

There Is No Natural Boundary between a Semiconductor and an Insulator

— The Value Runs Continuously across a Span of 10^{70} without One Jump — Diamond, an “Insulator”, Stands at 1000 K a Factor of 3.97×10^{13} above SiC, a “Semiconductor”, at Room Temperature — [Paper 275]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

August 2026

— *From thinking to syncing.* —

Abstract

Materials are divided into semiconductors and insulators. This paper asks where that boundary lies—the answer is nowhere. The intrinsic carrier concentration varies continuously as $\exp(-E_g/2kT)$, and there is not one place where it jumps. No new mathematical theorem and no new law is claimed. First, set out seven materials at room temperature. Germanium gives 2.3564×10^{-6} and silica 2.5312×10^{-76} —a span of 9.31×10^{69} (Section 2). Second, this is the core of the paper. Across that span of 10^{70} there is not one break—move E_g continuously and the value moves continuously (Section 2). Third, “above 3 eV is an insulator” is a stipulation. Drawing that line makes insulators of SiC (3.26 eV) and GaN (3.40 eV)—and both are called power semiconductors in practice (Section 3). Fourth, the boundary moves with temperature. Diamond gives 1.1325×10^{-46} at 300 K and 1.6452×10^{-14} at 1000 K—the same material rises by 1.4527×10^{32} (Section 4). Fifth, the ordering is exchanged. Diamond at 1000 K, an “insulator”, stands a factor of 3.97×10^{13} above SiC at 300 K, a “semiconductor” (Section 4). Sixth, the classification is not a property of the material. Diamond reaches silicon’s room-temperature value at 1465.2 K—without writing down the temperature, the classification is not settled (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—that the intrinsic carrier concentration goes as $\exp(-E_g/2kT)$, the band gaps of these materials, and the customary distinction between semiconductors and insulators are all standard. No solid-state physics is built—what is used is one exponential. Band theory is not treated—why a band gap arises is not treated at all. No absolute value is claimed— $\exp(-E_g/2kT)$ is a quantity for comparison with the prefactor dropped, and not a real carrier concentration. Neither effective masses nor their temperature dependence are included. Doping is not treated—only the intrinsic case is examined. Practical semiconductors are dominated by impurities, so the quantity here is not a real conductivity. The temperature dependence of the band gap is not included—in fact E_g shrinks with temperature. Section 4 neglects that and is therefore an estimate on the conservative side. No band gap is measured—all are cited representative values and vary between sources. No revision of the classification is urged—the custom is granted to be useful. What this paper says is only that it is a stipulation and not a discovery. Relation to earlier papers: Paper 265 treated the density of states of a crystal—this paper looks at the same crystal from the side of classification. Paper 269 wrote that what a crystal forbids is periodicity—this paper writes that the boundary of a classification is a stipulation. Both keep the same discipline of not mistaking what does the deciding. Paper 273 counted four different quantities written in the same unit—this paper writes that two names are cutting one continuous quantity. Paper 190 measured rare on a logarithmic scale—this paper writes the span of 10^{70} in orders of magnitude. Paper 201 counted “complete” as four different claims—this paper is the converse, writing that two names point at one continuous quantity. What is added is computing $\exp(-E_g/2kT)$ for seven materials and obtaining a span of 10^{70} , observing that a line at 3 eV makes insulators of SiC and GaN, computing that diamond rises by 1.45×10^{32} at 1000 K, obtaining that diamond at 1000 K exceeds SiC at 300 K by 3.97×10^{13} , and obtaining 1465.2 K as the temperature at which diamond reaches silicon’s room-temperature value.

1. Notation and Placement

Setting: the carrier concentration of an intrinsic semiconductor follows

$$n_i \propto \exp\left(-\frac{E_g}{2kT}\right)$$

Below, $\exp(-E_g/2kT)$ with the prefactor dropped is used as a quantity for comparison. At room temperature $kT = 0.025852$ eV.

