



**PROMIS – Postgraduate Research on Dilute Metamorphic
Nanostructures and Metamaterials in Semiconductor
Photonics**

Marie Skłodowska-Curie Initial Training network (ITN)
Grant agreement No 641899

Progress Report



Progress report – ITN

1. General progress of the action

Overall progress of the project in the first 12 months has been excellent, with full engagement from all partners and ESRs.

WP1 Materials for ICT

Major progress has been made towards the realization of novel single-photon sources based on hydrogenated (In)GaAsN quantum dots (QDs) to be integrated into photonic devices. In ROME, GaAsN (In-containing samples from UMR are being processed) QDs have been fabricated by a two-step process involving H irradiation and laser annealing (D1.1). The dots perform as excellent single-photon sources. QDs with highly uniform emission energy were also obtained by hydrogenation following deposition of H-opaque masks. This result was enabled by the knowledge of GaAsN band structure and H diffusion profile (D1.2). Tyndall has studied the emission dynamics of GaAsN QDs using time-resolved photoluminescence, revealing a series of interesting effects. ROME prepared GaAsN/GaAsN:H wire heterostructures for TEM characterization at UMR and UCA.

WP2 Materials for Security

Al(Ga)AsSb wafers grown to optimise the doping profile were evaluated at SHEFF. Two APDs showed distinct punch-through voltage, with dark current density of 10^{-4} A/cm² suggesting that the doping profile is close to optimum. These wafers will also provide the 1st iteration of devices for D2.2 and D2.4. Three APD samples (InAs pin, InGaAs/InAlAs APD, InGaAs/Al(Ga)AsSb APD) have been sent to Tyndall-UCC for lifetime measurements for D2.3. Low temperature TRPL revealed decay times ~ 1 ns and high radiative efficiency. APDs have been sent to SGENIA/UAM for integration with plasmonic lens. SGENIA/UAM has designed and fabricated a preliminary plasmonic lens based on Al-doped ZnO. Future designs will be using e-beam lithography to achieve operation wavelength of 1.55 μ m. Ga nanoparticles are also being investigated and these will contribute towards D2.4.

WP3 Materials for Energy

Intermediate band solar cells containing 5 or 10 stacked layers of GaSb quantum dots (QD) have been grown and characterised using PL spectroscopy at ULANC and TEM at UCA. Delta doping and the positioning of the GaSb QDs within the active region have been investigated. Results are reported in 2 joint publications (D 3.1). Tyndall-UCC are developing calculations of emission and capture rates from the GaSb intermediate band states in advance of the next growth iterations. Successful MBE growth of AlInAsSb on GaSb has been achieved at UM. This material has been little studied and very few references are available, requiring a detailed study of the growth conditions, but designs of multi-junction solar cells on GaSb and of tandem solar-cells grown on Si have been developed. III-V Lab has intensively studied MOVPE growth of high quality GaInP and AlInP lattice-matched on GaAs with adequate p-doping. The importance of a low-mobility GaAs buffer-layer has been evidenced and modelling of InP-based solar cells was also performed.

WP4 Materials for Environment

MBE growth and hydrogenation studies are progressing on target. Prototype LEDs have been fabricated which exhibit emission near 3.3 μ m and 4.2 μ m for hydrocarbons and CO₂ detection (D4.1). GSS Ltd have also provided LEDs for benchmarking at ULANC. InAsN(Sb)/GaAs samples containing different amounts of N grown at ULANC were sent to ROME for hydrogenation and to UMR for TEM analysis, to UM for carrier concentration measurements and for p-i-n diode evaluation at SHEFF. The influence of N and H on luminescence efficiency and carrier concentration are being studied at ULANC, ROME and NOTT and have shown significant enhancements – results published recently. The plasmonic modes due to the H-induced increase of electron density in InAsN are under study by optical techniques at NOTT and UM2. The first InAsN/InAlAs resonant tunnelling diodes have been grown and fabricated at ULANC and are now being characterised by the ESR at NOTT. Monitoring the doping level of the InAsSb layers for plasmonics grown by MBE was done at UM and bio-functionalisation is in progress on GaSb and InAs substrates at Sikémia.

