15 June 2018

To Oeko-Institut

Response to (RoHS 2, Pack 15) 1st Stakeholder Consultation – Questionnaire for Indium phosphide (CAS 22398-80-7; EC 244-959-5)

Introduction to Oclaro

Oclaro, Inc. is a leader in optical components, modules, and subsystems for optical transport and metro networks, enterprise networks, and data centers. Leveraging more than three decades of innovation in laser technology, photonic integration, and transceiver/subsystem design, Oclaro's solutions are at the heart of the fast optical networks and high-speed interconnects that are enabling the next wave of streaming video, cloud computing, voice over IP and other high-speed and bandwidth-intensive applications.

Market Focus

Demand for bandwidth and low latency in the core network continues to explode, with video services, cloud computing, voice over IP and social media driving more network traffic. The telecommunications market has started to expand beyond the small number of very large equipment providers… and is now migrating to captive networks, created solely for in-house use by large video services, search engine and cloud computing companies. In addition, the changing needs of the internet are driving an evolution in network topologies. This evolution, combined with the dramatic increase in the need for bandwidth and reduced latency, has created opportunities for new optical technologies and component innovations. At Oclaro, we are investing our R&D where our technology innovation delivers real value and differentiation for the customers we serve. With our heritage of optical innovation we are leading in the very high speed segments of the optical communications market at 40G and above. These solutions are targeted at…:

Telecom Optical Networks

*The core optical network is at the heart of the Internet highway that provides the bandwidth, speed, reach and flexibility to run new and exciting applications such streaming video, social media, cloud computing and voice over IP. Oclaro are a leading supplier of optical products at the component, transceiver, and module level, including tunable lasers, receivers, (*etc.*); that are needed for high-speed transmission and (*Oclaro*) are leading the fastest growing 100G segment (*and beyond, based on InP technology).

Enterprise Networks and Data Centers

Enterprises and data centers have grown in complexity as they manage the rapidly escalating demands for increased bandwidth and diverse types of data driven through the consumerization of IT and the transition to SaaS services. These next generation architectures, such as hyper scale data centers, require very high speed interconnects to support intensive data traffic within and

between corporate datacenters. We are a leading supplier of client-side and short reach optical transceivers at 10G, 40G, 100G and, in some cases, less than 10G, into data communications and enterprise solutions.

Abbreviations and Definitions

EEE	Electrical and Electronic Equipment
InP	Indium Phosphide
InGaAsP	Indium Gallium Arsenide Phosphide
InGaAlAs	Indium Gallium Aluminium Arsenide
DWDM	Dense Wavelength Division Multiplexed systems (Many wavelengths can share a single fiber for transmission. Prisms and lenses combine different wavelengths into a single DWDM beam; it can then be demultiplexed back into separate wavelengths at the receiving end of the fiber transmission)
Photonics	Photonics is the physical science of light generation, detection, and manipulation through emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing (Wikipedia)
EWC	European Waste Catalogue (and Hazardous Waste List)

Consultation Questions

1. Applications in which indium phosphide is in use:

Oclaro Product Portfolio

Oclaro components and modular sub-assembly products leverage photonics technologies to transmit, amplify, regenerate and receive data across fiber optic networks. These products enable our telecommunications and data communications customers to increase network bandwidth, reduce latency, and offer new services to their customers, flexibly and cost effectively. Such networks support optical telecom fixed line and mobile communications, internet, cloud data centers, etc.

At a high level, Oclaro products include:

- Tunable and fixed lasers and transmitters
- Receivers
- Transceivers
- Coherent pluggable modules (equipment sub-assemblies)

The above components and modular sub-assemblies contain InP chips.

These components comprise critical in feeds to systems manufactured by leading companies worldwide in the telecommunications and internet field, including: Nokia, Cisco, Huawei, ZTE, Ciena, Fujitsu, etc. and other equipment providers. The end users employing Oclaro InP components include: The major telecom service providers worldwide, as well as major data center operators including: Microsoft, Google, Amazon.

a) Information concerning products and applications in which the substance - is in use.
   I. In your answer please specify if the applications specified are relevant to EEE products and applications or not.

