AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE	PAGE OF PAGES
	1 | 7

2. AMENDMENT/MODIFICAITON NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. (If applicble)
A00001	01/06/2014	63-6011-14	

6. ISSUED BY	CODE	7. ADMINISTERED BY (If other than Item 6)	CODE
Supply Officer (Code 3410) Naval Research Laboratory Phone: 202-767-0105 E-mail: donna.speight@nrl.navy.mil	N00173	Purchasing Officer (Code 3410) Naval Research Laboratory 4555 Overlook Avenue, S.W. Washington, DC 20375-5329	N00173

8. NAME AND ADDRESS OF CONTRACTOR (No., street, county, State and ZIP Code)

ALL QUOTERS

CODE | FACILITY CODE

(X) 9A. AMENDMENT OF SOLICIATION NO.

[X] N00173-14-Q-0067

9B. DATED (SEE ITEM 11)

12/30/2013

10A. MODIFICATION OF CONTRACT/ORDER NO.

[ ]

10B. DATED (SEE ITEM 13)

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

[X] The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers [X] is extended, [ ] is not extended.

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods: (a)By completing items 8 and 15, and returning _____ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment your desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPIRATION DATA (If required)

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
[ ]	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: (Specify authority) THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
[ ]	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (such as changes in paying office, appropriation date, etc.) SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
[ ]	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
[ ]	D. OTHER (Specify type of modification and authority)

E. IMPORTANT: Contractor [ ] is not, [X] is required to sign this document and return 1 copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION (Organized by UCF section headings, including solicitation/contract subject matter where feasible.)

This amendment is issued to extend the closing date and add revised specifications and correction to block 4 requisition no.

The above referenced Request for Quotation (RFQ) is extending the closing date to 01/17/2014.

See attached specification sheet with revised specs. Block 4 should read 63-6011-14.

All other terms and conditions will remain the same.

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER (Type or print)		16A. NAME AND TITLE OF CONTRACTING OFFICER (Type or print)	
		Donna M. Speight/Purchasing Agent	
15B. CONTRACTOR/OFFEROR (Signature of person authorized to sign)	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA Donna Speight (Signature of Contracting Officer)	16C. DATE SIGNED 1/3/2013

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Previous edition unusable

STANDARD FORM 30 (REV. 10-83)
Prescribed by GSA FAR (48 CFR) 53.243

Rapid Thermal Chemical Vapor Deposition Hybrid System

NRL requires a rapid thermal Chemical Vapor Deposition (CVD) hybrid system for the growth of heterostructures consisting of two dimensional (2D) materials, specifically including but not limited to graphene and hexagonal boron nitride (h-BN), with ferromagnetic metals. The system shall provide for CVD growth and electron beam deposition on 2" diameter substrates. The system shall provide for rapid changes of sample temperature over the range 25°C to 1100°C for CVD growth at operating pressures from 10^{-2} Torr to 760 Torr in gas atmospheres which include 20 Torr of methane or hydrogen. It shall be capable of growth upon 2" diameter substrate wafers and shall include four gas channels for CVD growth. The electron beam (e-beam) system shall provide for deposition at an operating pressure of 10^{-6} to $5x10^{-8}$ Torr of six separate materials onto the 2" substrate wafer – typical examples include iron, cobalt, nickel, permalloy, tantalum and gold. The e-beam hearth shall be separated from the deposition chamber by an 8" conflat flange gate valve. The system shall include all instrumentation, power supplies, vacuum pumps, flanges, viewports and cabling to meet the performance specifications.

NRL shall provide all necessary electrical, compressed air, water and gas requirements, an 8" conflat flange gate valve, and 2 new dry scroll pumps (one Iwata ISP-250C-SV, 10.6 CFM, 12 mTorr base pressure, and one Iwata DVSL-100B Vacuum Scroll Pump 4.2CFM 150mTorr base pressure) for rough pumping.

General system features

- Stainless steel cold wall chamber
- Copper gasketed Conflat style flanges
- Optical viewport for viewing sample during growth
- Optical viewport with shutter for viewing e-beam hearths
- Fast digital PID sample temperature controller
- One purge gas line
- Four stainless steel process gas lines with independent digital mass flow controllers
- Pressure measurement
- Downstream pressure control for CVD growth processes
- Oil-free high vacuum turbo molecular pump and dry backing pump
- Floor standing system with wheels and feet with all equipment integrated within the system frame (not including roughing pump and sources for process gases, water, air and electrical power)
- Optical access for future in-situ optical monitoring of sample during growth

Vacuum and gauging

- E-beam chamber base pressure of $5x10^{-8}$ Torr or less
- Vacuum gauging with digital readout to monitor pressure from system base pressure to atmosphere

