CHAPTER VI

DISCUSSION AND CONCLUSIONS

In this work, we have studied the critical temperature of a bilayered AFS by using the mean field model of AFS given by Nass, Levin, and Grest (Nass, Levin, and Grest,1981,1982) and the proximity effect is based on the tunneling model of McMillan (McMillan,1968).

In our work, we have made the assumption that an AFS consists of two coexisting phenomena superconductivity and antiferromagnetism. A superconductor can be described by the BCS theory and antiferromagnetism can be represented by the staggered molecular field. The tunneling model based on tunneling model of the proximity effect between superposed normal metal and superconducting metal films was presented by McMillan (McMillan,1968) and the tunneling model of the proximity effect between superposed two superconducting films was presented by Mahabir and Nagi (Mahabir and Nagi,1979). The tunneling Hamiltonian is treated to second order by self-consistent perturbation theory. We derive the T_c formula by using the one dimensional nesting condition which is amenable to solutions. In this case, we take $Q \approx 2k_F$ so that $\varepsilon_k = -\varepsilon_{k+Q}$ for k near $|k_F|$.

The critical temperature is given by Eq. (4.38), which demonstrates the interplay of the tunneling effect and the staggered molecular field on superconductivity in a variety of proximity junctions.

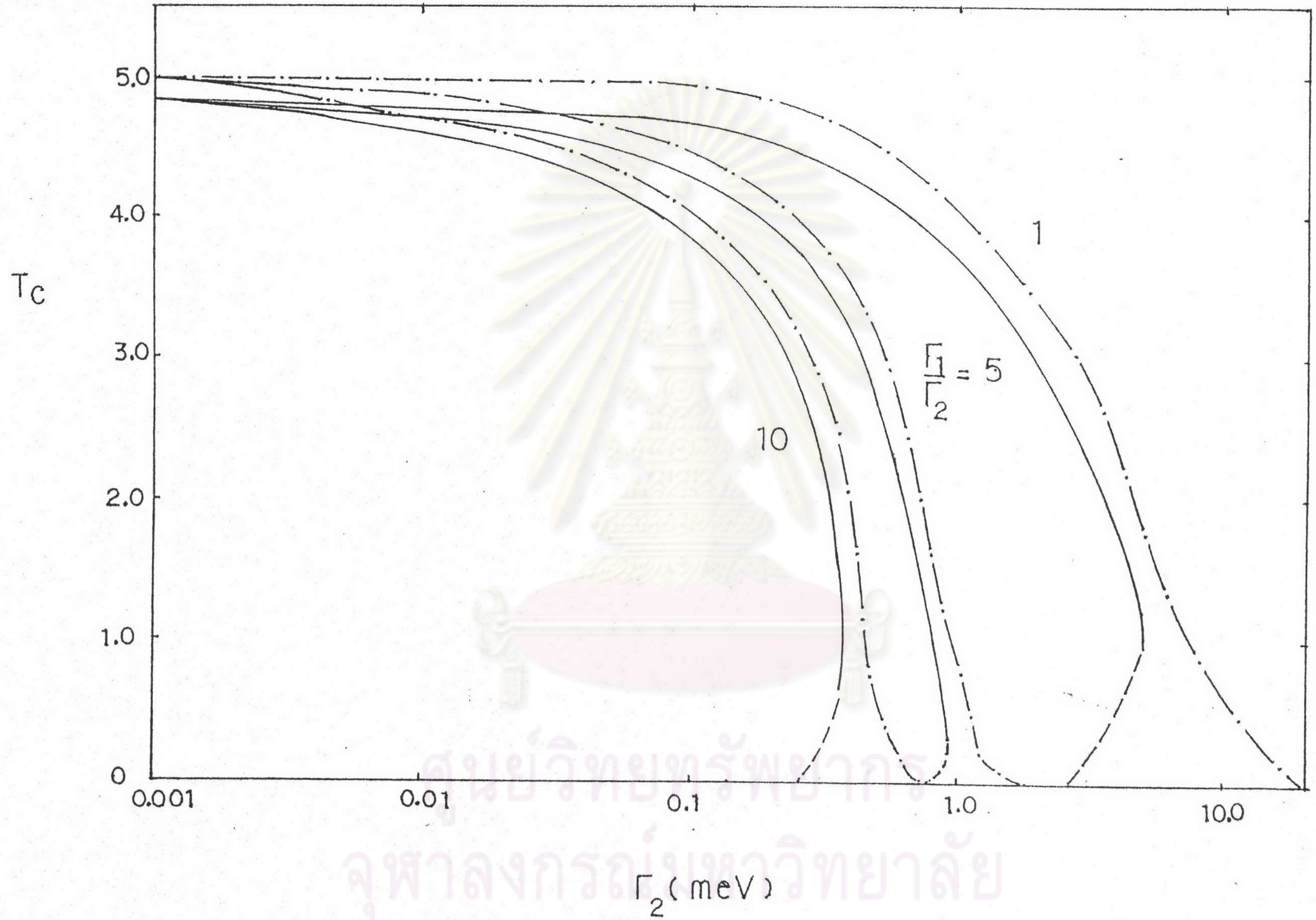

Fig. 6.1 Critical temperature T_c of AFS-N sandwich vs. Γ_2 for various value of Γ_1/Γ_2.(————) AFS-N results ; (–·–·—·–) S-N results(McMillan results).The parameters used are λ_1 = 0.246, ω_{D1} = 16.78 meV, $H_{Q1}/2\pi T^*_{c1}$ = 0.05, T^*_{c1} = 5.0 .Dashed curves denote unstable T_c .