Oclaro components and modular sub-assemblies are used by a wide range of customers in their EEE communications equipment that may be in scope of RoHS. The RoHS guidance definition of 'fixed installation' is not always clear to interpret in relation to the infrastructure of internet and optical communications and telecom networks and related equipment. Some Oclaro customers that potentially install EEE to what might otherwise have been considered as fixed installations, as part of telecom global infrastructure, may assume the need to comply with RoHS due to lack of clarity. Therefore, Oclaro supports component and modular sub-assembly compliance to RoHS recast article 4 (2011/65/EU as amended) and per regional implementing regulations and guidance, for affected customers who advise Oclaro of this requirement.

II. Please elaborate if substitution of the substance is already underway in some of these applications, in relation to the properties for which indium phosphide is used (for example semiconductor and photovoltaic properties) and/or in relation to specific applications in which it is used (for example critical communication components),

No substitution can be considered by Oclaro for InP components.

InP is the only material that can produce the source of light in the appropriate wavelengths, supporting Oclaro in producing essential technical innovations for the photonics optical communications critical communications components.

This is in terms of current needs and supporting future optical communications related developments, for ever increasing speed / bandwidth technology, which is constrained to the physical wavelength limitations of optical fiber. As optical fiber only operates, (at low signal loss) in two wavelengths: 1.55µm and 1.3µm, for which InP offers the only technically suitable solution.

III. Where relevant, please elaborate which chemical (on the substance level) or which technology (elimination of the need to use InP) alternatives may be relevant for this purpose.

No substitution is relevant.

b) Please specify if you are aware, if aside from actual use of the substance, it may be re-introduced in to the material cycle through the use of secondary materials.

I. Please detail in this case what secondary materials may contain indium phosphide impurities and at what concentrations as well as in the production of what components/products such materials are used.

Not aware of secondary (recycled) materials re-introduced.

II. If possible please provide detail as to the changing trends of indium phosphide concentrations in such secondary materials as well as the changing trend of use of the respective secondary material in EEE manufacture.

Not aware of secondary (recycled) materials re-introduced.

c) Please specify in which applications indium phosphide is used as a material constituent, as an additive or as an intermediate and what concentration of indium phosphide remains in

the final product in each of these cases (on the homogenous material level).

Starting with an InP wafer 650µm thick, this goes through epitaxy process stages, in which thin layers of InGaAsP and/or InGaAlAs are grown on the wafer surface and patterned to form the device. These processes are conducted by metal organic chemical vapour deposition (MOCVD), also known as metal organic vapour phase epitaxy (MOVPE), in which the layers are formed from precursors in gaseous form. The thickness of material deposited is typically less than 10 µm.

A large proportion of the wafer substrate has to be ground away to make the individual chips. Generally 3 inch wafers, 650µm thick, go through a back grind process, to reduce them down to typically 135µm. (The production process related InP back grind waste stream is outside the scope of RoHS law, as other EU / UK waste regulations apply to business process hazardous waste).

% of InP is high at the homogenous level, for example chip components are typically greater than 90% InP. However, individual chip sizes vary according to function, but are all relatively small. Some popular smaller Oclaro chip components shipped in high volumes in 2017 contain 0.17mg of InP and other Oclaro types of laser chip components, used for client side / Datacom communications equipment contains 0.05mg InP. Higher complexity high performance chips for coherent transmission systems can range up to 10mg InP.

2. Quantities and ranges in which indium phosphide is in use

a) Please detail in what applications your company/sector applies indium phosphide and give detail as to the annual amounts of use. If an exact volume cannot be specified, please provide a range of use (for example – 10-100 tonnes per annum).

