The opinion in support of the decision being entered today was not written
for publication and is not binding precedent of the Board.

Paper No. 25

# UNITED STATES PATENT AND TRADEMARK OFFICE

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# BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

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Ex parte YOSHIHIRO SUGIYAMA,
and YOSHIAKI NAKATA

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Appeal No. 1999-2580
Application No. 08/753,598

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HEARD: July 11, 2002

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Before KRASS, BARRETT, and LALL, Administrative Patent Judges.

KRASS, Administrative Patent Judge.

## DECISION ON APPEAL

This is a decidsion on appeal from the final rejection of claims 1, 3-12 and 14-34, all of the pending claims.

The invention is directed to a quantum semiconductor device and method of making the same, wherein the semiconductor device includes quantum dots. It is alleged that the instant invention is based on the discovery that the freely grown quantum dots cause a deformation when an intermediate layer having a thickness smaller than the height of the freely grown quantum dots is formed so as to cover the freely grown quantum dots. As a result of the deformation of the intermediate layer, the vertically aligned quantum dots cause a strong quantum mechanical coupling that

provides a sharp optical absorption spectrum. In particular, the degree of quantum mechanical coupling increases significantly by setting the thickness of the intermediate layer to be smaller than the height of the freely-grown quantum dot.

Representative independent claim 1 is reproduced as follows:

1. A quantum semiconductor device, comprising:

a semiconductor substrate;

an active layer formed on said semiconductor substrate and including a quantum structure;

said quantum structure comprising:

a plurality of intermediate layers stacked on each other repeatedly, each of said plurality of intermediate layers having a substantially flat top surface and being formed on a first semiconductor crystal having a first lattice constant;

each of said intermediate layers including a plurality of quantum dots of a second semiconductor crystal having a second lattice constant different from said first lattice constant, said second semiconductor crystal forming thereby a strained system with respect to said first semiconductor crystal, each of said quantum dots in an intermediate layer having a height substantially identical with a thickness of said intermediate layer, and each of said intermediate layers has a thickness smaller than a height of said quantum dots in a freely grown state;

said quantum dot in an intermediate layer aligning with another quantum dot in an adjacent intermediate layer in a direction perpendicular to a principal surface of said semiconductor substrate;

each of said plurality of intermediate layers having a thickness equal to or smaller than a Bohr-radius of carriers in said intermediate layer.

The examiner relies on the following references:

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| Sakai et al. (Sakai) | 4,992,837 | Feb. 12, 1991 |
| Wallace et al. (Wallace) | 5,606,177 | Feb. 25, 1997<br>(Filed Dec. 6, 1994) |

Xie et al. (Xie), "Vertically Self-Organized InAs Quantum Box Islands on GaAs(100)," Physical Review Letters, Vol. 75, No. 13, pp. 2542-2545 (1995)

Solomon et al. (Solomon), "Vertically Aligned and Electronically Coupled Growth Induced InAs Islands in GaAs," Physical Review Letters, Vol. 76, No. 6, pp. 952-955 (1996)

Claims 1, 3-12 and 14-34 stand rejected under 35 U.S.C. § 103. As evidence of obviousness, the examiner cites Solomon and Xie with regard to claims 1, 3-11 and 23-31, adding Sakai with regard to claims 12 and 14-22, but adding Wallace to the original combination with regard to claims 32-34.

Reference is made to the briefs and answer for the respective positions of appellants and the examiner.

OPINION

It is the examiner's position that Solomon discloses the growth of a quantum structure on a semiconductor substrate, where the structure has multiple layers and each layer comprises InAs islands, or "quantum dots," surrounded by or buried within a GaAs spacer layer. The examiner cites the first full paragraph of the second column of page 952 of Solomon wherein the InAs islands are about 40 angstroms high and the GaAs spacer layers are 56 angstroms high and states that islands in subsequently grown layers grow so that they are aligned above the islands in the layer beneath. The examiner contends that because the spacer layers are thicker than the islands, each island is separated from the island beneath it by about 15 angstroms, so that the separation is approximately the spacer thickness minus the island thickness.

After concluding that the InAs islands are in a strained or compressed state within the GaAs layer, and the lattice constant within each island is somewhat less than it would be if there were no GaAs constraining the island [answer-page 7], the examiner explains that "the lattice constant within each island is somewhat less than it would be if

the island were in its freely grown, relaxed, or stress-free, state. Because the thickness of the island is equal to the number of atomic layers in the island multiplied by the lattice constant, the height of the dot in its constrained state surrounded by the GaAs layer is less than the height of the dot in its freely grown or unconstrained state" [answer-pages 7-8]. The examiner further explains that the instant claims are drawn to the situation where the spacer layer has substantially the same thickness as the islands and this is the same situation taught by Solomon near the bottom of the first column at page 955 since Solomon's GaAs spacer layer thickness of 40 angstroms is the same as the island thickness.