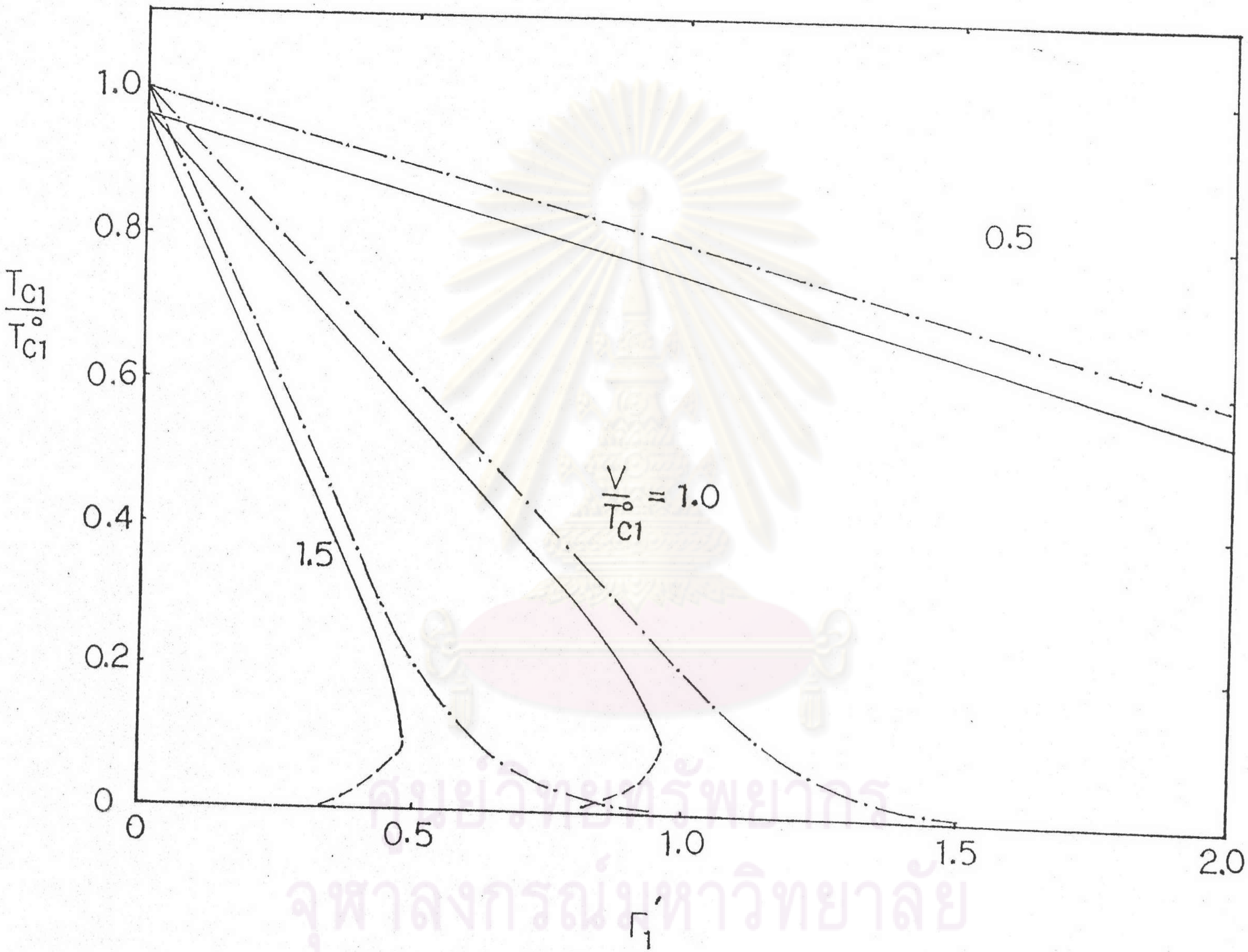

Fig 6.2 Critical temperature T_c of AFS-N sandwich vs. Γ_1' ($\Gamma_1' = \pi A d_2 N_2(0) T^{\circ}_{c1}$) for various value of V/T°_{c1}.

(————) AFS-N results ; (—·—·—) S-N results(McMillan results). The parameters as in Fig. 6.1.

In order to obtain quantitative results we solved expression for T_c on a computer. We used an iteration procedure to find a solution. The Newton's iteration method has been used in this work.

For an AFS-N system, the T_c formula is shown as in Eq.(5.16). T_c and T_{c1}° are the transition temperature of the composite and the first BCS superconductor, respectively. Eq.(5.15.4) indicates that the exchange field, we consider to be a constant in the AFS layer, exist also in the N layer.

In Fig.(6.1), we show our calculated values of T_c of an AFS-N proximity sandwich as a function of Γ_2 (for various values of Γ_1/Γ_2). In this case, Γ_2 is function of V^2. It demonstrates the effect of the square tunneling magnitude on T_c of the 1st layer at constant thickness of 2nd layer (Γ_1/Γ_2 is function of d_2/d_1 and d_1 is kept constant). We find that, at $V^2 = 0$ (there is not proximity between layers), the T_c of AFS-N is less than 5 (we kept T_{c1}° to be 5) and T_c's of S-N system is equal to 5. Our theory predicts a depression of T_c as Γ_1/Γ_2 is increased and T_c decreases monotonously not only when Γ_1/Γ_2 is increased but also when Γ_2 is increased. We also find that S-N bilayer has more value than AFS-N bilayer at the same parameter. The result indicates that $H_{Q1}/2\pi T_{c1}^{\circ}$, V^2 and d_2 destroy superconducting state additively.

In Fig.(6.2), we show calculated values of T_c of an AFS-N proximity sandwich as a function of Γ_1' (for various values of V/T_{c1}°). Γ_1' is dimensionless parameter where $\Gamma_1' = \pi A d_2 N_2(0) T_{c1}^{\circ}$. In this case, we consider Γ_1' as a function of d_2. Fig.(6.2) implies that the profound effect of the thickness of the 2nd layer on T_c of the system at the