InP in chips includes primary uses in client-side laser applications and DWDM transmission communications (telecom / internet, etc.).

Oclaro global manufacturing FABs total amount of InP in shipped chips (including in any sub-assemblies shipped), worldwide in 2017, was 1.77kg.

b) Please provide information as to the ranges of quantities in which you estimate that the substance is applied in general and in the EEE sector in the EU and globally.

Individual chip sizes vary according to function, but are all relatively small. Some popular smaller Oclaro chip components shipped in high volumes in 2017 contain 0.17mg of InP and other Oclaro types of laser chip components, used for client side / Datacom communications equipment contains 0.05mg InP. Higher complexity high performance chips for coherent transmission systems can range up to 10mg.

As Oclaro sell the InP components and sub-assemblies to various multi-national EEE manufacturers or component distributors, and the end EEE is marketed worldwide. Oclaro are not privy to the specific EU InP shipment figures in end EEE, but they will be significantly less than 1.77kg InP total Oclaro shipped worldwide in 2017.

c) If substitution has begun or is expected to begin shortly, please estimate how the trend of use is expected to change over the coming years.

No substitution is applicable for Oclaro InP applications.

InP component demand has increased as optical communications have been rolled out by telecom companies and for Government Policies (e.g. UK Government 'Digital Communications Infrastructure Strategy'; European Commission 'Building a European Data Economy', etc.).

This strategy for increasing digital communications relies on optical communications to meet ever increasing data volume and speed demands, based on InP technology, (the only suitable source of light in data transmission for the appropriate wavelengths for fiber optic data transmission technical requirements).

3. Potential emissions in the waste stream

a) Please provide information on how EEE applications containing indium phosphide are managed in the waste phase (with which waste is such EEE collected and what treatment routes are applied)?

Oclaro parts are currently supplied to professional companies, who use Oclaro InP components and sub-assemblies in their EEE aimed at the EU and global markets. These EEE manufacturers and network equipment operators handle their EEE waste in the EU as business to business WEEE (according to the law and local WEEE arrangements).

b) Please detail potentials for emissions in the relevant treatment processes.

This aspect is also under further investigation by Oclaro, as we are requesting the support of a major UK (and global) network operator, to establish how their specific EEE waste is treated.

However, from past experience of that organization and having experienced taking part in an environmental and safety audit of a typical UK EEE waste recycling treatment plant in the past, (that was undertaking telecom network equipment recycling) it is expected that in Europe these network operators' waste arrangements comply with the applicable EU Waste Directives and any applicable local regulations, including WEEE. The WEEE Directive and implementing regulations require treatment facilities to safely recycle / dispose of WEEE hazardous wastes. Member states provide further guidance on methods to employ for WEEE safe disposal, per UK government Waste Electrical and Electronic Equipment (WEEE) reuse and treatment guidance 'Best available treatment, recovery and recycling techniques (BATRRT)'.

As InP components are not specifically identified in this guidance or in EWC waste classifications, these are not removed from WEEE during pre-treatment, due to the very small size of InP components and specialist use they do not pose a significantly higher risk to recyclers than some other materials that are more widely used in electronics (e.g. glass, glass fibers and fiber glass are a much larger proportion of optical electronics materials and are classified per ECHA in the glass oxide chemicals InfoCard as Carcinogenic and Reproductive toxicity, but most glass materials do not require any special pre-treatment, recyclers follow safety practices for preventing particulates exposures during recycling as employed for other WEEE materials).

Therefore as small InP chips remain in WEEE residues after pre-treatment, that may be shredded prior to any final disposal method employed. Recycling operatives, for general EU health and safety requirements, must be protected from particulate emissions. The small mass of InP likely in any WEEE (due to the small amount supplied to market and

small size of individual InP chips that may be present in the WEEE) means the concentration of InP in any particulates will be relatively low. The particulate size, expected during shredding operations, is not expected to be below the particulate size that widely available filters can be used to control, to avoid it's inhalation by recycling operatives. Such shredding operations are expected to comply with safety risk assessment process, ['Best available treatment, recovery and recycling techniques (BATRRT)'] and dust or other emissions are also required to be controlled by the recycling facilities, for the protection of the wider environment.