- At least one vacuum gauge in the CVD chamber shall be insensitive to gas composition over the range 1 mTorr to 760 Torr. An acceptable example of such a gauge is a capacitance manometer.
- Pumping system: the vacuum pumps must be oil free. The main high vacuum pump shall be a turbo molecular pump of at least 300 liter/sec speed (N_2) and capable of achieving a pressure in the e-beam chamber of 10^{-7} Torr after a dry nitrogen backfill to atmosphere within 12 hours, and a pressure of less than 10^{-6} Torr after sample transfer from atmosphere within 3 hours.
- Vacuum valving: a gate valve shall isolate the deposition chamber from the turbomolecular vacuum pump. Other valving necessary to meet vacuum and performance specs shall be included.
- Venting the chamber: the system shall include a means to automatically vent the e-beam chamber by backfilling the chamber with dry nitrogen. The dry nitrogen source will be supplied by NRL.
- Operating pressures during growth (typical ranges)
  CVD: 10 mTorr to 760 Torr
  E-beam: $1x10^{-6}$ to $5x10^{-8}$ Torr

Deposition chamber

Chamber: the chamber shall be a stainless steel water cooled cold wall chamber with conflat style flanges It shall include the following ports:

- A port for the CVD sample manipulator
- A port with a viewport and shutter to view the e-beam hearth
- A port with a viewport for optical monitoring of sample surface during growth
- an auxiliary port with a 6" OD or 8" OD conflat flange for an optional upgrade to add a load lock chamber for future wafer transfer.
- An 8" conflat flange gate valve shall isolate the e-beam hearth from the deposition chamber.

Gas handling: the system shall provide for introduction of 4 separate gases either individually or any combination thereof into the growth chamber at a user selected flow rate for each gas and user selected total growth chamber pressure.

- Mechanism: electronically controlled mass flow controllers with individual digital readout
- Channels: a minimum of 4 independently controlled channels for 4 gases
- Gases: methane, hydrogen, argon, and borazine.
- Flow rates and accuracy: 1% of full scale accuracy and 1% of reading. Individual controllers will have full scale flow rates selected from 10 – 1000 sccm (specified at time of order)

Pressure control during growth: active downstream pressure control to maintain user selected growth chamber pressure for CVD growth for a user-selected gas flow process. Example: a graphene CVD growth process with 25sccm CH4 and 300 sccm Ar/H2 at a total

pressure of 50 Torr. An acceptable example of such downstream control is an adjustable throttle valve at the vacuum pump port with suitable feedback to the pressure management hardware and electronics.

Operating pressures during growth (typical):

CVD: 10 Torr to 760 Torr

Sample stage for CVD/e-beam growth

Sample size: the sample stage shall hold substrates ranging in size from 1 cm x1 cm up to 2" in diameter. A typical substrate would be a Si(001) wafer. The sample stage shall securely hold the sample for heating as specified below.

Sample temperature: the system shall include a sample heater, power supply, temperature measurement device, and digital PID controller system to meet the following performance specifications. The sample heater shall be capable of meeting these specs from the system base pressure to atmosphere in a gas environment of up to 20 Torr of methane or hydrogen.

Range: 25 – 1100°C

Rate: 50°C/min over the range 100-900°C. The sample shall reach a temperature of 1000°C from 25°C within 30 minutes at a pressure of 1 mTorr

Uniformity: ± 5 % over the 2" diameter substrate wafer after a settle time of 10 minutes at the user-selected temperature

Accuracy: ± 5°C after a settle time of 10 minutes at the user-selected temperature

Stability: ± 5°C over a 30 minute period after a 10 minute settling time

Electron Beam Evaporation

The electron beam deposition system shall include the following capabilities.

- The e-beam system shall include 6 independent sources with water cooled hearths with at least 7 cc source capacity and 6 kW power: an acceptable arrangement would be a 6-pocket rotary source
- The e-beam system shall be mounted in a water-cooled chamber
- An 8" conflat flange gate valve shall isolate the e-beam hearth from the deposition chamber.

- Deposition rate at sample: 0.3 nanometer / second for iron
- rate monitor: a measurement instrument shall be included within the chamber to measure the e-beam deposition rate during deposition with a measurement range from 0.01 to 1 nanometer/sec and an accuracy of ±0.01 nm/sec. An acceptable instrument would be a quartz crystal microbalance.
- shutters: the system shall include 2 shutters: a sample shutter within 1" of the sample face which shields the sample from the e-beam hearth, and a shutter directly above the

e-beam hearth or on the rate monitor so that the e-beam rate can be stabilized using the rate monitor at a user-selected rate before the sample shutter is opened for actual deposition on the sample. Both shutters shall be electro / pneumatically controlled.