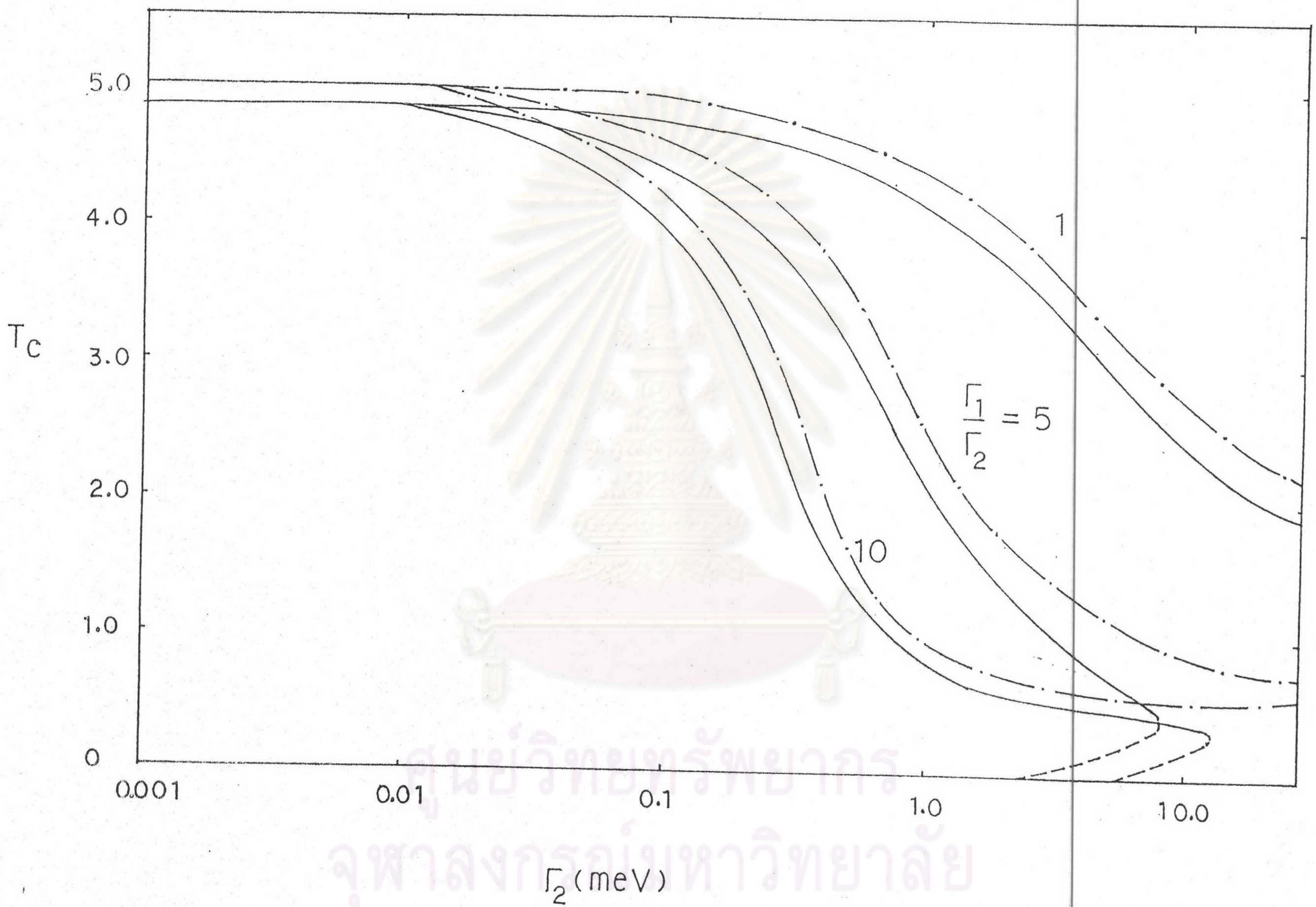

Fig. 6.3 Critical temperature T_c of AFS-S sandwich vs. Γ_2 for various value of Γ_1/Γ_2. (———) AFS-S results ; (—·—·—·) S_1-S_2 results(Mohibir and Nagi result). The parameters used are $H_{Q1}/2\pi T^{*}_{c1} = 0.05$, $\lambda_1 = 0.246$, $\lambda_2 = 0.171$, $\omega_{D1} = 16.78$ meV, $\omega_{D2} = 32.21$ meV, $T^{*}_{c1} = 5.0$. Dashed curves denote unstable T_c .