4. Substitution

a) Please provide details as to the substitution of indium phosphide:

I. For which applications is substitution scientifically or technically not practicable or reliable and why.

No substitution is applicable for Oclaro InP applications at the required wavelengths for Oclaro component applications

II. For which applications is substitution underway? Please specify in this respect which alternatives are available on the substance level (substitution) and which are available on the technological level (elimination). For example, which alternatives can be applied instead of indium phosphide used in solar cells and in semiconductor applications (e.g. gallium arsenide)

No substitution is applicable for InP applications at the required wavelengths, for Oclaro optical communications component applications.
Gallium arsenide (GaAs) does not naturally operate in the required wavelengths for Oclaro DWDM and other optical communications applications.
GaAs is also at least as hazardous as InP (if not more so) according to ECHA InfoCard for GaAs, it is classified as a Carcinogen and Reproductive toxin.
Although silicon components are used in some photonics functions, these always need to be paired with an InP device for light generation or amplification.

III. What constraints exist to the implementation of the named substitutes in a specific application area (provide details on costs, reliability, availability, roadmap for substitution, etc.).

Specific Wavelength of DWDM / optical fibers and other optical communications technologies requires InP components, to reliably create the applicable light source specifically in the required wavelength.

5. Socio economic impact of a possible restriction

Please provide information as to the socio-economic impacts if indium phosphide is to be restricted under RoHS. Please specify your answers in relation to specific applications in which the substances are used and/or in relation to the phase-in of specific alternatives in related application areas. Please refer in your answer to possible cost and benefits of various sectors, users, the environment, etc. where possible; please support statements with quantified estimations.

For Oclaro the economic impacts relate to the fact that the majority of Oclaro income, particularly related to growth of the company and the related employment this supports directly in Oclaro, is reliant on InP technology. Oclaro is then also supporting the employment opportunities to the wider communities

and economic benefits to the industries servicing and supplying goods to Oclaro.

Oclaro customers' industries, that are utilizing Oclaro InP technology in their EEE and in global networks service provision, supports employment and economic benefits to their industries in the EU and globally. In turn communications network users worldwide gain economic and social benefits through access to and use of these digital communications networks; that cover a wide range of communication services and that EC policy aims to further increase.

InP technology is Oclaro's core business. Oclaro employs around 1700 people globally. Oclaro has two InP chip manufacturing FABs with significant Research and Design capabilities, one in the UK / EU (directly employing around 350 people at this location in Caswell, Northamptonshire) and the other in Japan. Oclaro also runs other optical communications components and sub-assemblies factories in Italy and China and utilizes contract manufacturers elsewhere and has smaller commercial and engineering offices in various other regions.

For the years ended July 1, 2017, July 2, 2016 and June 27, 2015, Oclaro revenues were $601.0 million, $407.9 million and $341.3 million, respectively and InP technology innovation was behind this growth.

As for the wider socio economic benefits of optical communications, for telecom, internet and other forms of digital data transmission that rely on InP photonics technology, EC policy (as mentioned briefly above) is relevant in outlining the benefits:

> *'Digital data is an essential resource for economic growth, competitiveness, innovation, job creation and societal progress in general.*
>
> *The value of the EU data economy was more than EUR 285 billion in 2015, representing over 1.94% of the EU GDP. Due to a year-on-year growth rate of 5.03%, this value increased to EUR 300 billion representing 1.99% of the GDP in 2016. If favourable policy and legislative conditions are put in place in time and investments in ICT are encouraged, the value of the European data economy may increase to EUR 739 billion by 2020, representing 4% of the overall EU GDP.'*
>
> Source *'Building a European Data Economy'*

In reality life without telecommunications and the internet is now unthinkable, since the entire economy depends upon these services, which are critically dependent upon optical communications that in turn depends on InP technology.

