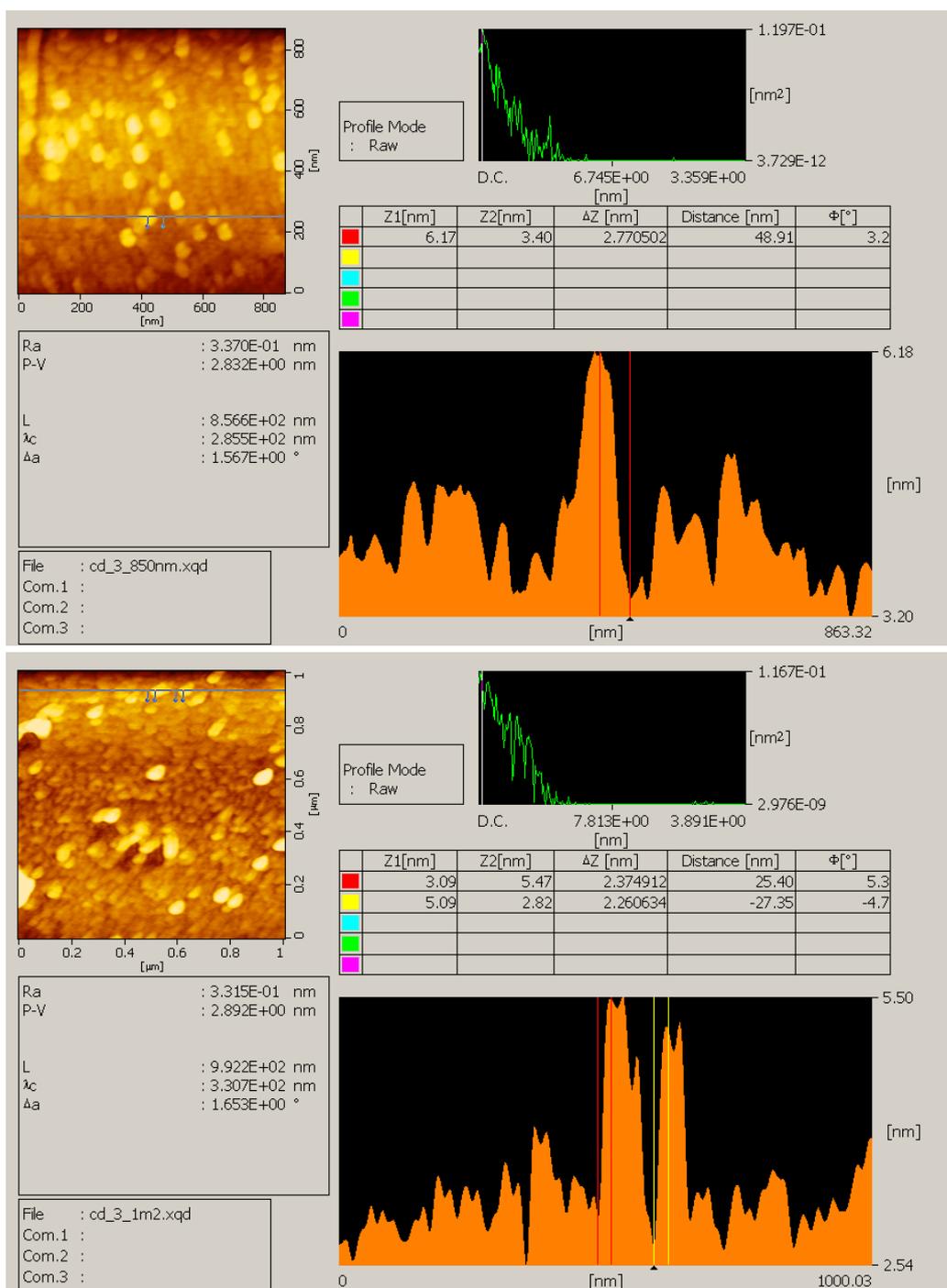


Figure S10. AFM images of PCDs and their corresponding height profile at two different areas.

