EUROPEAN COMMISSION
Horizon Europe Framework Programme (HORIZON)

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Subject: **HORIZON**

Call: HORIZON-EIC-2022-PATHFINDEROPEN-01

Proposal: 101099083 — HYPERSONIC

Right-to-react-pilot cover letter

Dear Madam/Sir,

I am writing in connection with your proposal for the above mentioned call.

As part of the right-to-react ('rebuttal') process in this evaluation, we are sending you the individual comments from the evaluators involved in the evaluation of your proposal. **Please note that these comments do not constitute the final assessment of your proposal.**

You may respond to these comments. In order for your response to be considered, it must be:

- limited to points raised in the individual comments, correcting, with evidence from the proposal, supposed factual errors;
- in pdf format not exceeding 2 pages (pdf documents exceeding the page limit are blocking by the system);
- submitted by the Coordinator via the Funding and Tenders Portal within 8 days of the date that this letter is uploaded to the Portal. The actual deadline is indicated in the Funding and Tenders Portal. Please note that midnight is 24:00 of the indicated date, and it is local Brussels time.

Please note that, at the Portal, while you may upload multiple versions, you can only submit once. To submit, you must click on the 'Complete' button, otherwise your response will not be received.

To facilitate the review process of your response, please:

- organise your comments per the award criteria and their respective aspects to be taken into account;
- indicate the evaluator's number and comments;
- indicate the reference page (s) in the proposal.

Please also note that the following formatting conditions apply.

- The reference font is Times New Roman (Windows platforms), Times/Times New Roman (Apple

platforms) or Nimbus Roman No. 9 L (Linux distributions).
- The minimum font size allowed is 11 points. Standard character spacing and a minimum of single line spacing is to be used.
- All margins (top, bottom, left, right) should be at least 15 mm.

Once the 8 calendar days are over, the evaluation process will continue and your response will be reviewed. The evaluation panel will decide the final assessment of your proposal, which will be communicated to you in the evaluation result letter.

Please note that you can upload a pdf document multiple times, but you can only submit it once by clicking on the Complete button. If you do not Complete and submit your reaction, the uploaded document will be deleted upon the response deadline.

I would be grateful if you could inform the other members of your consortium (if any) of this letter.

Yours faithfully,
Call coordinator

Right to React Report

Call:	HORIZON-EIC-2022-PATHFINDEROPEN-01
Type of action:	HORIZON-EIC
Proposal number:	101099083
Proposal acronym:	HYPERSONIC
Duration (months):	48
Proposal title:	High mobilitY Printed nEtwoRks of 2D Semiconductors for advanced electrONICs
Activity:	HORIZON-EIC-2022-PATHFINDEROPEN-01-01

Criterion 1 - Excellence

1. *The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:*

Long-term vision: How convincing is the vision of a radically new technology towards which the project would contribute in the long term?

2. Science-towards-technology breakthrough: How concrete, novel and ambitious is the proposed science-towards-technology breakthrough with respect to the state-of-the-art? What advancement does it provide towards realising the envisioned technology?

3. Objectives: How concrete and plausible are the proposed objectives? To what extent is the high-risk/high-gain research approach appropriate for achieving them? How sound is the proposed methodology, including the underlying concepts, models, assumptions, appropriate consideration of the gender dimension in research content, and the quality of open science practices?

4. Interdisciplinarity: How relevant is the interdisciplinary approach from traditionally distant disciplines for achieving the proposed breakthrough?

Expert 1

1. The long-term vision of ultra-cheap printed electronic devices with a performance of ~10–100 times that of the current state of the art is well stated and very convincing. The development of this new technology will represent a major progress in the field of printed electronics as it will bring the performance of printed electronic devices to the level of standard silicon-based devices.

2. The proposed science-towards-technology breakthrough to produce semiconducting 2D nanosheets with carrier mobilities 10–100 times beyond the state of the art is highly innovative and clearly outlined. The proposed chemical and physical approaches to reduce the inter-nanosheet junction resistances of the networks of semiconducting 2D nanosheets differentiate this new technology from current paradigms. The project is highly ambitious because it addresses the existing mobility bottleneck of inter-nanosheet charge transfer. The selected proof-of-concept prototype is very appropriate to demonstrate the disruptive potential of the proposed new technology. It will advance science to technology through engineering.

