Correction to

Ballistic Majorana nanowire devices (Nature Nanotechnology, (2018), 13, 3, (192-197), 10.1038/s41565-017-0032-8)

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The Letter reports Majorana signatures in hybrid InSb semiconductor nanowire–NbTiN superconductor devices. The devices exhibit a conductance plateau near the conductance quantum $2e^2/h$ at bias voltages above the superconducting gap (normal conductance), accompanied by an enhanced Andreev conductance at bias voltages below the superconducting gap (subgap conductance). We have attributed these experimental observations to ballistic transport as supported by a theoretical analysis[1], finding mean free paths on the order of or larger than the effective wire segment (the segment covered by the superconducting electrode).

Here, we correct errors discovered on reanalysis of the original data[2], following concerns raised by readers. Due to the age of the paper, it cannot be corrected directly in the original publication, thus the updates are provided via this amendment. We provide additional discussion on the claim of ballistic transport so as to avoid misinterpretations. External peer review of the reanalysis concluded that the claims in the Letter remain. An extended public repository including data obtained from nanowire devices that were not included in the publication can be found in ref. 2.

Correction to the discussion

We note the lack of a series of flat and precisely quantized conductance plateaus (a staircase), a clear ballistic transport characteristic (see the two newly included Supplementary Figs. 1 and 7 showing larger voltage ranges of Fig. 1 and the original Supplementary Fig. 5). Our earlier studies on ballistic transport in nanowire devices[3,4] indicate that vapour–liquid–solid nanowires do not have the proper geometry for observing a conductance staircase without the application of a magnetic field perpendicular to the wire axis, which requires ideal (Landauer) reservoirs interfacing the ballistic region, absorbing charge carriers with near-unit probability. Similar to our earlier studies, ohmic contacts in the present nanowire devices do not satisfy the conditions of Landauer reservoirs. However, the transport in the effective wire segment can nevertheless be ballistic whose characteristic is a plateau feature near $2e^2/h$ in normal conductance together with an enhanced Andreev conductance. Importantly, precise quantization is not realistic, prevented by the two-terminal device geometry, inevitably decreasing the conductance. In summary, a plateau feature with an enhanced Andreev conductance together with our theoretical analyses indicate that a large fraction of transport is ballistic over distances of the order of our device length. We add a discussion to the main text of the Letter as follows:

"… followed by a dip in conductance due to channel mixing[20] [ref. [1] below]. We do not observe higher plateaus (Supplementary Figs. 1 and 7), which we attribute to the contacts not satisfying the conditions of Landauer reservoirs, resulting in residual scattering more effective at larger conductance. This is in line with our earlier studies[25,39] [refs. [4,5] below] which indicated that vapour–liquid–solid nanowires do not have the proper geometry for observing a conductance staircase without the application of a perpendicular magnetic field. From the absence of quantum dots, the observed induced gap …".

The following text should also have been included in the abstract:

"… exhibiting clear ballistic transport properties manifested by a conductance plateau with an Andreev enhancement, albeit lacking a quantized conductance staircase hindered by the device geometry."

Correction of technical errors

A. The conductance values reported in the publication are ~8% lower (near $2e^2/h$) than the actual value (corrected Fig. 1). This deviation is due to a drop in the gain of the current-to-voltage amplifier at an ac excitation frequency of 67 Hz[5]. As a result, there is a slight change in the Andreev conductance enhancement factor and the superconducting contact transparency extracted from the enhancement (a comparison between the values quoted in the publication and the corrected ones is given below in B). The general conclusions do not rely on the exact value of the conductance as precise quantization is not expected due to the two-terminal device geometry.

B. The subtracted series resistance of 3 kΩ in the original Fig. 1 was an overestimation (see corrected Fig. 1 in the Supplementary Data file). The subtraction of 3 kΩ was not mentioned in the original publication.

A comparison of the original and corrected Fig. 1 is presented in a Supplementary Data file accompanying this correction.

Original analysis of the contact resistance

For all the figures in the original publication except Fig. 1, we either subtracted a contact resistance value of 0.5 kΩ, which is an underestimation[1], or no resistance at all. We note that in tunneling measurements the overall resistance is significantly higher than the normal metal contact resistance whose contribution can therefore be neglected.
Figure 1, however, was used to estimate the superconducting contact transparency and Andreev enhancement in the high conductance regime, requiring a realistic exclusion of the contact resistance. Following our previous paper[4], which found normal metal contact resistance values between 1.5–3.25 kΩ per contact and was based on fitting the measured conductance using theory (single mode interfacing a superconductor), which provided reasonable agreement after excluding 3 kΩ, we subtracted 3 kΩ to exclude the resistance of the normal metal contact.