Question: where does the boundary between a semiconductor and an insulator lie?

The answer is nowhere. Move E_g continuously and this quantity moves continuously—there is not one place where it jumps.

A caution: the quantity here is intrinsic. Practical semiconductors are dominated by impurities, so this is not a real conductivity—the two are not conflated.

2. The Core: Not One Break across a Span of 10^{70}

Check 2.1: set out seven materials at room temperature (300 K).

Material	E_g [eV]	$\exp(-E_g/2kT)$
Ge	0.67	2.3564×10^{-6}
Si	1.12	3.9121×10^{-10}
GaAs	1.42	1.1817×10^{-12}
SiC	3.26	4.1420×10^{-28}
GaN	3.40	2.7622×10^{-29}
Diamond	5.47	1.1325×10^{-46}
SiO ₂	9.00	2.5312×10^{-76}

Observation 2.2

largest over smallest is 9.31×10^{69} , a span of roughly 10^{70} . As an ordering of a physical quantity this is extraordinarily wide.

Observation 2.3

and still there is not one break. E_g is a continuous quantity and the exponential is continuous—nowhere along that span of 10^{70} is there a jump.

Observation 2.4

the separator—what has to be changed for the value to change. Only E_g and T . And both move continuously—not one discrete quantity enters.

3. “Above 3 eV Is an Insulator” Is a Stipulation

Check 3.1: apply the customary line at **3 eV** to the table above.

Material	E_g	Under the 3 eV line	Called in practice
Ge	0.67	semiconductor	semiconductor
Si	1.12	semiconductor	semiconductor
GaAs	1.42	semiconductor	semiconductor
SiC	3.26	insulator	power semiconductor
GaN	3.40	insulator	power semiconductor
Diamond	5.47	insulator	insulator (though studied as a semiconductor)

Observation 3.2

drawing the line at 3 eV puts SiC and GaN among the insulators. Both are in fact used as power semiconductors—the stipulated line disagrees with the use.

Observation 3.3

draw the line elsewhere and the classification changes. At 4 eV both SiC and GaN fall on the semiconductor side—what settles where the line goes is not the material but whoever draws it.

Observation 3.4

a point to state honestly—it is not said that the customary classification is useless. In practice it is useful—what this paper says is only that it is a stipulation and not a discovery.

4. The Boundary Moves with Temperature

Check 4.1: look at diamond at two temperatures. At **1000 K**, $kT = 0.086173$ eV.

Material	Temperature	$\exp(-E_g/2kT)$
Diamond	300 K	1.1325×10^{-46}
Diamond	1000 K	1.6452×10^{-14}
Factor risen	—	1.4527×10^{32}

Observation 4.2

one and the same material rises by 1.45×10^{32} on raising the temperature alone. Not one thing was done to E_g —only T was moved.

Check 4.3: set diamond at 1000 K beside materials at 300 K.

Material	Temperature	Value	Called
GaAs	300 K	1.1817×10^{-12}	semiconductor
Diamond	1000 K	1.6452×10^{-14}	insulator
SiC	300 K	4.1420×10^{-28}	semiconductor
GaN	300 K	2.7622×10^{-29}	semiconductor

Observation 4.4

diamond at 1000 K stands a factor of 3.97×10^{13} above SiC at 300 K. And still one is called an “insulator” and the other a “semiconductor”—the ordering of the names disagrees with the ordering of the quantity.

Observation 4.5

a point to state honestly—in fact E_g shrinks with temperature, so the value at 1000 K would be larger than the one given here. That is, the disagreement would widen—this estimate is on the side that makes it look smaller.

5. Without a Temperature, the Classification Is Not Settled

Check 5.1: find the temperature at which each material reaches silicon’s room-temperature value (3.9121×10^{-10}).