3. The proposed research is high-risk/high-gain since it aims at improving the carrier mobility in printed devices by a factor x10-100 with respect to the current state-of-the-art. The five research objectives are plausible. The research methodology is convincing and very appropriate for

achieving the project objectives, for example it explores two distinct approaches with two risk levels. The open science practices are well described based on “as open as possible, as closed as necessary” for publications. The gender dimension of the proposed research is adequately addressed.

4. The project is highly interdisciplinary as it combines different disciplines such as physics and chemistry, computational science and engineering that are traditionally distant. The added value of the interdisciplinarity of the proposal is that it will address the longstanding mobility bottleneck of inter-nanosheet charge transfer through innovative physical and chemical approaches.

Expert 2

1. The proposed development of novel material science approaches to boost the performance of printed electronic devices to the levels of conventional siilicon electronics will allow to combine low-cost, low-power, large-area printing onto flexible substrates with enhanced device performance suitable for disruptive long-term applications in many strategic fields. The idea is convincing though very challenging, given the present state of the art.

2. The main goal of the proposal, i.e. the improvement of the state of the art electrical mobility of available 2D semiconductor films by 2 orders of magnitude by reducing the inter-sheet junction resistance, is worth and ambitious, though not novel as it is a wanted breakthrough since decades. The advancement provided by making the inter-sheet junction resistance much smaller than the intra-sheet one would be a very effective breakthrough for the realization of the envisioned printed electronics technology.

3. The objective of going beyond the present state of the art of liquid exfoliation of 2D material nanosheets, by finding alternative ways to enhance the aspect ratio of nanosheets in the hope to have a positive impact on the limited electrical mobility of printed films is a high risk/high gain idea. However, the idea of exploring alternative methods like electrochemical exfoliation is not presented in a convincing and plausible way. Particularly, solutions to the crucial problem of increasing the reported aspect ratio trends in 2D materials, beyond fundamental limits that are well explained by statistical physic laws, are not discussed in a concrete way. The objective of exploiting chemical cross-linking among nanosheets is expected to have a scarce efficacy as it is inherently limited to performance similar to those of organic films, which are too low for the final goal. Considerations on the gender dimension are scarcely mentioned. The open science practices are properly discussed.

4. The proposed interdisciplinary approach, based on chemistry, materials science, physics, either experimental or computational, as well as optoelectronic device engineering is relevant to achieve the proposed breakthrough.

Expert 3

1. The vision is clear and convincing: achieving the scalable printing of electronic devices with a performance and cost comparable to traditional silicon electronic devices is a radical advance. The proposal offer a convincing route to this through boosting the charge transport in 2D nanosheet networks by extremely novel approaches to junction engineering to achieve carrier mobilities up to 100 times the state of the art. This will transform printed electronics device’s performance to compete with existing silicon realisations whilst additionally offering mechanical flexibility and conformability to facilitate integration in wearable systems. A demonstrator application in healthcare/physical rehabilitation represents a first step towards achieving this vision. Large area films may also be printed opening up applications not addressed using traditional silicon devices.

2. The proposed science towards technology breakthrough is clearly defined, and quantified, in terms of increasing the carrier mobility of printed nanostructured films to approach that of

traditional silicon. Specific chemical and geometric approaches to achieving this are detailed and justified. This is an ambitious target, which will remove the existing bottleneck currently holding back applications of printed electronics. Achieving this target will allow printed electronics to approach the performance of the existing silicon based realisation whist adding flexibility, conformability and low cost. This will result in a large number of new applications not currently achievable by existing silicon-based devices. In summary, a significant advancement is offered supported by a convincing science breakthrough.