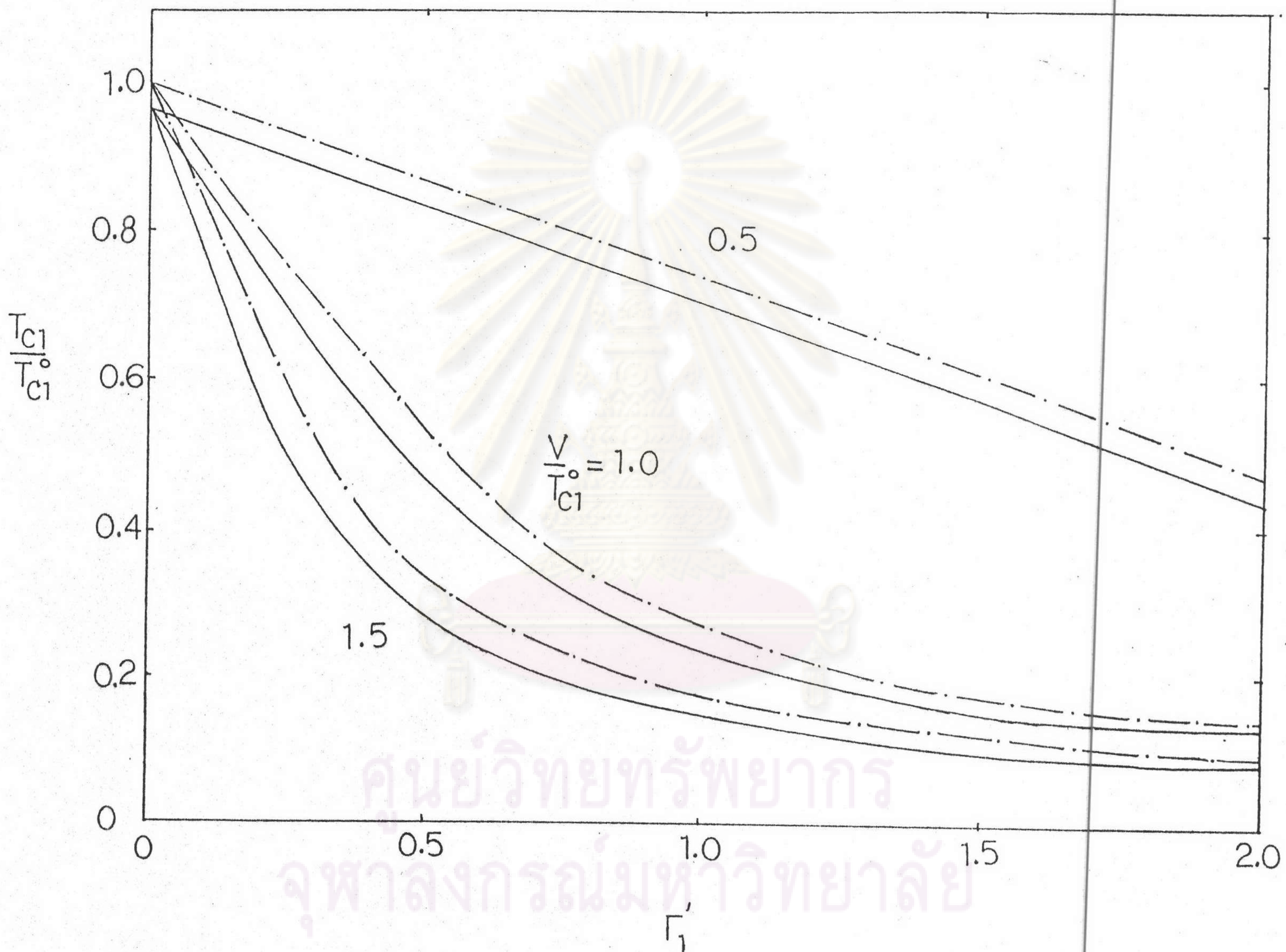

Fig 6.4 Critical temperature T_c of AFS-S sandwich vs. $\Gamma_1'(\Gamma_1' = \pi A d_2 N_2(0) T_{c1}^{\circ})$ for various value of V / T_{c1}°.