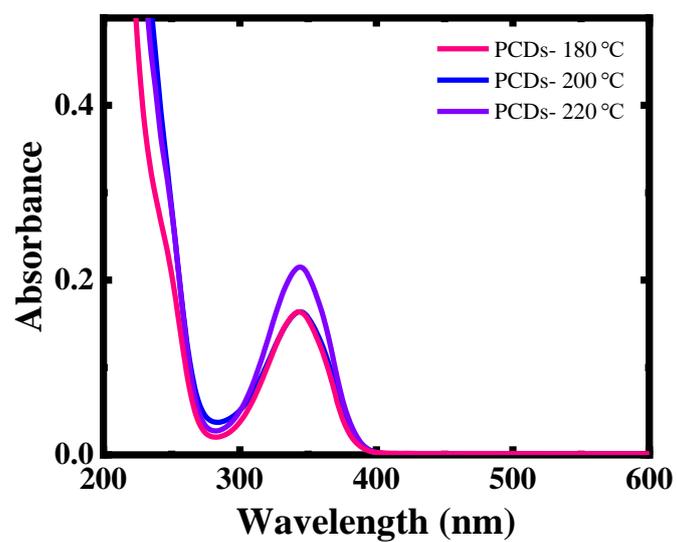


Figure S11. Comparison of UV-vis absorbance spectra of 0.01 wt.% PCDs solution synthesized at different temperatures.



Figure S12. Digital photograph of solid PCDs and its emission in solid-state by UV (365 nm) light excitation.

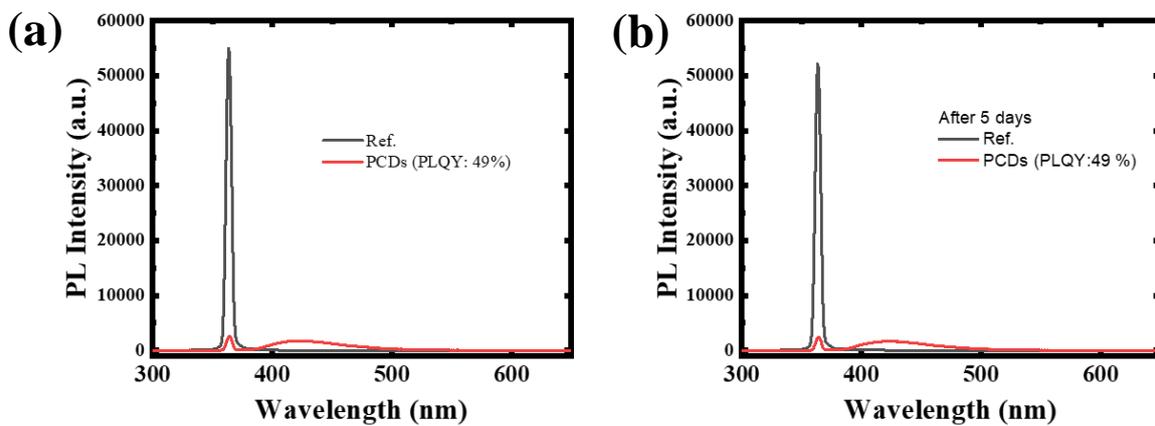


Figure S13. (a and b) PLQY of PCDs aqueous solution by 365 nm UV light excitation within 5 days interval.