- Control instrumentation: the system shall include the necessary power supplies and instrumentation to meet the above e-beam evaporation performance specs and control e-beam rate, e-beam shutter and sample shutter to deposit predetermined user-selected thickness of film deposited from e-beam source.
- Operating pressure during e-beam deposition (typical): $1x10^{-6}$ to $5x10^{-8}$ Torr
- The following specific conflat flanged ports shall be included
  - Two optical viewports to monitor the sample surface during e-beam deposition
  - A viewport with a shutter to see the e-beam hearth
- Additional conflat flanged ports shall be included as necessary to meet overall system specifications for vacuum, gauging, venting, pumping, etc

Computer interface

- all pumps, valves, mass flow controllers, gauging and other instrumentation shall include an electronic interface to enable future upgrade to computer control. Acceptable output interfaces are RS232, GPIB, USB, or Firewire.

Computer: No computer or software will be supplied with this procurement.

Installation and training

The vendor shall assemble and install the system at NRL and provide a hour training session of at least 4 hours to a group of 4 users.

Drawings: vendor shall submit drawings of proposed system design with bid illustrating compliance with specifications above, and full chamber drawings for approval by end user before fabrication.

Demonstrated growth performance and acceptance specs

- **Growth of graphene:** The system shall have demonstrated growth of graphene on copper foil and/or nickel foil to a thickness of 1-3 layers within a 30 minute growth time
- **Graphene quality:** The system shall have demonstrated growth of graphene on copper foil and/or nickel foil with a Raman "D" defect peak intensity less than 10% of the "G" peak intensity for graphene films 1 layer thick on copper and up to 1-10 layers thick on nickel. Raman measurements will be performed onsite by NRL using 488 or 532 nm laser excitation at room temperature.

Warranty : 1 year parts and labor

OPTIONS

The vendor is requested to provide pricing for the following options which may or may not be included in the order. Options should be available and pricing should be effective up to 6 months after system installation at NRL.

OPTION 1. Load lock / sample introduction and transfer system

The system shall include a load lock chamber and sample transfer assembly attached to and isolated from the deposition chamber by a gate valve for the introduction of 2" diameter substrate wafers. The load lock shall be pumped independently of the deposition chamber through either separate pumps or appropriate isolation valves. It shall enable the user to introduce a new substrate wafer from atmosphere and load it onto the sample manipulator within 30 minutes while allowing the deposition chamber pressure to remain below 1 mTorr. The load lock chamber shall also serve as an additional CVD chamber.

- The chamber shall be a stainless steel cold wall chamber with conflat style flanges. The walls shall be water cooled.
- The chamber shall include provisions for CVD growth, including delivery of source gases per the specs above, pumping / pressure measurement / regulation per the specs above, heated sample stage per the specs above capable of receiving a sample from and transferring a sample back to the sample transfer arm.
- If this option is exercised, the heated sample stage in the main procurement shall be utilized in the sample load lock / CVD chamber, and shall be replaced by an unheated sample stage in the e-beam deposition chamber capable of receiving a sample from and transferring a sample back to the sample transfer arm.
- The chamber shall include the following ports
    - A port for introduction of samples, which shall have a hinged o-ring sealed flange providing access at least 6" in diameter to the sample area
    - A port for the CVD sample manipulator
    - A port for the transfer arm assembly
    - A port with a viewport for optical monitoring the sample surface during growth
    - an auxiliary port with a 4.5" or 6" OD flange for an optional upgrade to a turbo molecular pump.

OPTION 2. Turbo pump on load lock

- An additional turbo pump with at least a 50-80 liter/sec pumping speed (N2) and gate valve shall be mounted on the load lock to enable a base load lock pressure of 10^{-6} Torr within 6 hours of venting and pumping load lock.

OPTION 3. Computer and Control software and hardware to provide the following functions:

- Simultaneous control of sample temperature, gas flow rates for all 4 gas channels, and operating pressure to accomplish the CVD growth of graphene films. For a given growth

run stream, the control software shall provide 20 separate user-defined segments. In each segment, the user shall be able to specify sample temperature, temperature ramp rates and soak times, system pressure and gas flow for each of the 4 gas channels.

- Deposition control: control e-beam rate, e-beam shutter and sample shutter to deposit predetermined user-selected thickness of film deposited from e-beam source.
- Automatic venting and pump down of growth chamber or load lock

OPTION 4. Additional mass flow controllers

- Two additional mass flow controllers (MFCs), control electronics and gas plumbing / valves from MFC to growth chamber.

OPTION 5. The system shall include capability to generate atomic hydrogen near the sample surface for pre-cleaning the growth substrate, facilitating growth of graphene / etching graphene, h-BN and heterostructures thereof with ferromagnetic metals, and etching the graphene and h-BN after growth. This will include a two-color infrared (IR) pyrometer with LED digital display for measuring and monitoring and the hot filament temperature through an optical fiber.