Method for releasing carbon foils from substrates†

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The development of long-life carbon foils (C-foils) for charge strippers at RIKEN RI Beam Factory began in 1999. Because C-foils are manufactured via vapor deposition on a glass substrate or silicon wafer, they must be removed from the substrate or wafer prior to their installation in the accelerator beam line. The condition and quality of the C-foils directly affect the C-foil lifetime and stability of the charge-stripped beam intensity. Therefore, a suitable technique is required for removing C-foils from the substrates.

A thin C-foil with a thickness ranging from 10–80 μg/cm^2 was fabricated using the arc discharge method.[1)] Before evaporating carbon, a chloride-based releasing agent was deposited onto the substrate using a resistance-heated source. The C-foil was removed from the substrate using the general method of floatation on water and was subsequently attached to a holder.

A C-foil thicker than 0.1 mg/cm^2 was fabricated using the magnetron sputtering method.[2)] Similar to the case of the thin C-foils, the substrate surface was initially treated with a releasing agent. For carbon thicknesses of 0.1–0.3 mg/cm^2, fluorine-based releasing agents, such as DAIFREE (GA-6310)[3)] are suitable. For C-foil thicker than 0.3 mg/cm^2, a silicon-based releasing agent RELEASE[4)] is suitable.

To quantify the surface condition of the substrate before C-foil deposition, the contact angles of pure water were measured on various substrates using the sessile drop method. Table 1 lists the measured contact angles for each combination of the substrate and releasing agent along with the C-foil thickness ranges and deposition methods. Release agents giving higher contact angles are needed for foils with increased thickness. In other words, a negative relationship exists between the C-foil thickness and the required wettability of the substrate.

Table 1. Summary of the contact angles and C-foil thicknesses.

Thickness (μg/cm^2)	Method	Releasing agent	Substrate	Contact angle (deg.)
10-40	AC arc	$NiCl_2$	Slide glass	31.5
60-80	AC+DC +AC	$LaCl_3$	Slide glass	36.5
100-300	Magnetron sputtering	DAIFREE Fluorine based	5-inch Si wafer	57.6
300-10000	Magnetron sputtering	RELEASE Silicon based	5-inch Si wafer	103.5

† Condensed from the article in EPJ Web Conf. **285**, 05001 (2023)

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Furthermore, potential candidates for application as efficient releasing agents have also been identified. Ionic liquids (ILs), which negligibly evaporate at room temperature, or even in vacuum, are potentially promising materials as releasing agents. Since ILs do not easily change state in any environment, it is thought that the effect on the C-foil is small as well even if it is taken out of the chamber after vapor deposition. Moreover, if IL is deposited on a substrate while maintaining its properties as a liquid, an extremely thin and uniform layer of release agent can be formed.

This time, a water-soluble IL (ILA48-32)[5)] was tested to determine the feasibility of using it as a releasing agent. This IL had a decomposition temperature of 170°C.

The IL was tested as a releasing agent as follows:

1. The IL was placed in a deep Ta boat and covered with a perforated Ta lid.
2. The IL was evaporated with a resistance-heating evaporation source.
3. Carbon was deposited via the arc discharge method.
4. The carbon-deposited substrate was removed from the device and allowed to float on water. The carbon layer was then peeled off.

The peeled C-foil condition was poor, possibly because the IL amount was not optimized, and the IL did not spread uniformly on the substrate. The optimization of the IL amount is difficult because the thickness of the IL layer cannot be measured using a crystal rate thickness monitor. Herein, the entire releasing agent is heated simultaneously, and the IL is immediately boiled, forming various sizes of molecular clusters of the IL as a flux to the substrate. As a result, the IL does not adhere uniformly to the substrate because of the various sizes of the molecular clusters in the deposits. It is thought that when the IL amount is controlled and a small amount of IL is evaporated many times in a short period to result in a flux with a uniform molecular density, the IL will adhere uniformly to the substrate.

References

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DOI:10.34448/RIKEN.APR.57-014