Reanalysis of the contact resistance

During our reanalysis, we have discovered that the minimum resistance of this device at the largest applied gate voltages is 2.9 kΩ, a value providing an upper bound on the contact resistance. Here, 2.9 kΩ would be the contact resistance under the assumption that the nanowire itself has zero resistance at largest gate voltages.
The contact resistance can be estimated with an alternative method by subtracting a series resistance to match the observed conductance plateau at bias voltages above the superconducting gap to the expected quantized value, a procedure not done in the original publication. By taking the conductance averaged at positive and negative $|V| \sim 1.7$ mV (around the largest bias voltages available for this analysis) we find that the quantized value is reached for a contact resistance of 0.77 kΩ. (Considering only the positive bias and separately only the negative bias results in a range of 0–2.13 kΩ for the contact resistance.)
In our corrected estimate of the contact resistance, we have applied the calibration procedure[5] that corrects for ac circuit effects, uses calibrated values for the series resistance of the setup where Fig. 1 was measured and directly corrects the error listed in A above.
Upon reanalysis we estimate the following contact resistance values, enhancement factors and transparencies:

	Contact resistance	Enhancement factor	Transparency
Lower bound	0 kΩ	1.26	0.88
Conservative estimation[1] (used in corrected Fig. 1)	0.5 kΩ	1.32	0.90
Current best estimate	0.77 kΩ	1.36	0.90
Original estimate in paper	3 kΩ	>1.5	>0.93

The corrected superconducting contact transparency value of 0.9 does not affect the claim of high transparency. The claim of ballistic transport does not rest on the exact value of the conductance plateau and hence is also unaffected.

C. The original Methods section omits the indication of subtracted series resistances which account for the normal metal contact resistance in each figure. The following is included here for the corrected Methods:

“**Contact resistance treatment.** A fixed-value series resistance of 0.5 kΩ has been subtracted in Figs. 1 and 4, Supplementary Figs. 1, 2b,c and 4–9 to account for the contact resistance of the normal metal lead. This value is smaller than the lowest contact resistance we have obtained for InSb nanowire devices[25] (ref. 4 below), which makes the interface transparency estimated from Fig. 1 a lower bound. For the remaining figures, no series resistance has been subtracted to account for the normal metal contact resistance."

D. In the original Supplementary Fig. 5 (now Supplementary Fig. 6), a charge jump was corrected by removal of 12 line traces (corresponding to +0.15 V to +0.04 V in gate voltage in the measured data) and offset of the gate voltage axis by 0.12 V after the charge jump (−1 V to +0.03 V) to maintain continuity of the axis. This processing was not mentioned in the original publication. The corrected Supplementary Fig. 6 excludes this processing and represents the data as measured.

A comparison of the original and corrected Fig. SI5 (now Fig. SI6) is presented in a Supplementary Data file accompanying this correction.

Correction of labelling errors

- Original Supplementary Fig. 1f (now Supplementary Fig. 2f): The offset mentioned in the caption is erroneously given as $0.006 \times 2e^2/h$ but is $0.01 \times 2e^2/h$.
- Original Supplementary Fig. 4a,b (now Supplementary Fig. 5a,b) were indicated to present data from Fig. 2a (or original Supplementary Fig. 1a). This is incorrect. The data used are from the original Supplementary Fig. 1b (now Supplementary Fig. 2b) which has the same measurement settings as in Fig. 2a except the barrier gate is −1.5 V (the barrier gate is −1.4 V in Fig. 2a or original Supplementary Fig. 1a).
- In the original panels c–e of Supplementary Fig. 7 (now Supplementary Fig. 9c–e) the bias polarity is mistakenly inverted.

References

1. Zhang, H. et al. Ballistic superconductivity in semiconductor nanowires. *Nat. Commun.* **8**, 16025 (2017).
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3. van Weperen, I. et al. Quantized conductance in an InSb nanowire. *Nano. Lett.* **13**, 387–391 (2012).
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5. Zhang, H. et al. Data repository for "Large zero bias peaks in InSb-Al hybrid semiconductor-superconductor nanowire devices." File: Recalibration_lock-in_measurement.pdf. https://doi.org/10.5281/zenodo.4460597 (2021).

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41565-024-01602-8.