Supplementary Information

Fabrication of 100 × 100 mm² nanometer-thick graphite pellicle for extreme ultraviolet lithography by peel-off and camphor-supported transfer approach

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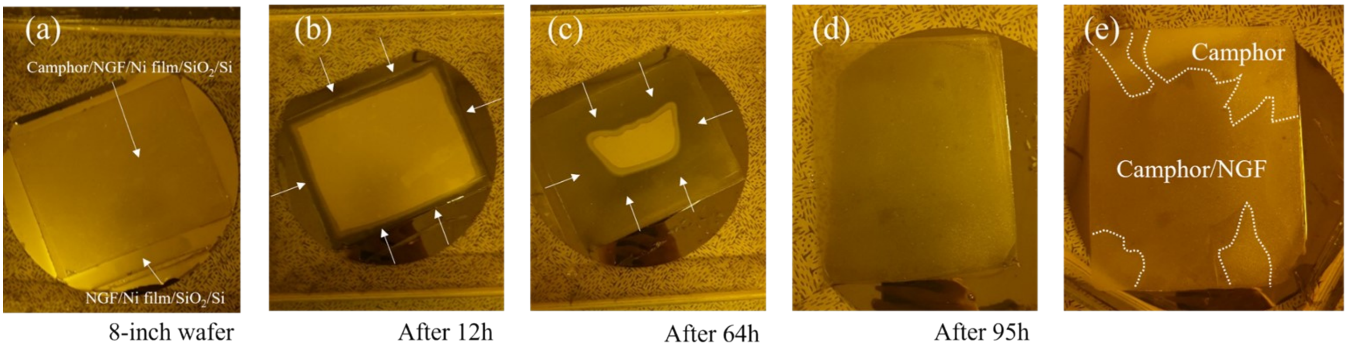

Fig S1. The etching process of camphor/NGF/Ni film/SiO_2/Si wafer without using peel-off method

This step is a process to separate the camphor/NGF from the SiO_2/Si wafer by etching the Ni film. Without immersing the camphor/NGF/Ni film/SiO_2/Si sample in the etchant solution, the height of the etchant was adjusted to be slightly lower than the height of the camphor to ensure the solution penetrates through the interface between the NGF and Ni. As the pellicle size got larger, the thickness and area of the deposited camphor increased, which caused a long etching time of the Ni film and the separation between the camphor and NGF.

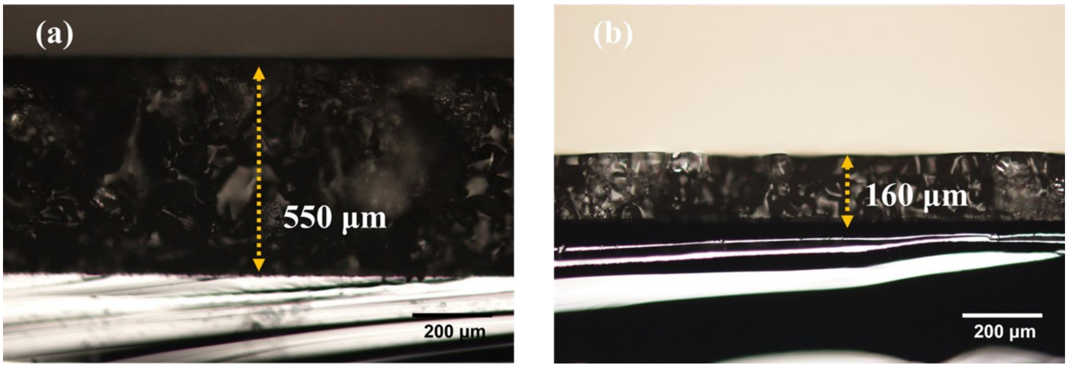

Fig S2. Optical images (cross-section) of the change in camphor thickness with respect to deposition time. (Temperature 80 °C and working pressure 2 Torr) (a) 6 min 30s. (b) 2min 30s.