Material	E_g	Temperature at which it arrives
Si	1.12	300.0 K (by construction)
SiC	3.26	873.2 K
Diamond	5.47	1465.2 K
SiO ₂	9.00	2410.7 K

Observation 5.2

every material has a temperature at which it stands where silicon stands at room temperature. Being an insulator does not put it forever out of reach—without writing the temperature, the classification is not settled.

Observation 5.3

the separator—what has to be changed for the classification to change. The temperature one looks at. Neither the material nor E_g has been moved.

Observation 5.4

Paper 273 counted four different quantities written in the same unit. This paper is the converse, two names cutting one continuous quantity—the count of names and the count of quantities can disagree in either direction.

6. Roll Call and Closing

1. A span of 10^{70} (Check 2.1): from 2.3564×10^{-6} to 2.5312×10^{-76} .
2. Not one break(Observation 2.3): both E_g and the exponential are continuous.

3. No discrete quantity enters(Observation 2.4): only E_g and T move.
4. The 3 eV line disagrees with use(Check 3.1): SiC and GaN fall on the insulator side.
5. A person draws the line(Observation 3.3): at 4 eV the classification changes.
6. A factor of 1.45×10^{32} with temperature(Check 4.1): diamond, 300 to 1000 K.
7. The ordering is exchanged(Observation 4.4): diamond at 1000 K above SiC at 300 K by 3.97×10^{13} .
8. The estimate is conservative(Observation 4.5): including the temperature dependence widens it.
9. There is always an arriving temperature(Check 5.1): 1465.2 K for diamond.

Closing: between a semiconductor and an insulator there was no natural boundary. At room temperature the values run from 2.3564×10^{-6} for germanium to 2.5312×10^{-76} for silica, a span of 10^{70} , and nowhere along that road is there a jump. The line “above 3 eV is an insulator” is a stipulation, and drawing it makes insulators of SiC and GaN—both of which are power semiconductors in fact. And moving the temperature moves the boundary itself. Diamond rises by 1.45×10^{32} at 1000 K and stands a factor of 3.97×10^{13} above SiC at 300 K—the “insulator” has overtaken the “semiconductor”. One thing separates them—writing down at what temperature one is looking. Write it down, and the property of the material separates from the line that was drawn. Do not write it down, and one reads a boundary drawn by people as one drawn by nature across a continuous span of 10^{70} .

References

1. Ashcroft, N. W. and Mermin, N. D. (1976). *Solid State Physics*. New York: Holt, Rinehart and Winston.
2. Sze, S. M. and Ng, K. K. (2007). *Physics of Semiconductor Devices*, 3rd edition. Hoboken: Wiley.
3. Kittel, C. (2005). *Introduction to Solid State Physics*, 8th edition. New York: Wiley.
4. Varshni, Y. P. (1967). Temperature Dependence of the Energy Gap in Semiconductors. *Physica*, 34(1).
5. Baliga, B. J. (2008). *Fundamentals of Power Semiconductor Devices*. New York: Springer.
6. Wort, C. J. H. and Balmer, R. S. (2008). Diamond as an Electronic Material. *Materials Today*, 11(1--2).
7. Yamagishi, Y. (2026). “Rare” Is Measured on a Logarithmic Scale [Paper 190]. Zenodo. 10.5281/zenodo.22106182
8. Yamagishi, Y. (2026). “Complete” Is Four Separate Statements, and What Ties Them Into One Is That the Metric Is Positive Definite [Paper 201]. Zenodo. 10.5281/zenodo.22109052
9. Yamagishi, Y. (2026). What Separated the Two Low-Temperature Models Is Not Quantisation but the Density of States [Paper 265]. Zenodo. 10.5281/zenodo.22169749
10. Yamagishi, Y. (2026). What a Crystal Forbids Is Not the Symmetry but the Periodicity [Paper 269]. Zenodo. 10.5281/zenodo.22169855
11. Yamagishi, Y. (2026). Four Different Quantities, All Written in J/kg [Paper 273]. Zenodo. 10.5281/zenodo.22169983

— *From thinking to syncing.* —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)