3. The objectives are plausible; the supporting science towards them is outlined in a previous discussion of the technology's novelty/ambition. Also included in this discussion are target values for the carrier mobility (and RJ). These values are however not included in the objectives thus making them less concrete and less quantifiable. Underlying concepts etc. relevant to the methodology are discussed in detail; the arguments and methodology are sound and well justified and supported by preliminary modelling for the physical approach. Detail/discussion is also provided on potential materials and realisation techniques adding additional plausibility to the methodology. The approach is high risk/gain. Gender dimension is briefly considered and it is recognised that it may become more important after the project.This is appropriate since the research is fundamental science. Open science is sufficiently addressed via a DMP and the “as open as possible, as closed as necessary” philosophy.

4. The project is interdisciplinary combining physics, chemistry, materials science, computational science, engineering and business. This approach is essential to achieve the breakthrough. With the exception of business, the involved disciplines all scientific disciplines so the distance between disciplines is limited since for example social science or humanities are not involved. This is however a minor shortcoming.

Expert 4

1. The long term vision for a 10-100 times improvement in printed semi-conductor mobility is radical and the need for this is convincing. The new material developments and two technology approaches (chemical and physical) that they propose are the basis for the new technology; leading to cheap and easily manufacturable alternatives to traditional silicon devices. The vision is backed up with examples of key applications that would benefit from this approach, and the general availability of this technology to improve a diverse range of other applications. They present a very convincing potential new technology which would see a seismic shift in the performance of printed electronic devices in the long term and generate a new field, moving away from low cost simple sensors and devices to more technological advanced complete printed systems.

2. The proposal details significant detail on the two main chosen approaches that will enable the scientific breakthrough to then enable the new technologies. The science is very novel and ambitious, producing an advancement in performance increase of 100-1000 times; which would match the state of the art for silicon but without the significant disadvantages that silicon has (fabrication costs, environmental impact, lack of flexibility). The state of the art for organic semi-conductors is well detailed and the differences between their approach are novel and sufficiently evidenced as concrete and viable. Current state of the art printed organic semi-conductors cannot compete directly with silicon, thus the Hypersonic science would enable a significant technological breakthrough and make high performance printed electronics a reality.

3. The five main objectives of the work are very well defined and plausible; the initial objectives of novel material development with subsequent objectives of material and device characterisation and the final demonstrator objectives. The main detail is provided on the high risk/high gain material development part of the project. The methodology for chemical and physical development

paths are both high risk but the methodology, assumptions and underlying concept of the improved nanosheet mechanics are appropriate. A minor shortcoming is the lack of detail on demonstrator fabrication, it is alluded to in various sections but requires assumptions. The gender dimension was discussed but deemed unnecessary at this stage, but was discussed for future system demonstrators so it has been given due consideration. The open science aspects are very well defined with a clear pathway from initial protection to subsequent sharing; good detail on the open access licensing model.

4. There is a lot of interdisciplinary work in the proposal, and this is essential to the delivery of the project and achieving the breakthrough. There is a mixture of material science, physics, chemistry, simulation, electronics and manufacturing but these are all very close and traditionally work together on these printed electronic developments. There are no included partners or areas of traditionally distant disciplines but as this is a fundamental science breakthrough it is not necessary at this stage; it is however given some minor consideration for future post-project breakthroughs with the inclusion of healthcare professionals but again this is only relevant after the project is complete.

Criterion 2 - Impact

1. *The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:*

Long-term impact: How significant are the potential transformative positive effects that the envisioned new technology would have to our economy, environment and society?

2. Innovation potential: How adequate are the proposed measures for protection of results and any other exploitation measures to facilitate future translation of research results into innovations? How suitable are the proposed measures for involving and empowering key actors that have the potential to take the lead in translating research into innovations in the future?

3. Communication and Dissemination: How suitable are the measures to maximise expected outcomes and impacts, including communication activities, for raising awareness about the project results' potential to establish new markets and/or address global challenges?

Expert 1

1. The transformative effects expected from the proposal are correctly identified and extremely positive for our economy and society. The targeted technology will contribute to the development of the next generation of printed electronics, supported by the commercial outcome of the project that is a proof-of-concept prototype related to Sentriflex's sensors. The project will definitely contribute to strengthening research and innovation capacity in Europe and support European industries in the fields of material manufacturing and printed electronic devices. The project has a clear impact on society, as the technology has the potential to have a significant effect on people's lives through the development of low-cost, everyday healthcare monitoring systems.