6. Further information and comments

The information compiled on this substance for the stakeholder consultation has been prepared as a summary of the publicly available information reviewed so far. If relevant, please provide further information in this regard, that you believe to have additional relevance for this review, as well as references where relevant to support your statements.

Oclaro recommends that photonics / optical communications InP use is not subject to a RoHS restriction. InP chips are an individual homogenous material in

EEE, so the % of InP is high at the homogenous level, for example chip components are typically greater than 90% InP, but as noted earlier typical mass of InP in individual chips is very small. Based on Oclaro chip volumes shipped globally in 2017 the average by volume per chip is ~0.2mg InP.

Furthermore, the total amount of indium phosphide Oclaro place on the market, in the Oclaro InP chip components, is small in terms of weight. We believe the risk is relatively low for end of life disposal of finished EEE that contains these small InP chips. As recycling facilities are expected to apply good health and safety practices to protect workers from dust inhalation, such as during WEEE shredding operations, to comply with current EU health and safety law and guidance for recycling plants [such as UK Gov. 'Best available treatment, recovery and recycling techniques (BATRRT)]

A RoHS restriction of InP would significantly disrupt the digital communications photonics components supply chain, which would disrupt the related optical communications equipment industry supply chain and digital optical communications / data transmission applications.

As no safer material substitution is possible or likely in the future, RoHS exemptions are not the appropriate approach. Exemptions are more appropriate as a temporary reprieve, for situations where substitution is possible and can be further developed and implemented during the exempted period. This is not the case for InP use for Optical Communications.

References / Links

Oclaro https://www.oclaro.com/about-oclaro/our-company/

Oclaro financial report 2017
http://investor.oclaro.com/static-files/0c49c389-d0ae-45e6-84f1-fc7bae085297

UK Government Digital Communications Infrastructure Strategy
https://www.gov.uk/government/publications/the-digital-communications-infrastructure-strategy/the-digital-communications-infrastructure-strategy

European Commission 'Building a European Data Economy'
https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

ECHA (European Chemical Agency) InfoCard on Gallium Arsenide
https://echa.europa.eu/substance-information/-/substanceinfo/100.013.741?_disssubsinfo_WAR_disssubsinfoportlet_backURL=https%3A%2F%2Fecha.europa.eu%2Finformation-on-chemicals%3Fp_p_id%3Ddisssimplesearchhomepage_WAR_disssearchportlet%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3D_118_INSTANCE_UFgbrDo05Elj__column-1%26p_p_col_count%3D1%26_disssimplesearchhomepage_WAR_disssearchportlet_sessionCriteriaId%3D

ECHA (European Chemical Agency) InfoCard on Indium Phosphide
https://echa.europa.eu/substance-information/-/substanceinfo/100.040.856

ECHA (European Chemical Agency) InfoCard on Glass Oxide Chemicals
https://echa.europa.eu/substance-information/-/substanceinfo/100.060.023?_disssubsinfo_WAR_disssubsinfoportlet_backURL=https%3A%2F%

2Fecha.europa.eu%2Fhome%3Fp_p_id%3Ddisssimplesearchhomepage_WAR_disssearchportlet%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-1%26p_p_col_count%3D2%26_disssimplesearchhomepage_WAR_disssearchportlet_sessionCriteriaId%3D

UK government Waste Electrical and Electronic Equipment (WEEE) reuse and treatment 'Best available treatment, recovery and recycling techniques (BATRRT)'
http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/waste/producer/electrical/documents/weee-batrrt-guidance.pdf

UK guidance on EU Waste Classification (EWC)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/427077/LIT_10121.pdf

Photonics definition (Wikipedia)
https://en.wikipedia.org/wiki/Photonics

Yours Faithfully

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