Development of graphene coatings on transparent windows for high-performance anti-icing applications

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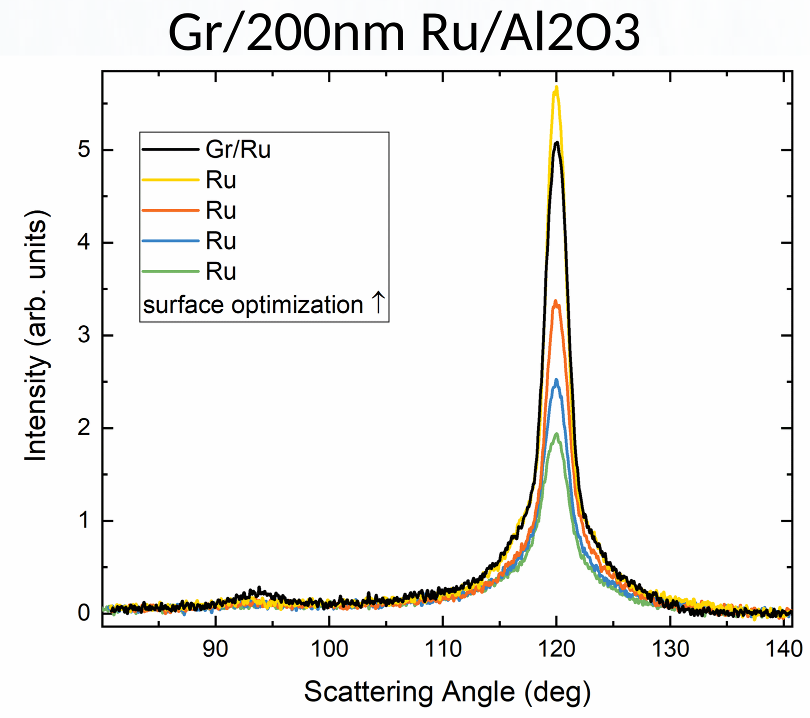
Abstract

A recent study has shown that fluorinated graphene (Gr) on Ru/sapphire is a robust anti-icing coating, delaying ice formation for 90 minutes at -15°C up to 6 hours and 45 minutes at -5°C [1]. However, previous work used Gr grown on opaque thick (200 nm) Ru films. Here, we explore two approaches to obtain high-quality Gr on transparent substrates. The first method is a bottom up approach where Gr is grown on top of an ultra-thin metal film deposited on a transparent substrate (sapphire and fused silica) using a newly developed method [2]. The second method is a top-bottom approach, where CVD Gr/Cu/sapphire is treated in UHV to remove the Cu layer [3]; afterwards, the adhesion of the Gr layer to the substrate is improved by the intercalation of a transition metal thin film underneath the Gr layer. Characterization of the grown films is performed using Helium Atom Scattering, a technique with high sensitivity to surface defects and to the Gr-substrate bond strength [4]. The quality of the resulting graphene layer has been checked using Raman spectroscopy, atomic force microscopy and optical transmission.

