Response Letter to Reviewers

We would like to express our deepest gratitude to the reviewer for reading our manuscript carefully as well as for the efforts they have spent in coming up with insightful comments and suggestions to improve the quality of the manuscript. We have tried our best to reply to all the comments carefully and made changes in the manuscript accordingly.

To make this text clearer and more readable, the original comments from the reviewers are styled *italic*, our replies are styled **bold**, and further indications of changes in the manuscript are <u>underlined</u>. The line, paragraph, section, page numbers, and reference numbers are referred to the revised manuscript.

Comments from Reviewer 1:

The manuscript "Polymer-Embedding Germanium Nanostrip Waveguide of High Polarization Extinction" show an interesting study of Ge nanostrips embedded in polymers and their polarization effect. There are some parts that need to be addressed.

1. The authors used a lot of abbreviation as example TE and TM not explained throughout the manuscript. Please explain it where mention first as the abstract. Others are there as well that needs more definition as example Im(ε) or n-κ model. Please check also other abbreviations throughout the manuscript.

Many thanks for this comment. We have checked all the abbreviations in the manuscript and made necessary explanations when they appear for the first time as listed below:

Line 12, "<u>optical parameters (*n*-*κ*, refractive index and extinction coefficient)</u>"
Line 63, "<u>CVD (chemical vapor deposition)</u>"
Line 69, "<u>Im(ε) (imaginary part of the complex dielectric function)</u>"
Line 80, "<u>TE (transverse electric)</u>"
Line 80, "<u>TM (transverse magnetic)</u>"

2. Why the author used perfluorinated acrylate for a polymer why not silicon based as most research direction goes that direction? What advantages have Exguide ZPU12-450? Please give more explanation in the introduction.

We thank the reviewer for the question. Thanks to the low-index-contrast nature of the polymer-based waveguide and simple edge coupling technique for light input/output with a standard single mode fiber, it is easy to capture and measure the near-field profile emitted from the waveguide facet. However, for the widely studied silicon waveguide, adoption of the grating coupler makes it difficult to "see" the original mode profile. Furthermore, Ge is a typical dopant material for Si, the Ge atoms may penetrate the silicon layer and complicate the waveguide design. Perfluorinated acrylate serves as an electronic blocking layer and we do

not observe any Ge layer degradation under our fabrication temperature of 200°C. Embedding Ge nanostrip waveguide in this polymer cladding is technically straightforward. It also makes good use of the polymer waveguide platform in terms of mode profile examination and propagation loss characterization.

In addition to the introduction of the Exguide ZPU12-RI material in the original manuscript, we have added the following text.

"A high-aspect-ratio (~100) Ge nanostrip is embedded in a commercial perfluorinated polymer (Exguide ZPU12-450, ChemOptics) cladding with a refractive index of 1.45 at 1550 nm wavelength. In this highly-customized resin, the C-H bonds in the polymeric chain are mostly replaced by C-F bonds for a lower light absorption at infrared wavelengths compared to the unoptimized acrylates and some inorganic optical materials [22,23]. This polymer material also functions as an electronic blocking layer to embed the Ge nanostrip without noticeable ion diffusion."

Related references:

22. Oh, M.C.; Chu, W.S.; Shin, J.S.; Kim, J.W.; Kim, K.J.; Seo, J.K.; Lee, H.K.; Noh, Y.O.; Lee, H.J. Polymeric optical waveguide devices exploiting special properties of polymer materials. *Opt. Commun.* 2016, 362, 3–12.

23. Oh, M.C.; Kim, K.J.; Chu, W.S.; Kim, J.W.; Seo, J.K.; Noh, Y.O.; Lee, H.J. Integrated Photonic Devices Incorporating Low-Loss Fluorinated Polymer Materials. *Polymers* 2011, 3, 975–997.

3. There is some figure as example Figure 3 that belongs to experimental part and not result hence it's just the measurement device you using and there nothing novel in that.

Figure 3 and its related description have been moved into Section 2 (Material and Method) as a new subsection renamed "Experimental Setup".

4. For the results obtained in this research there should be a proper comparison to other research made using as well Ge in polymers. Please include a Table at best place in the discussion part to show where your results are more favorite than others.

We thank the reviewer for the comment. To the best of our knowledge, this is the first time that a germanium nanostrip is embedded in polymer cladding as an optical waveguide. However, we have collected reports of Ge waveguides on other material platform, i.e., the Ge-on-Insulator (GeOI) platform. We have made comparison to highlight the low loss characteristics of our approach at ~2 μm wavelength.

Ref. No.	Material platform	Cross-sectional parameter	Waveguide type	Propagation loss (dB/cm)
[13] (Sample A)	GeOI	1 μm (w) × 0.3 μm (h)	Rib	25.2
[13] (Sample B)	GeOI	1 μm (w) × 0.3 μm (h)	Rib	10.7
[14]	GeOI	1 μm (w) × 0.27 μm (h)	Strip	84

[19]	GeOI	2 μm (w) × 0.3 μm (h)	Rib	14
This work	**Polymer**	**4 μm (w) × ~40 nm (h)**	**Strip**	**4.89**

The related explanation has been added in Page 5:

"The comparison shown in Table 1 reveals a better transmission performance of the polymer-embedding Ge nanostrip waveguide compared to previous demonstrations on conventional material platforms (such as GeOI) at ~2 μm wavelength."

Related references:

13. Zhao, Z.; Lim, C.-M.; Ho, C.; Sumita, K.; Miyatake, Y.; Toprasertpong, K.; Takagi, S.; Takenaka, M. Low-loss Ge waveguide at the 2-μm band on an n-type Ge-on-insulator wafer. *Opt. Mater. Express* 2021, *11*, 4097–4106.

14. Fujigaki, T.; Takagi, S.; Takenaka, M. High-efficiency Ge thermo-optic phase shifter on Ge-on-insulator platform. *Opt. Express* 2019, *27*, 6451–6458.

19. Kang, J.; Takenaka, M.; Takagi, S. Novel Ge waveguide platform on Ge-on-insulator wafer for mid-infrared photonic integrated circuits. *Opt. Express* 2016, *24*, 11855–11864.