(————) AFS-S results ; (-·-·-·-) S_1-S_2 results(Mohibir and Nagi result). The parameters are as in Fig.6.3 .

constant tunneling magnitude. We find that for $\Gamma_1' = 0$, the ratio $T_c/T_{c1}^{\bullet}$ of AFS-N is less than 1 and the same ratio for the S-N equal to 1. The graph shows that the stagger molecular field reduces the T_c of AFS composite. When $\Gamma_1' > 0$, the ratio $T_c/T_{c1}^{\bullet}$ is reduced by increasing the thickness of the 2nd layer and tunneling magnitude.

For an AFS-S case, the T_c formula is shown as in Eq.(5.20). In Fig. (6.3), we show our calculated values of T_c as a function of Γ_2 (for various values of Γ_1/Γ_2). We have also shown the results obtained for the S1-S2 bilayer (taking $H_{Q1}/2\pi T_{c1} = 0$ in Eq.(5.17.5)).We find that in the present calculation, T_c of the AFS-S system is considerably smaller than that of the S_1-S_2 system. As $\Gamma_2 \rightarrow 0$, the two curves are parallel, and at other values of Γ_2, there are significant differences. T_c of an AFS-S bilayer will be suppressed as H_{Q1}, Γ_2 and Γ_1/Γ_2 increase. We note that the induced staggered field also exists in the S layer.

In Fig.(6.4), we show our calculated value of T_c of an AFS-S proximity sandwich as a function Γ_1' (for various values of $V/T_{c1}^{\bullet}$). In this case, it showes the same maner as in AFS-N system but it reduced more than AFS-N system.

