Department of Engineering – Risk Assessment

Ref No. B965

Title of project/experiment/activity

Fabrication of Layered Material-Based Optoelectronic Devices

Location of activity	**Start and end dates**
• EEDB Annexe, CGC Cleanroom (Class 100 and 1000) • EEDB Cleanroom (Class 100 and 1000)	01/07/2017 - continuous

Brief description (or attach procedure/protocol)

- Use of solvents and acids
- Use of hot plates
- Mechanical exfoliation of layered materials and transfer
- CVD growth (Graphene Square Furnace) and transfer
- Reactive ion etching
- Lithography processes (EBL and Laser Writer)
- Metal deposition by thermal evaporation
- Lift-off

Chemicals/Gases/Substances:
Solvents and developers: *isopropanol, ethanol, acetone, chloroform, anisole, methyl isobutyl ketone, AZ351B*
Acids and bases: *ammonium persulfate, acetic acid*
Metal pellets or wires: *aluminium, chromium, titanium, gold, platinum, palladium*
Gases: *argon, hydrogen, nitrogen, oxygen, methane*
Polymers: *poly-methyl-methacrylate, polycarbonate, polypropylene carbonate, polydimethylsiloxane, polyvinyl alcohol, AZ 5214*

Hazard	Effect	Control measures	Residual risk
Slips, trips, and falls	Minor injury	Ensure work area is free from trailing cables, tools, materials, debris, and spills. All work should be from a suitable and stable work platform.	Low risk
Electricity	Electric shock	Check condition of lead and plug before use. Use 110V or battery tools or RCD where practical. Do not work where water is present without specialist advice. Qualified person to test all portable electrical hand tools at least annually	Low risk
Chemicals	Minor to serious injuries	Wear protective equipment at all times and use dedicated fume hoods for handling acids and solvents. Dispose of chemicals in appropriate containers. Keep flammable solvents away from heat sources, hot plate, sparks, open flames, and other ignition sources. Weigh ammonium persulfate in a glove box.	Low risk

Heat sources	Burns	If hot plate is hot (in use), other procedures must be carried out at sufficient distance to hot plate to avoid contact with skin. If it is left unattended, clear warning signs must be placed to alert other laboratory users of hazard.	Low risk
Gas Leak	Explosions	Keep system fully enclosed.	Low risk
Laser	Damage to the eyes	Keep all lasers enclosed inside a laser safety enclosure. Auto-shut-off of whole system when this safety box is lifted or removed.	Low risk

Personal Protective Equipment required [*eye/face protection, respiratory protection, gloves, lab coat etc*]

Cleanroom coveralls, gloves (purple nitrile) and eye protection (safety specs) required in the lab at all times. Gloves, eye protection, over-boots, and lab coat must be worn during the whole process of fabrication. The equipment must only be used by those approved by Domenico De Fazio after appropriate training. The cleanroom rules will be respected.

Emergency Instructions & First Aid

Fire:
In case of fire, the fire alarm should be sounded and fire service called.

First aid:
General advice: Consult a physician. Show this safety data sheet to the doctor in attendance.
If inhaled: If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.
In case of skin contact: Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.
In case of eye contact: Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

Gas Leak:
In the case of a gas leak, the flow controller should be closed, as should the forming gas cylinder. If the leak triggers the clean room gas alarm, then the clean room should be evacuated

Burn:
In the event of burn, rinse with running water and seek first aid if necessary. Report any accident. /YA

Any special monitoring required [*e.g. hearing test, vibration monitoring, health surveillance*]

N/A

Further control measures required? If yes, list with actions.

Gloves, eye protection, over-boots, and lab coat must be worn during the whole process of fabrication. The equipment must only be used by those approved by Domenico De Fazio after appropriate training. The cleanroom rules will be respected.