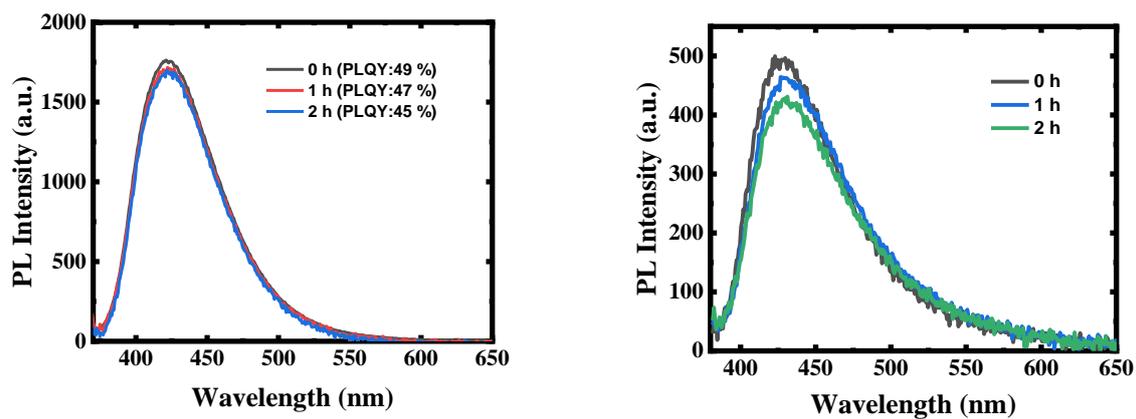


Figure S14. (a and b) Photoluminescence stability of PCDs in aqueous solution and glass coated solid-film by continuous irradiation of 365 nm UV light for 2 h.

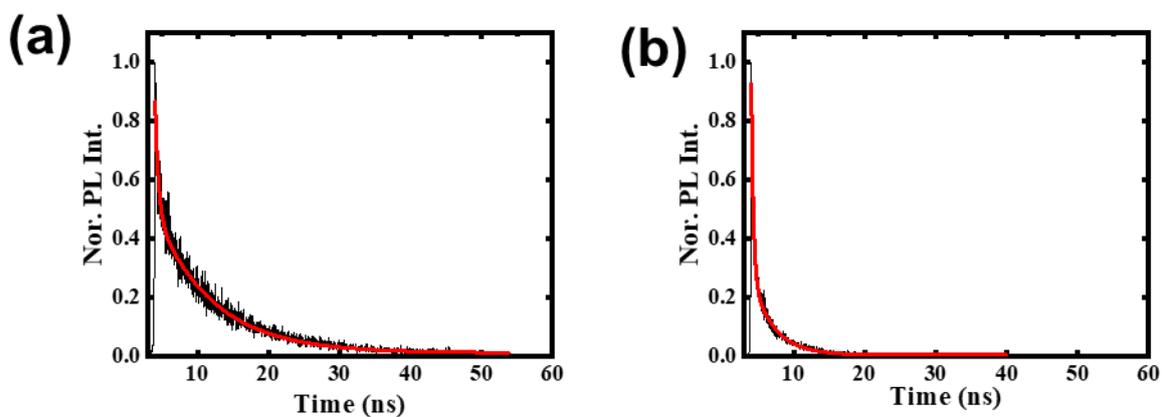


Figure S15. Experimental and fitted TRPL spectra of (a) PCDs dispersion and (b) film.

Table S1 The results of CHNO elemental analysis of PLys and PCDs

Sample name	C (wt.%)	H (wt.%)	N (wt.%)	O (wt.%)	C:H:N:O (atomic ratio)
PLys	55.52	9.71	21.56	12.65	4.62:9.71:1.54:0.78
PCDs	45.99	5.38	6.29	42.44	3.83: 5.38:0.44:2.68

Table S2. PL decay lifetimes and fitting parameters of PCDs dispersion and solid film

Sample name	$\tau_1$ (ns)	$A_1$ (%)	$\tau_2$ (ns)	$A_2$ (%)	$\tau_{avg}$ (ns)
Dispersion	0.464	55.7	8.15	44.3	7.63
Film	0.296	96	3.081	4	1.1

The average PL lifetime ( $\tau_{avg}$ ) was obtained from the bi-exponential fitted time decay spectra using the following equation:  $\tau_{avg} = (A_1 \tau_1^2 + A_2 \tau_2^2) / (A_1 \tau_1 + A_2 \tau_2)$ , where  $A_1$ , and  $A_2$  are the amplitudes, and  $\tau_1$  and  $\tau_2$  are the PL decay times.