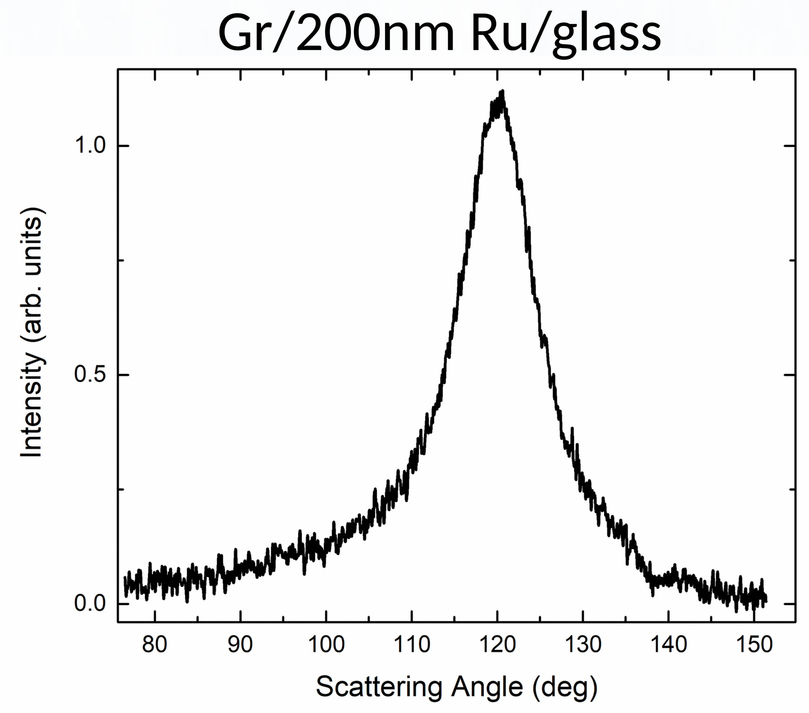
Al2O3 → metal thin film → Graphene

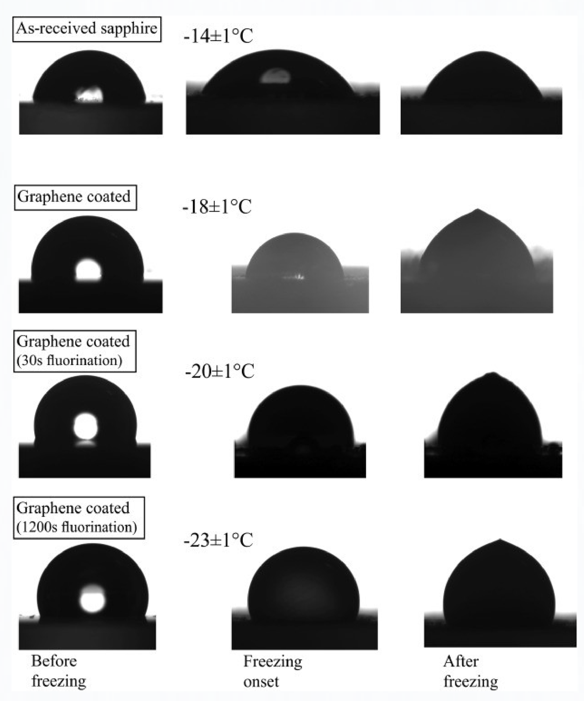
Growth of high quality Ru films requires improving the surface quality of the transparent substrate with precise polishing methods then optimizing the growth conditions. As a result we managed to prepare 100% Gr covered surface on Ru/Al2O3, as tested by exposure to air. Best results are obtained by growing thick films of Ru followed by decreasing the thickness via *in situ* sputtering and thermal annealing at high temperatures, followed by Gr growth.

Gr/200nm Ru/Al2O3

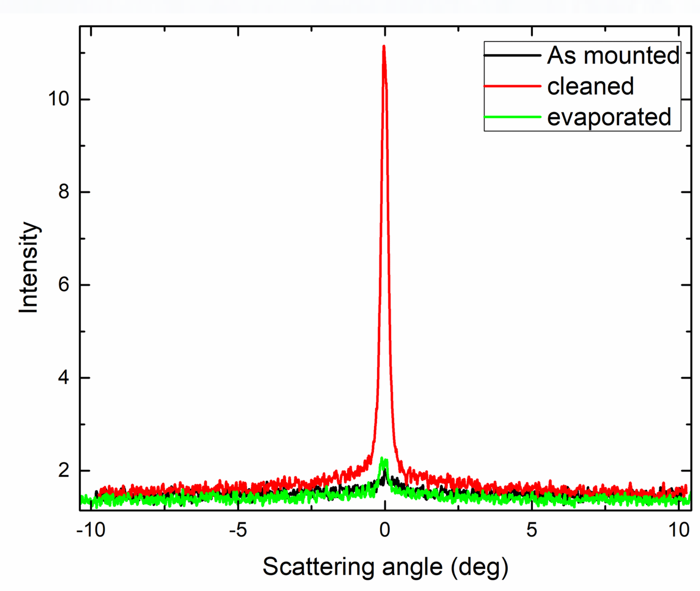


Gr/200nm Ru/glass





Images of water droplets (4 µl) on sapphire samples with and without coatings. Left panel shows images taken at room temperature. Middle panel shows images taken at freezing onsets while right panel shows the images taken after complete freezing with temperature unchanged [1]