When using **solvents and acids** the beakers of liquid should only be handled inside the extracted fume cupboard. Solvents and acids must be handled in dedicated bays. Additional protective equipment, such as rubber gloves, apron, or face shields, should be worn when handling acids if required. Wipes with a small quantity of solvent may be used elsewhere in the laboratory using the wash bottles. Acids are added to water and never the opposite to prevent uncontrolled exothermic reactions resulting from dilution. After use they are disposed in the appropriate waste bottle, which are kept in the dedicated fume hood and removed when the maximum fill level has been reached. Possible hazards include exposure to fumes and spillages (Likelihood: 2, Severity: 3). For any process step, keep amount of solvents and acids to the minimum amount required. Solvents will never be heated.

The greatest hazards when using **spin coaters** are fumes and spillages. The people at risk can be: operator, other people in laboratory (fumes) (Likelihood: 1, Severity: 1). A mechanical (injury) hazard possible from spin coater can happen only if it has no interlock to ensure closed lid. Resulting injury would be minor, as sample size is small (Likelihood: 1, Severity: 1).

Hot plates can reach high temperatures. Splashes of solvent may catch fire if hot plate is hot. People at risk: operator and other people in building (Likelihood: 1, Severity: 3) The preventive measures are the following: if hot plate is hot (in use), no other procedures involving flammable substances may be carried out in proximity. If left unattended, clear warning signs must be placed to alert other laboratory users of hazard. There is also risk of burns. People at risk are: operator, or other people working near hot plate (Likelihood: 1, Severity: 1). The preventive measures are the following: if hot plate is in use, other procedures must be carried out at sufficient distance to hot plate. If left unattended, clear warning signs must be placed to alert other laboratory users of hazard. Use tweezers to place and remove samples. Another hazard for hot plates is solvent evaporation over long periods. The people at risk are: the operator and other people in laboratory. Use parafilm to cover beakers during treatment.

CVD Growth and Transfer (Graphene Square furnace, CGC Cleanroom):
The guidelines for safe operation of the furnace equipment provided by the manufacturer must be read and followed. The operator must ensure that the side panels are mounted before switching on the system. Ensure that the screws on the lid of the furnace are loose while venting to prevent tube explosion. Do not place anything (clean room wipes, tools, samples etc.) inside the reactor as they pose a fire hazard and may block the movement of the heater element. Solutions for substrate cleaning and wet etching during growth and transfer are prepared in the acid bay

Reactive Ion Etching (Moorfield NanoEtch RIE, CGC Cleanroom):
There is a risk of exposure to reactive gases. It is also possible that the user is exposed to radiofrequency (RF) radiation used as an ionizing source for dry etching. During the process an appropriate distance from the chamber should be respected, while after the process the machine should be pumped to base pressure (5×10^{-5} mbar for the NanoEtch machine) before venting.

Electron Beam Lithography (Nanobeam, EE Cleanroom):
Mask preparation with polymers is carried out in a fume hood. The system itself contains an electrical hazard: 100kV power supply is used, digital & analogue electronics cabinet. Actions: 100kV power supply has shielding cables to avoid exposure/human accidental contact, warning labels placed to indicate high kV, electronics and analogue cabinet are kept in a separate room away from user

Laser Writer (Type LW405C, CGC Cleanroom):
Usage of laser writer is covered by a dedicated risk assessment.

Thermal Evaporator (MBraun Glovebox Thermal Evaporator, CGC Cleanroom):
This thermal evaporator is accessible from the back of the glove box and can be used as stand-alone equipment.

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When using evaporator user must allow cooling down of the evaporating source by waiting at least 10 minutes before venting.
Biological/Laser/Radiation Approval [*requires relevant Specialist Safety Officer signature and date*] Laser approval needed.
Out of hours/Lone working These procedures can be operated out of hours, upon permission of Head of Division, only if a buddy is nearby and checks regularly that everything proceeds regularly. These procedures cannot be run overnight.

Signature to confirm that this is a suitable and sufficient assessment of risk and that stated control measures are in place. This risk assessment should be reviewed if additional risks not covered in this assessment are identified or if there is any reason to indicate that the control measures are insufficient.

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Departmental Safety Office IAN SLACK	**Signature**	**Date** 27 JUL 2017