Specifically with regard to instant claim 1, the examiner employs the general reasoning, as above, and further states, at page 10 of the answer:

> Because the InAs dots within the GaAs layer are compressed as compared to the "freely grown state," the height of the InAs dots in the "freely grown state" will inherently be larger than 40 angstroms. (Compressed dots are inherently less thick than uncompressed dots.) Each quantum dot in a GaAs layer is aligned with another dot in an adjacent GaAs layer either above or below. Each of the GaAs layers is 40 angstroms thick, which is less that [sic, than] the Bohr-radius of 120 angstroms (specification, page 16, line 24). Claim 1 is thus anticipated by Solomon et al. Alternatively, it would have been obvious...to make both the InAs dots and the GaAs spacer layer of the Solomon structure of substantially identical height, in order to increase the coupling between InAs dots in adjacent layers as desired by Solomon et al. As noted above, Xie et al. is relied upon generally for discussion of SK growth, and more specifically for the micrograph of figure 2.

For their part, appellants contend that there is no teaching or suggestion in Solomon that the intermediate layers have a thickness smaller than a height of the quantum dots in a freely grown state, as claimed. Appellants urge that Solomon "merely changes the thickness of the intermediate layer that is grown over the

heteroepitaxial quantum dots with a thickness larger than the height of the quantum dots" [reply brief-page 1] and that Solomon does not teach that the islands are compressed when the GaAs spacer layer is deposited.

The examiner contends that an InAs dot would shrink when covered by an overgrown intermediate layer, and appellants do not dispute the truth of this allegation but appellants contend that it is they who discovered this phenomenon and that "such a shrinkage of a quantum dot has not been a common knowledge to a person skilled in the art, even if the argument of lattice misfit presented by the Examiner is taken into consideration" [reply brief-page 2].

Appellants take issue with the examiner's finding of obviousness because appellants take the position that nothing in Solomon and/or Xie would have led the artisan to reduce the thickness of the intermediate layer below the height of the freely grown quantum dots, "as such would be expected to cause various problems such as the quantum dots projecting beyond the intermediate layer and producing a rough undulated surface in the intermediate layer" [principal brief-page 5]. Thus, appellants argue that the instant invention is the result of an "unexpected result" which lies in the discovery that the freely grown quantum dots cause a deformation when covered by an intermediate layer having a thickness smaller than the height of the freely grown quantum dots. Appellants state that the claimed property of each of the intermediate layers having a thickness smaller than a height of the quantum dots in a freely grown state is not an inherent property due to the strained relationship noted by the examiner.

We have carefully reviewed the Solomon reference and, while it does teach many of the claimed elements, such as a vertically coupled quantum dot structure with

the dots vertically aligned, we fail to find any suggestion of the intermediate layers having a thickness smaller than a height of the quantum dots in a freely grown state, as claimed. The examiner makes an interesting argument regarding the "inherency" of Solomon's intermediate layers having a thickness smaller than a height of the quantum dots in a freely grown state since the intermediate layers compress the quantum dots to fit between the intermediate layers. However, each of the independent claims requires that the intermediate layers have thicknesses smaller than a height of the quantum dots "in a freely grown state."

Solomon does not appear to teach that the islands, or quantum dots, are compressed when the GaAs spacer layer is deposited. Thus, the islands, or quantum dots, of Solomon may very well be in their freely grown state at the time of depositing the GaAs spacer layer, in which case the thickness of the intermediate layer would *not* be smaller than the height of the quantum dots. In such case, the thickness of the intermediate layer would be larger than, or possibly equal to, the height of the quantum dots. The examiner cites highly relevant art and makes some salient points and, if there was any suggestion within Solomon or Xie that the quantum dots were compressed from their freely grown state when the intermediate layer is deposited, we would agree with the examiner that the claimed subject matter would be obvious within the meaning of 35 U.S.C. § 103. However, because Solomon is not clear (and Xie fails to provide for the deficiency) in suggesting that the islands, or quantum dots, have been compressed from their freely grown state when the intermediate layer is deposited, for us to agree with the examiner would require speculation on our part. A prior art rejection must not be based on speculation.

Accordingly, the examiner's decision rejecting claims 1, 3-12 and 14-34 under 35 U.S.C. § 103 is reversed.

REVERSED

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| LEE E. BARRETT<br>Administrative Patent Judge | ) |
| ERROL A. KRASS<br>Administrative Patent Judge | ) BOARD OF PATENT<br>) APPEALS AND<br>)<br>) INTERFERENCES |
| PARSHOTAM S. LALL<br>Administrative Patent Judge | ) |

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