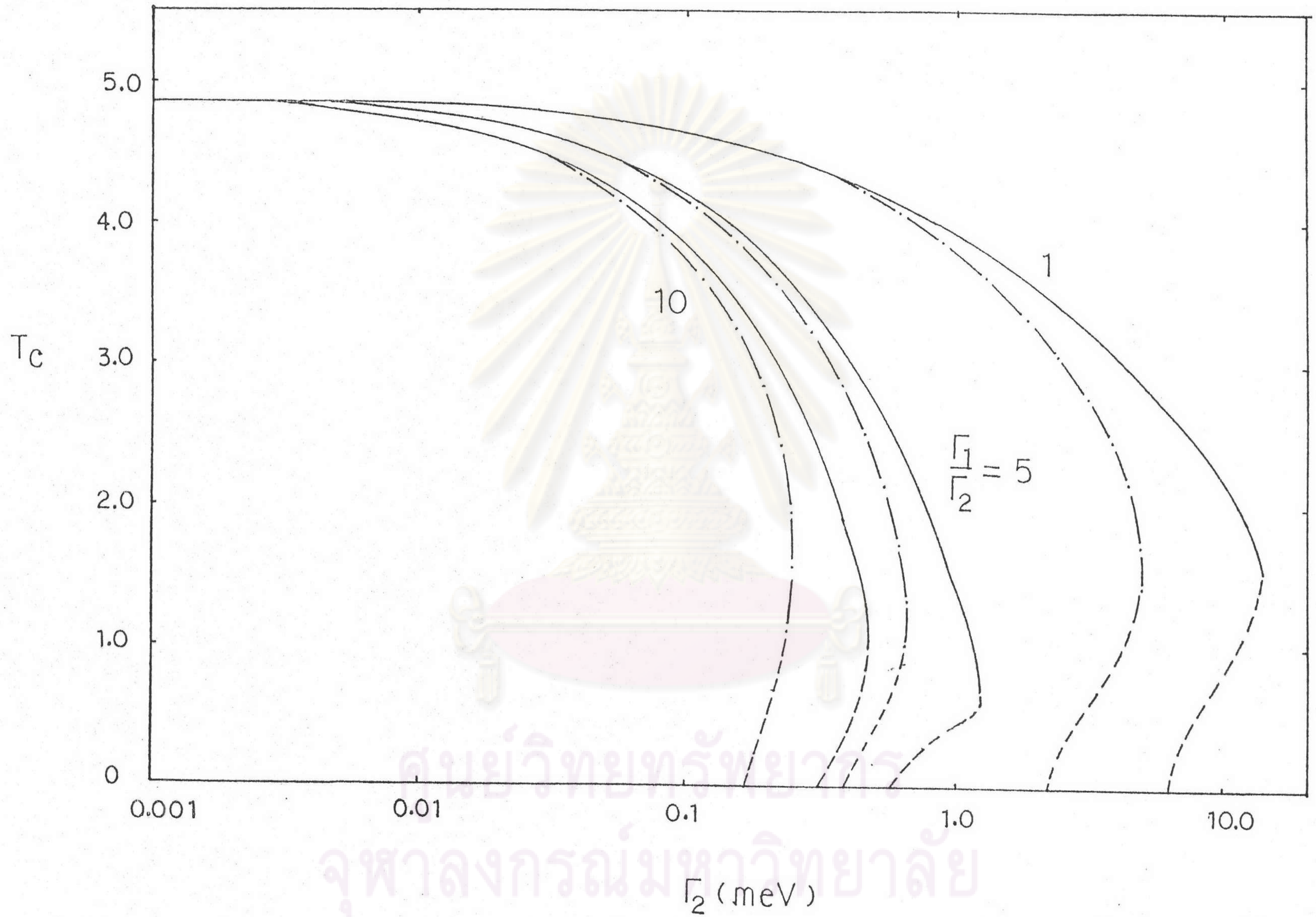

Fig. 6.5 Critical temperature T_c of AFS_1-AFS_2 sandwich vs. Γ_2 for various value of Γ_1/Γ_2.

(————) $H_{Q2}/H_{Q1}=0.5$ results ; (—·—·—) $H_{Q2}/H_{Q1}=2.0$ results. The parameters used are $\lambda_1 = 0.246$, $\lambda_2 = 0.171$, $\omega_{D1} = 16.78$ meV, $\omega_{D2} = 32.21$ meV, $T^*_{c1} = 5.0$. Dashed curves denote unstable T_c .