2. The measures proposed for protection of results and exploitation strategy are carefully thought and clearly presented in the proposal. The plan to ensure commercialization of the proposed technology, which includes intellectual property protection, market analysis, and business plan is very appropriate and comprehensive. One of the strengths in implementing the proposed exploitation strategy is the involvement of two key actors, Trinity Business School and Sentriflex, who have expertise and proven track record in fundamental research commercialization.

3. The research communication plan is of high quality and targeted at multiple audiences, ranging from industry and policy stakeholders to the general non-technical public. A wide range of highly

appropriate communication channels are envisioned, including press releases, social media channels, development of a project website, organization of internal events, and participation in external, public communication-of-science style events. The proposed communication measures are particularly compelling given that all partners have extensive experience in communicating with a broad audience. The dissemination plan addresses well the public disclosure of the knowledge/results to appropriate target groups which are mainly the scientific community and industry. The main dissemination channels are well identified and are effective in ensuring that the results of the project can establish new scientific and commercial advances, even after the duration of the project.

Expert 2

1. The generation of knowledge on the factors limiting the realization of 2D network transistors will add on a wide basis and hence is expected to generate a significant impact on the electronic industry and on the society at large.

2. The proposed strategies for the IP protection and exploitation of results are properly described with the involvement of all relevant actors, including technology transfer offices. It is valuable that a business plan based on a market analysis will be carried out to guide the technological outcome of the project towards the market. The involvement of and empowerment of key actor is just generically mentioned.

3. A suitable and comprehensive communication and dissemination plan is presented, properly addressing relevant target private and public audiences, based also on valuable experience within the consortium.

Expert 3

1. Economic impact promises to be extremely significant by offering a viable, in terms of performance, alternative to the traditional silicon-based approach but with specific application dependent advantages (e.g. flexibility). Similarly, the social advantage is demonstrated in terms of the application being demonstrated in the area of consumer health and physical rehabilitation. The wider social implications of this technology are therefore also significant through its potential to impact the wearable sphere. Environmental impact of the technology is not discussed although this is noted as a guiding principle of the consortium in section 3.1.

2. IP strategy is adequate. However, Partner 6 has first right for use of IP. This, since Partner 6 is a start-up (registered 25//3/22), reduces the credibility of the future translation of results to innovations; it is not clear if Partner 6 can address the myriad opportunities. Alternatives to this route (e.g. licensing to an established company) are not sufficiently discussed. Exploitation measures are outlined comprising market research/business plan.These measures should prove adequate to begin the translation of the research results into innovations. New markets will be considered in market analysis-preliminary markets: wearables/displays). Key actor involvement is limited to the activities of Partner 6/Partner 2's Business School. No measures are envisaged beyond this to translate the research into innovation so this is a shortcoming. For a groundbreaking platform technology the impact envisaged is limited to that which can be achieved through Partner 6.

3. Communication measures are envisaged throughout the project and beyond targeting industry, policy and the general public. A range of channels are identified such as the media, lab tours for young people, open days, TEDx, radio. These channels are sufficient to inform society. Events are planned to target entrepreneurs, companies and government departments. However the exact communication and dissemination measures to be undertaken, and their timing in the proposal, are not specified since they will be defined in the Communication Plan and the Dissemination and Exploitation plan both of which will be delivered at M6. This is therefore a shortcoming as concrete

actions to be inplemented both during and after the project are in the main not specified at proposal stage. However this shortcoming is partially mitigated by the mid-term think-in and the International workshop at M48.

Expert 4

1. The long-term impacts of the new technology are well defined and can be transformative; 100-1000 times increase in printed semi-conductor mobility would provide a paradigm shift in printed electronics capabilities and applications. The proposal rightly raises the issue of american and far east dominance of the IC market and the vulnerability this presents for the EU; the envisioned new technology would play on the existing high expertise in the EU for printed electronics and move to the next generation of printed IC market being centred in the EU to mitigate or remove this vulnerability as well as providing significant local economic benefits. The link to improved societal benefits via healthcare applications is clear, this activity occurs at the end of the project but also has a clear post-project plan for enhancing this impact. The environmental benefit is made clear from the replacement or reduction in standard IC manufacture which is very environmentally damaging.