2. **Recruitment** (All researcher's declarations have been submitted for each recruited researcher)

Fellow ID	Last Name	First Name	Last Country of residence of researcher prior to MSCA	Name of recruiting participant	Country of recruiting participant	Academic / Non-academic	Recruitment Start date	Recruitment End date	Contract Type ₁	Family charges	Working time commitment (100%)	Duration within reporting period FTE	PhD enrolment
1	Di Paola	Davide	Italy	University of Nottingham	UK	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
2	Pinel	Lucas	France	University of Sheffield	UK	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
3	Montesdeoca Cardenes	Denise	Spain	Lancaster University	UK	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
4	Repiso Menendez	Eva	Spain	Lancaster University	UK	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
5	Abdullah	Salman	Pakistan	University of Sheffield	UK	academic	01/11/2015	31/10/2018	A	Yes	100%	3 months	Yes
6	Arkani	Reza	Iran	University College Cork	Ireland	academic	01/10/2015	30/09/2018	A	Yes	100%	4 months	Yes
7	Alam Khan	Atif	Bangladesh	University of Cadiz	Spain	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
8	Gupta	Shalini	India	University of Marburg	Germany	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
9	Soresi	Stefano	Italy	III-V Lab	France	Non-academic	15/09/2015	14/09/2018	A	No	100%	4 ½ months	Yes
10	Bomers	Mario	Germany	Universite de Montpellier	France	academic	01/09/2015	31/08/2018	A	No	100%	5 Months	Yes
11	Tournet	Julie	France	Universite de Montpellier	France	academic	15/09/2015	14/09/2018	A	Yes	100%	4 ½ months	Yes
12	Nucciarelli	Flavio	Italy	Sgenia	Spain	Non-academic	13/07/2015	12/07/2018	A	No	100%	6 ½ months	Yes
13	Gandan	Shumithira	Malaysia	University College Cork	Ireland	academic	19/10/2015	18/10/2018	A	No	100%	3 ½ months	Yes
14	Younis	Saeed	Israel	Sapienza Università di Roma	Italy	academic	01/11/2016	31/10/2018	A	No	100%	3 months	Yes
15	Sharma	Mayank	India	Sapienza Università di Roma	Italy	academic	01/12/2016	30/11/2018	A	No	100%	2 months	Yes
*	Amri	Emna	Tunisia	ID Quantique	Switzerland	Non-academic	01/10/2015	30/09/2018			100%	4 months	Yes

*ID Quantique one of our partner organisations have been funded by SERI for Emna Amri

3. Recruitment strategy

The project Kick-off Meeting was held in Lancaster, UK on 10th – 11th March, 2015. During this meeting strategic discussions took place between the partners regarding the PROMIS recruitment plan. Subsequently, ESR positions were advertised widely through a number of resources, including: The EURAXESS jobs website (<http://ec.europa.eu/euraxess/jobs>); the CORDIS website (<http://cordis.europa.eu>); the PROMIS network website and individual partners' websites and via other advertisers normally used by the individual partners. The responsibility for recruiting each ESR was delegated to the individual partners and monitored throughout by the co-ordinator (ULANC). Following shortlisting and interviews the details of runner's up were circulated to the other partners. Interviews were by mixed gender panel and following local HR rules in each institution. As a result we have recruited an excellent contingent of capable well-motivated ESRs.

Of the 16 ESRs (15 EU plus 1 Non Marie Curie partner – ID Quantique), all have been recruited and almost all were in place by the end of month 11 as planned. The recruited ESRs include 10 male and 6 female Researchers, from both EU (8) and non-EU (8) countries.

Declaration of Conformity forms have been completed for all Marie-Curie recruited Fellows, and submitted online through the Participant Portal.

4. Career development plan for each recruited researcher

Supervisory arrangements have been successfully implemented for each ESR as originally planned. Each of the ESRs each has been allocated a principal supervisor, a mentor and in some cases a co-supervisor. Dr. S.E. Krier (ULANC) was appointed as the Training manager to oversee the network wide training. All ESRs are reported to have settled in to their environment and are progressing well. Career Development Plans have been developed and received from 14 of the ESRs (including the non-Marie Curie ESR). The remaining 2 ESRs were recruited recently (1st November and 1st December 2015 respectively) and their CDPs are in preparation.

The first PROMIS Workshop was hosted by the University of Sheffield from 21st -23rd September 2015 and included a 1-day Communication Skills course followed by an intensive 2-day programme of technical presentations. During the Communication Skills course, the ESRs were given the opportunity to prepare a short presentation, which they then presented to the whole meeting for constructive feedback. The 2-day technical programme was comprised of introductory lectures from high-profile speakers on growth and fabrication techniques pertinent to the PROMIS work packages. This included introductions to both MBE and MOVPE growth, Materials Characterisation, Defect Behaviour in Semiconductor Devices, Device Fabrication, Hydrogen in Semiconductors, Materials and Processing for ICT and Antimonide Materials. Twenty-one ESRs attended the workshop including 11 non-PROMIS researchers.