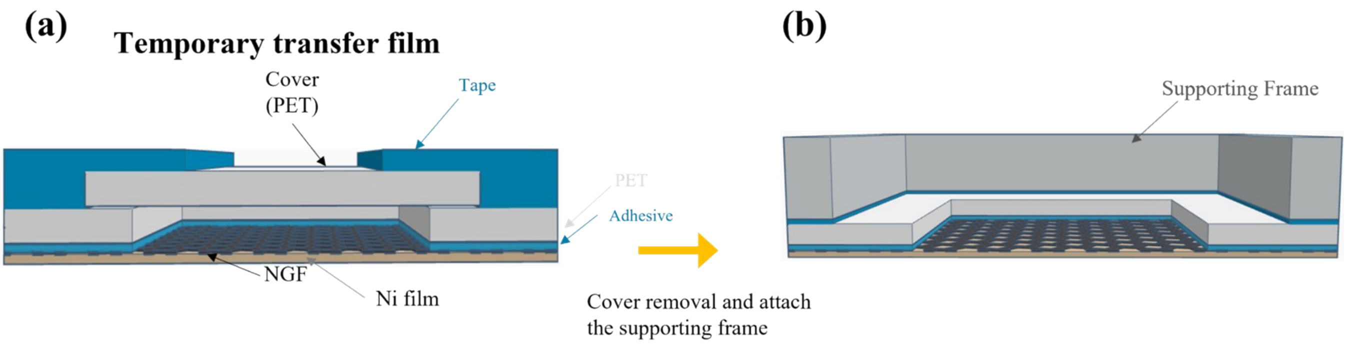

Fig S3. (a) Cross section of freestanding NGF/Ni film with temporary transfer film after NGF /Ni film peel-off process. (b) Cross section with supporting frame attached after removing the cover film.

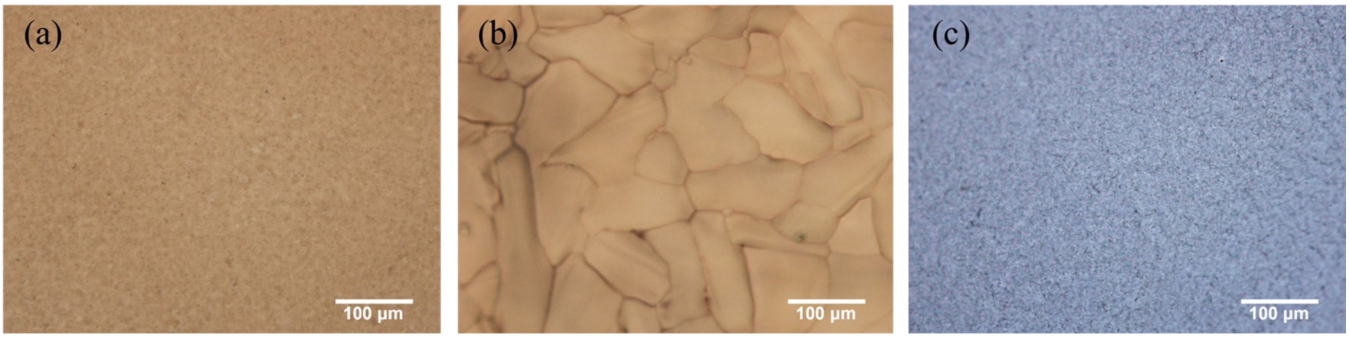

Fig S4. Optical image of the surface during the transfer process (a) Freestanding NGF/Ni film after peel-off process. (b) Camphor/NGF/Ni film. (c) Freestanding NGF after camphor sublimation.