2. IPR protection measures are very clear and suitable - a constant monitoring of results for patentable material before being released for open publication. The partner technology transfer offices (TTO) and the business school have significant experience with a clear procedural precedent in place, reinforced by the consortium agreement. The SME (Sentriflex) will be given first right to refusal to use any IP generated which will provide significant help to facilitate the translation of the research into innovations. The TTO and business school will provide market analysis and a business plan, this is targeted for the SME which will improve exploitation. A shortcoming is a lack of detail on potential links with some key actors, for example ink and printed device manufacturers. The integration of experienced and new researchers within the consortium is excellent, presenting a clear path for this work to be continued/exploited into the future with these next generation leaders.

3. The communication and dissemination plans are suitable for maximising impact on the scientific community and the public in particular. The PI's in particular have extensive media experience and are well placed to raise awareness of the results to a very broad audience. The dissemination plan includes methods to target the key stakeholders and puts particular emphasis on the end user application developer companies, this will help to establish potential new markets. The global challenge of increase electronics use and the requirement for higher performance printed electronic is also addressed via the communication plan from the targeted conference and exhibitions identifying and addressing the key stakeholders for these future developments. The proposed international workshop at the end of the project, specifically targeting the printed electronics theme is a very good idea and using it to also develop researcher careers is a welcome move.

Criterion 3 - Quality and efficiency of the implementation

1. *The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:*

Quality of the consortium: To what extent do the consortium members have all the necessary high quality expertise for performing the project tasks?

2. Work plan: How coherent and effective are the work plan (work packages, tasks, deliverables, milestones, timeline, etc.) and risk mitigation measures in order to achieve the project objectives?

3. Allocation of resources: How appropriate and effective is the allocation of resources (person-

months and equipment) to tasks and consortium members?

Expert 1

1. The consortium consists of 5 research groups and one industrial partner, each with their own complementary expertise. The consortium as a whole brings together the expertise and research background necessary for the successful implementation of all planned activities and ultimately the achievement of the project objectives. The consortium is well balanced, with each team being a leading European group that brings valuable expertise in the science and technology of 2D materials from chemistry, physics, engineering, business and a spin-out perspectives. The scientific quality of the individual partners is very high as demonstrated by their publications and scientific track records at the highest-level available in Europe. The consortium partners have the capacity to tackle with the proposed high-risk tasks. The collaboration between the partners is well established as they have worked together before, in particular in the Graphene Flagship and other forms of European projects.

2. The work plan is adequately structured in 4 technical work packages and 2 work packages dedicated to management and dissemination. The work packages are clearly described and the specific objectives associated with each work package are well-formulated. The interconnections between tasks are clearly described. The management and dissemination work packages are very well thought out. Dedicating a complete work package to Dissemination, Protection, and Exploitation is very effective in converting the results into further research and innovation activities. The deliverables of project are clearly defined for each work package to verify the execution of the tasks.The milestones and their timing are appropriate for monitoring project progress. The critical risks for implementation are correctly identified, however, some of the proposed risk mitigation measures lacks a detailed enough description.

3. The resources are properly allocated in view of the research tasks. All teams have in place the equipment required to fulfil the project. The allocation of resources is well-balanced between the partners.

Expert 2

1. The consortium is well qualified to carry on the proposed tasks, as it includes known experts and know-how on topics relevant for the production, processing and characterization of 2D materials for printable electronics.

2. The work plan in effectively structured, with coherent WPs, tasks and deliverables. The milestones and timeline are properly structured to moitor the project advancement. The main risks are properly identified. However, some of the proposed mitigation measures for risk characterized by a high severity, are insufficient. For example, in the case of failure to achieve a large enough aspect ratio via electrochemical exfoliation, no alternative route, but simply insisting on the optimization of parameters, is proposed. Analogously, in the case of failure to achieve the desire conductivity or field-effect mobility, mitigation measures known to have a limited effect are proposed. The allocation of man power

3. The allocation of person months and equipment resources are appropriate and well calibrated among the partners to carry on the planned tasks.