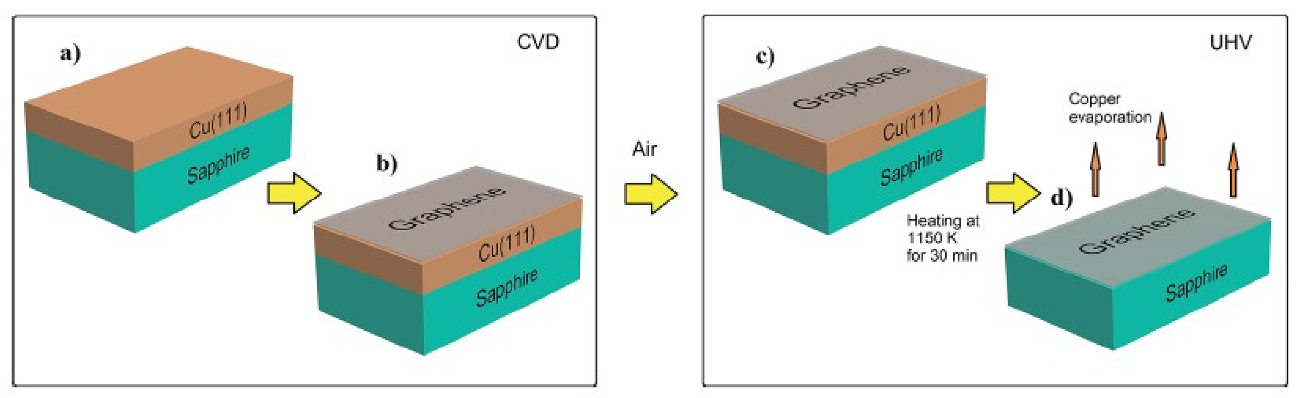


HAS from 10 nm Ru film on Al2O3 grown by a newly developped method [2]. The film is transparent. The specular He reflection intensity and FWHM indicate flatness and long range crystalline order.

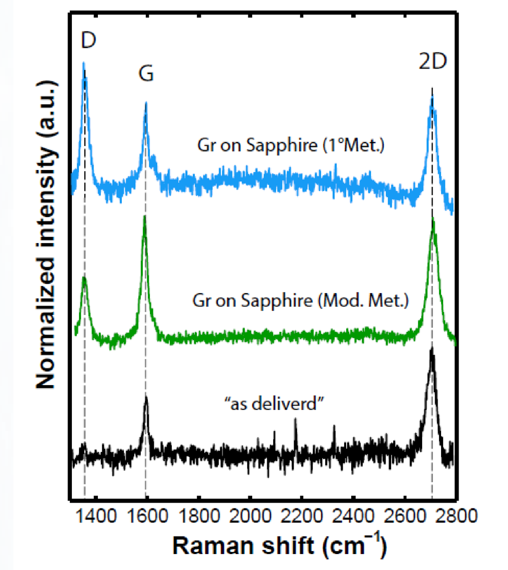
Growing Gr on ultra thin film is challenging due to metal evaporation at high temperatures.

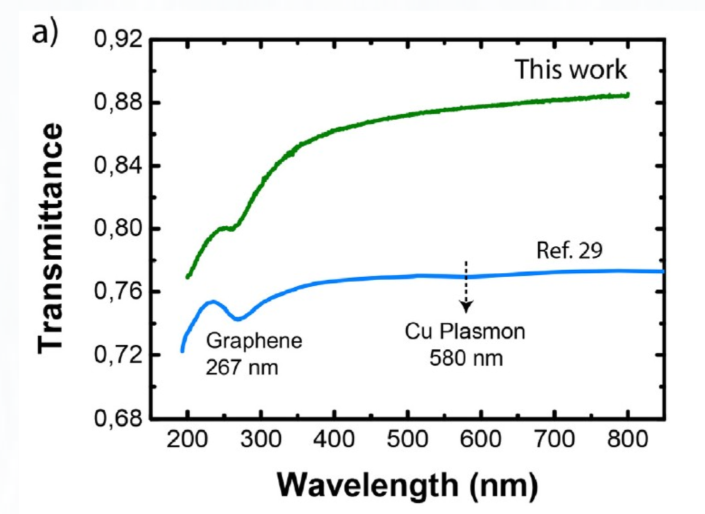
CVD Gr/Cu/Al2O3 → Cu removal → metal intercalation

A simple method for fabricating Gr n transparent surfaces, suitable for scalability [3]