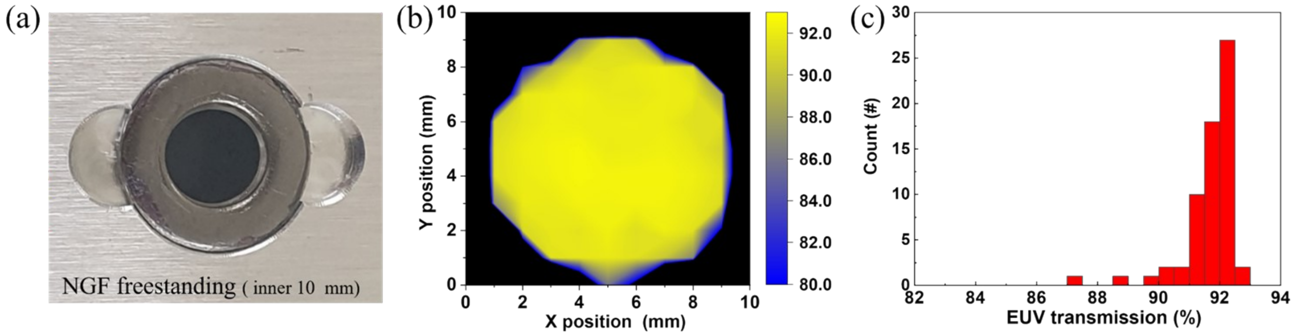

Fig S5. Measurement of EUV transmittance of NGF. (a) Photograph of freestanding NGF (inner 10 mm). (b) EUV transmittance mapping image of NGF. (c) Histogram of EUV transmission.

The thickness of NGF can be controlled by the amount of carbon dissolved in nickel. The thickness of Ni film sputtered on the SiO_2/Si wafer was reduced from 1.5 µm to 1 µm to thin the thickness of NGF. The NGF freestanding sample was fabricated using a peel-off and camphor-supported transfer process. Fig S5 shows the photograph (a) and EUV transmittance map (1 mm beam size, 64 pinots) of freestanding NGF in a circular frame with a diameter of 10 mm (b). The average EUV transmission is 91.6 ± 0.85 % in (c).

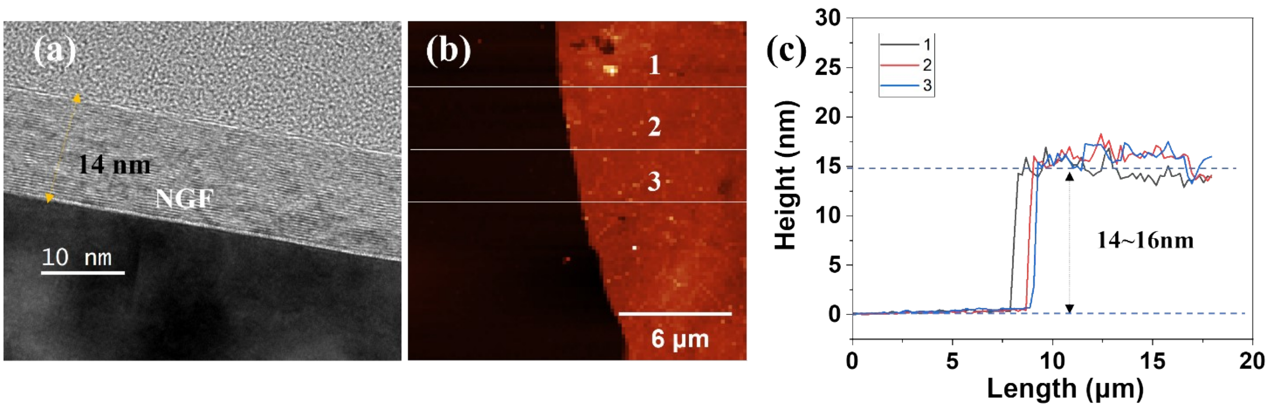

Fig S6. NGF thickness analysis (a) Cross–sectional TEM image of the thickness of ~14 nm (b) AFM image of the NGF on the SiO_2 wafer. (c) Thickness profile corresponding to the line shown in (b).