Expert 3

1. Broadly the project requires expertise in physics, chemistry, materials, computational science, engineering, business. This is present in the 6 beneficiaries. Specifically the objectives/tasks require expertise in printing/synthesis of semiconducting nanosheets, electronic characterisation of films, device realisation, sensors, digital and analog circuit integration. This expertise is outlined within the proposal and is in the main sufficient among the beneficiaries. However, the final

demonstrator is a strain sensor configured as a wearable device.There is no evidence presented that expertise in sensors or wearables existing in the consortium. Partner 6 is developing sensors/wearables but it a very new start up and it is not evidenced that such expertise exists. The expertise matches the requirements of the project apart from this shortcoming. The consortium's PIs are very high quality and influential in the field as evidenced by publication numbers, h-index and ERC grants.

2. The workplan is clear, effective, good quality, logical. Each task has an associated deliverable. Milestones are not quantified to allow progress monitoring.There is no target value for conductivity in M2, bendability in M1. No milestone explicitly addresses the value of the achieved carrier mobility or RJ which are key to the breakthrough. The status/configuration of Partner 6's sensor in WP4 is not clear nor why this sensor is selected. There is no sensor development in the project - Partner 6 is currently developing wearable devices but insufficient detail is given. The last risk associated with the sensor (developed by Partner 6 outside the project) will depend on its performance. There is a risk that this sensor requires too high performance or does not materialise. A key risk which is not included is associated with Partner 6 which is a newly formed start up without an established track record and unknown stability in terms of resources.

3. Person months are primarily allocated to WPs 1 (108PM), 2 (128PM), 4 (126PM) with WP3 slightly lower (86PM). WPs 1, 2, 3 are the fundamental materials investigations (optimisation and characterisation). WP1 would require more effort than WPs 2 and 3 since characterisation is typically more routine than optimisation. WP4 concerns the device development, which is typically a PM intensive task. Additionally WP1 is the key underpinning WP – if WP1 is not successful then WPs 2,3 won't help, as these WPs are focussed on characterisation.The PMs allocated to WP1 are therefore potentially insufficient since this WP is key to achieving the breakthrough.Equipment resources are appropriate. Among the partners Partner 2 plus Partner 6 (based at Partner 2) are allocated 228 PM combined which represents 42% of the total. But Partner 2 is involved in both material investigations and characterisation so this is acceptable although slightly unbalanced in a collaborative project.

Expert 4

1. An exceptional set of PI's and institutions. Clear roles for each partner which all have the necessary skills, experience and capacity to achieve the high risk project tasks. All the work package leader institutions and are world class in their respective fields. There is some minor concern regarding the SME, only established in March 2022 so their track record is difficult to assess as is their capacity, but they are within a very strong consortium which is a positive benefit to their development as a company and their trajectory is suitable for Pathfinder.

2. The work plan is very detailed for the material development tasks and is effective. The associated deliverables, milestones and timelines for these are clear and show a coherent progression in the scientific development. The number of work packages and the topics they cover are sensible, as is the interplay between the 4 main technical work packages, clearly showing the iterative approach to development which is essential with this type of material development. A minor shortcoming is the lack of a dedicated printing work package or task, this is a potentially limiting factor to the new material development. However, the range of printing methods described as options in some of the tasks is broad so it has been considered and factored into the development to some extent. The risks are well defined and the mitigation measures are suitable. A minor shortcoming is that no risk of printing problems is included, it is alluded to via stability and device performance only.

3. The allocation of resources is well balanced in terms of person months for each work package, and per partner participation in their key work package. The number allocated would make each

partner effective in their individual work package leadership role. A minor concern is the relatively low person months per partner outside of their main work package, considering the iterative and interlinked approach to the scientific breakthrough. There are significantly more person months available to partner 1 and 2, which is well justified by the additional coordination management role for partner 1 and for partner 2 by the additional dissemination lead role and business plan development with the SME which will benefit all partners. None of the partners have requested additional equipment resources.