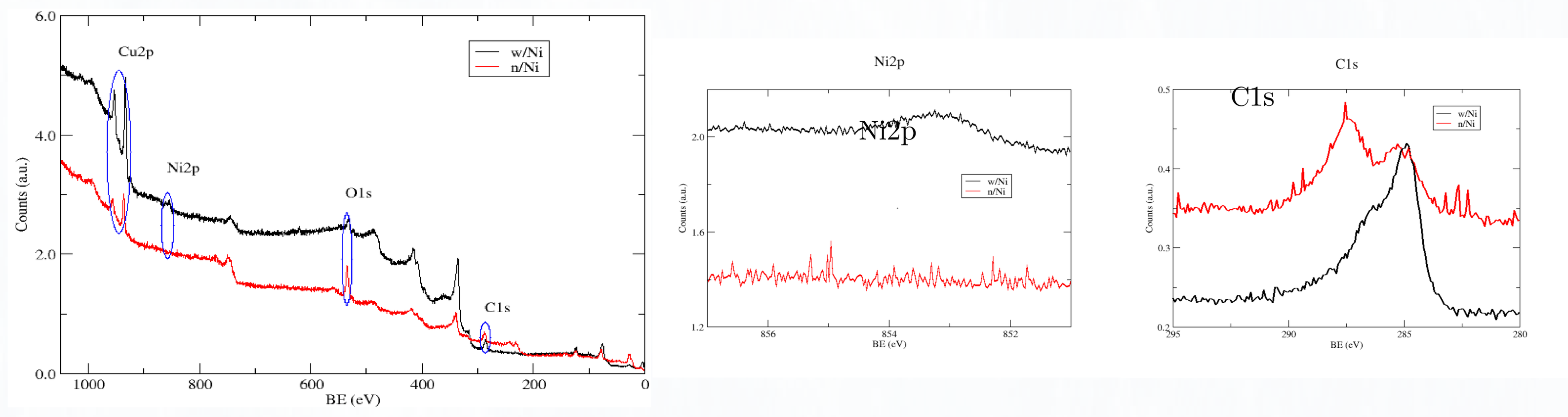


Raman and light transmission characterization of Gr/Al2O3 show enhanced quality by tweaking Cu removal conditions [3]

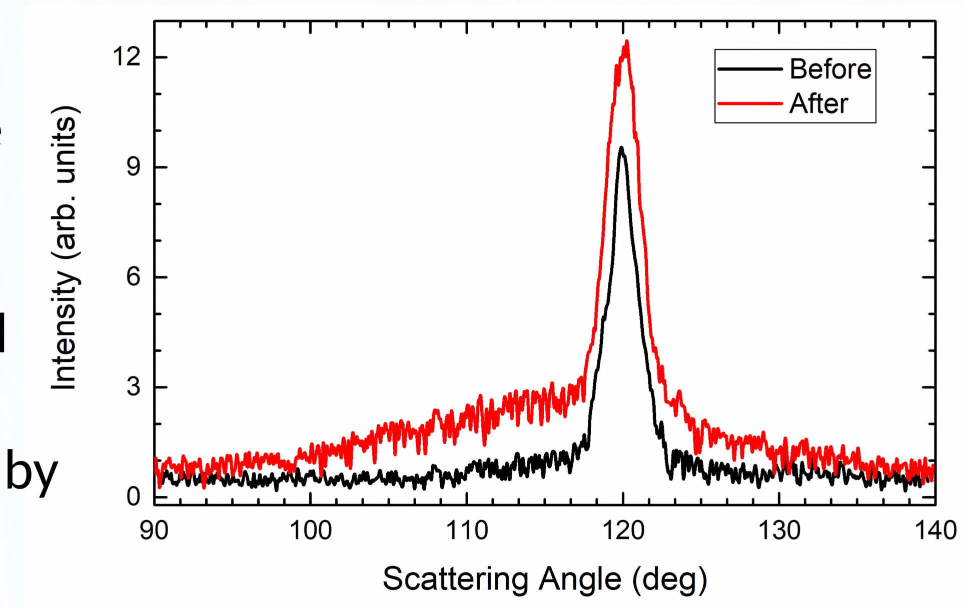




XPS characterization of intercalated Ni in Gr/Cu/Al2O3 shows that Ni remains close to the surface.



Increased HAS reflectivity after intercalation indicate increased effective surface atomic mass due to the increased Gr-substrate interaction strength, a well known phenomena in Gr/Metal surfaces studied by HAS [4]



Future work: intercalation of Ni in Gr/Al2O3

[1] N. Akhtar *et al. Carbon*, 141 (2019) 451-456

[2] W. Braun and J. Mannhart. *AIP Advances*, 9 (2019) 085310

[3] G. Anemone *et al. Carbon*, 139 (2018) 593

[4] A. Al Taleb *et al. 2D Materials*, 5 (2018) 045002