The ESRs are also receiving training appropriate to their own projects in their home institutions, this includes, for example, training in the safe use of cryogenic liquids and lasers, in the use of the characterisation tools (XRD, C-V profiles, Hall effect measurements and Transmission Electron Microscopy), in TEM sample preparation, device –processing and MBE and MOVPE growth and substrate preparation. In addition to undertaking their own literature reviews, some ESRs have also attended conferences and workshops to widen their subject knowledge and to take advantage of networking opportunities.

Two ESRs have been elected to serve on the Supervisory Board.

5. For EID and EJD

N/A

6. Management of the action

The project Kick-off Meeting was held in Lancaster, UK on 10th – 11th March, 2015. It was very well attended and PROMIS was formally opened by the Deputy Vice-Chancellor of Lancaster University. An overview of the PROMIS project was given and the administrative arrangements were highlighted by the co-ordinator and Dr. S.E. Krier of Lancaster University was subsequently appointed as the Training Manager. The structure and content of the first workshop were discussed and satellite meetings to discuss the individual work packages in more were also held. The Supervisory Board membership was finalised and dates for the first two workshops were confirmed. Minutes of this and subsequent meetings are available in the member's area of the project website.

The first Workshop was held in Sheffield, UK on 21st – 23rd September, 2015. The workshop included a Communications Skills course, as well as tutorial-style lectures on different III-V semiconductor growth and fabrication techniques. It allowed many of the PROMIS Fellows to meet face-to-face for the first time and was also well attended by other, non-PROMIS, students from the partner institutes. The atmosphere of the workshop was upbeat and enthusiastic with excellent interaction between the ESRs, supervisors and invited speakers throughout. Time was also provided for networking and discussion of the individual work packages led by the WP leaders. The second Supervisory Board meeting was also held on the last day of the workshop. Denise Montesdeoca (ULANC) and Davide Marie Di Paola (NOTT) were nominated to represent the ESRs at the next Supervisory Board meeting.

In addition to the formal network meetings there have been continuous email and phone interactions between WP leaders, the supervisors and ESRs as appropriate. There has also been very good interaction with the associated industrial and academic partners. Regular Internal web conferences are taking place between ESRs by WebEx. These web conferences give opportunity for the researchers to discuss a research challenge with their peers. During each of these sessions one or more researchers will outline a particular challenge that they need to master in order to progress their project and seek ideas and thoughts how to approach this problems for their colleagues. This approach will allow the expertise of all researchers to contribute to the individual research project to enhance the quality of the work. Having the researchers coordinate and organize these sessions will allow them to develop their organisational skills and foster a closer bond between the projects and partners.

7. Communication Activities

The launch of PROMIS was publicised via a formal opening and a press release from Lancaster and also through partner web sites. A PROMIS project website was then established at <http://www.physics.lancs.ac.uk/promis/> hosted by the coordinator, and logos and branding were developed. The website includes a project overview, descriptions of the partners and links to their websites, a detailed breakdown of each project along with a bio of each ESR, and a news section. The site also contains a Members Area accessible only to PROMIS members. This area includes a documents area where members can download and upload files. It is planned to expand the site to include detailed breakdowns of PROMIS activities.

The scientific outputs of PROMIS are beginning to emerge, even though the ESRs have only been in post for a few months, and have been disseminated via peer reviewed journals with articles published/accepted for publication in Microscopy Research Innovations, Applied Surface Science & Semiconductor Science & Technology.

PROMIS also participated in the Photonics Ireland Conference 2015 held in Cork from 2nd – 4th September at the Maryborough House Hotel (<http://www.photonicsireland2015.com>). Photonics Ireland is Ireland's leading photonics conference, held biannually since 2007. Dr. David Williams from the Cork Institute of Technology at Tyndall National Institute represented the PROMIS project at the conference exhibition.

8. Impact of the Action

Please describe the impact of the action on the recruited researchers and on the institutions involved or on the completion of the European Research Area.

Currently the impact of the action is difficult to measure with ESRS having been quite recently recruited. The PROMIS partners have recruited high quality researchers. These ESRs are all in place and settling well whilst at the same time actively engaging in the research. The PROMIS training network is beginning to create and contribute to high-quality innovative research and doctoral training, with commercial partners guiding and influencing the direction of the research. The work of the PROMIS network is already having a direct and useful impact on the ESRs and will also impact on the European photonics industry. The network continues to forge new collaborations and strengthen existing collaborations with network partners.