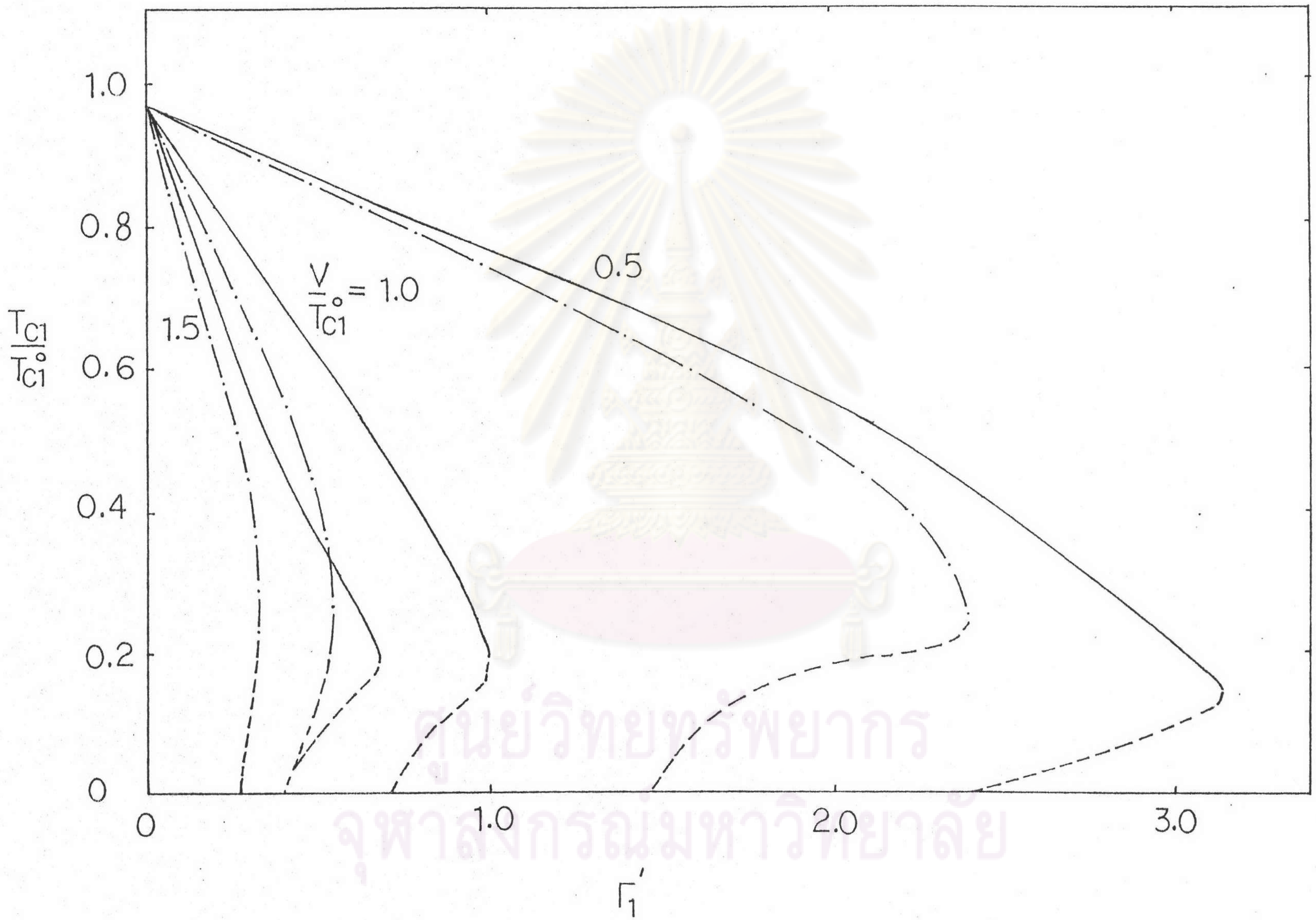

Fig 6.6 Critical temperature T_c of AFS_1-AFS_2sandwich vs. Γ_1' ($\Gamma_1' = \pi A d_2 N_2(0) T_{c1}^{\circ}$) for various value of V / T_{c1}°.

(————) H_{Q2}/H_{Q1}=0.5 results ; (—·—·—·—) H_{Q2}/H_{Q1}=2.0 results. The parameters are as in Fig. 6.5

Finally, when λ_α and $H_{Q\alpha}$ are finite and $H_{Q1}//H_{Q2}$, two AFS's are in proximity, the T_c equation is still given by Eq.(5.20) with P_α, R_α, A_α, B_α and K_α as defined by Eqs.(5.18.1), (5.18.2),(5.17.3),(5.17.4) and (5.21.3) respectively.

The dependence of T_c on Γ_2 is shown in Fig.(6.5) with some choices of Γ_1/Γ_2 and the dependence of T_c on Γ_1' is shown in Fig.(6.6) for various values of V/T°_{c1}. The comparison of the case $H_{Q2}>H_{Q1}$ with $H_{Q2}<H_{Q1}$ are shown in Fig.(6.5) and (6.6) . It may be noted that when V/T°_{c1}, Γ_1', Γ_2 and Γ_1/Γ_2 increases, the two curves agree and the T_c of the AFS_1-AFS_2 system is dramatically decreased.

Graphs in Figs.(6.1), (6.2), (6.3), (6.5) and (6.6) display unstable T_c. This is shown by the dashed lines. The unstability of T_c arises from the consideration of the free energy difference between normal state and superconducting state(Suzumura and Nagi,1981). As long as this quantity has a minimum at Δ=0, and the expansion of this difference in term of the order parameter is given. When the coefficient of Δ^2 is positive, T_c is stable and when it is negative, T_c is unstable. Our graphs were plotted accordingly.

In conclusion, we find that

1) The expression for Tc have been analytically for the AFS-N, AFS-S, and AFS_1-AFS_2 systems.

2) The staggered molecular field has destroyed the superconducting order.

3) An induced staggered field exists when AFS is in contact with N or S, in the other words, the S and N layers thus become a weakly AFS due to the proximity effect.

4) Both the induced AFS field and the tunneling phenomenon destroy the superconducting order.