The Role of Volumetric Strain to Electron Phonon Coupling in MgB_2 Films with Various Thickness of ZnO Buffer Layer

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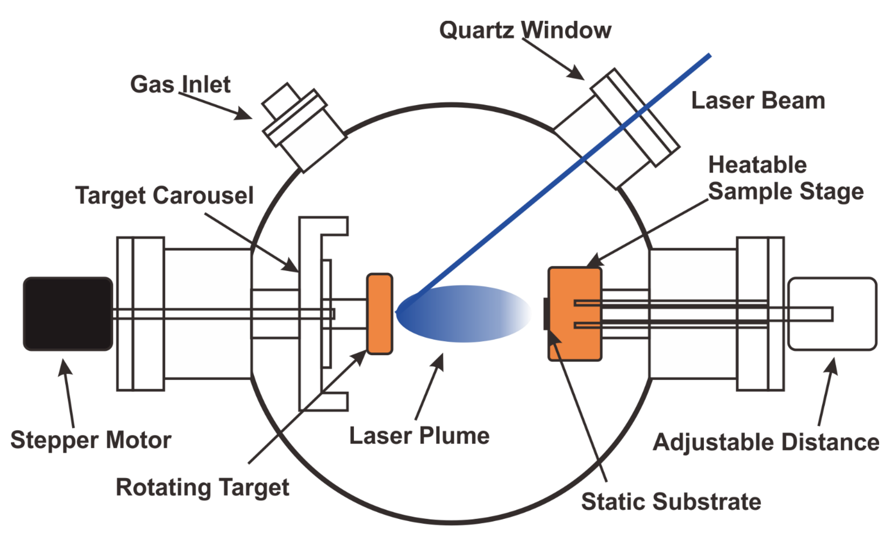
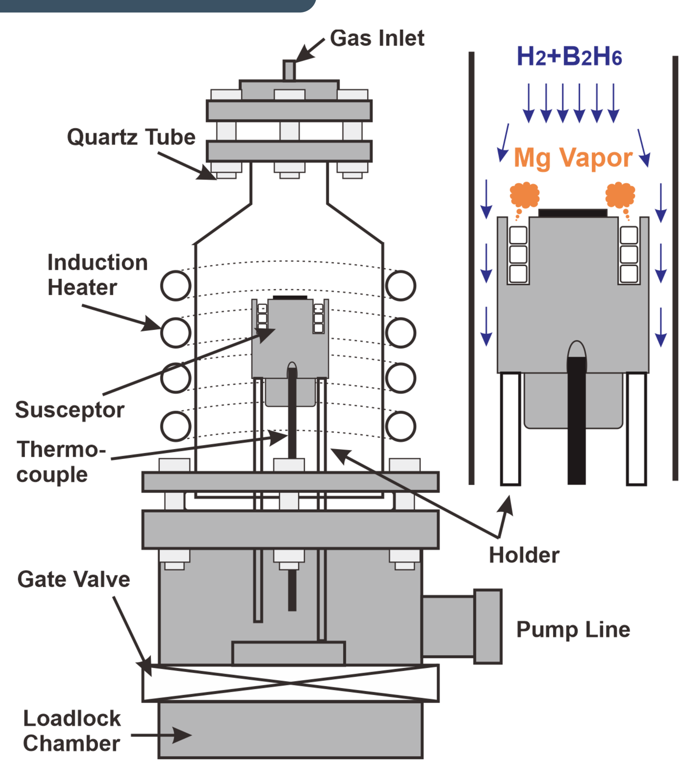
Introduction

- Magnesium diboride is a phonon mediated superconductor following BCS theoretical limit with critical temperature up to 40 K
- As a main substitution for archaic superconductors, enhancing its properties while bonded with metallic substrate in application field is important
- Discrepancy of a lattice parameter between MgB_2 and its metallic substrates still a main problem to overcome and ZnO is one of the solutions which can be act as a buffer layer to minimize it
- Unravel the effects of the strain introduced by the lattice mismatch on a bare and buffered substrate to the T_c and electron-phonon coupling become necessary to projects the way to treat MgB_2 for an application purpose
- Further study of electronic and phononic contribution of the Raman active frequency also conducted since it is closely related to the coupling mechanism

Experimental Details



PLD Schematic



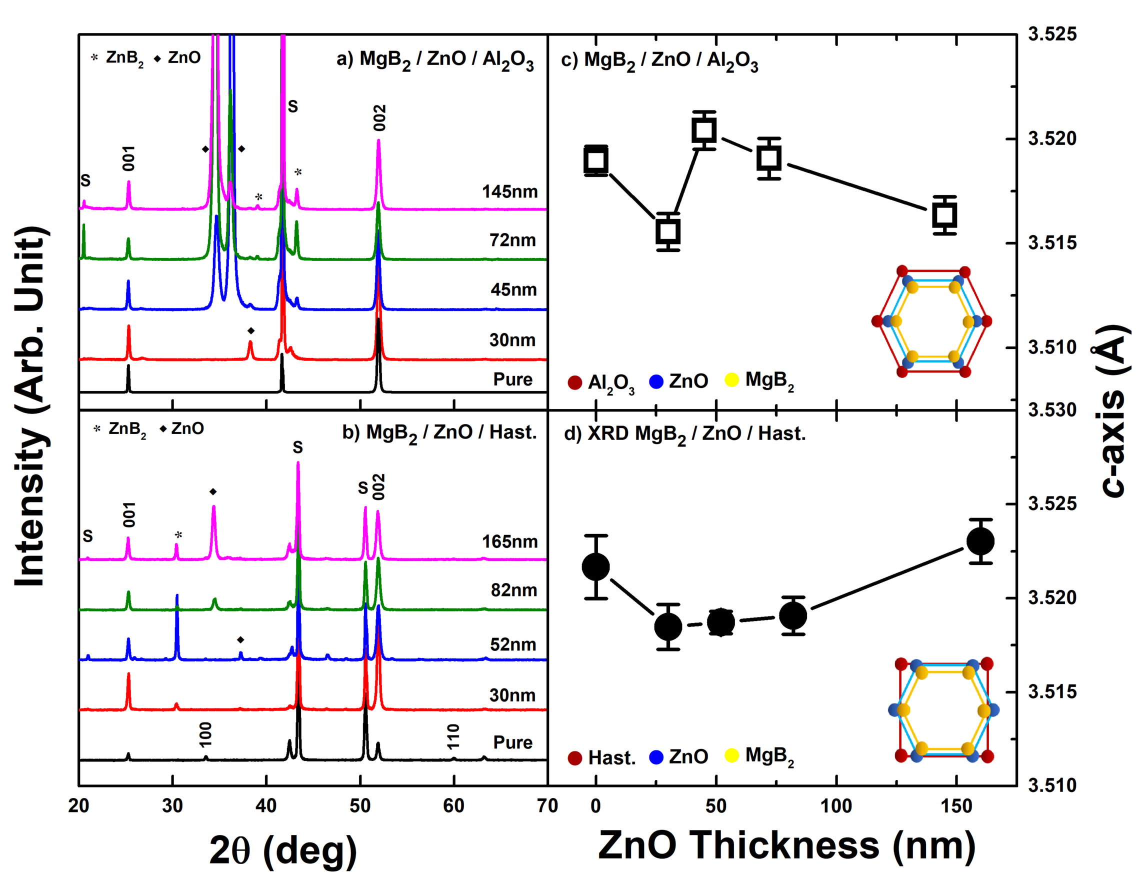
HPCVD Schematic

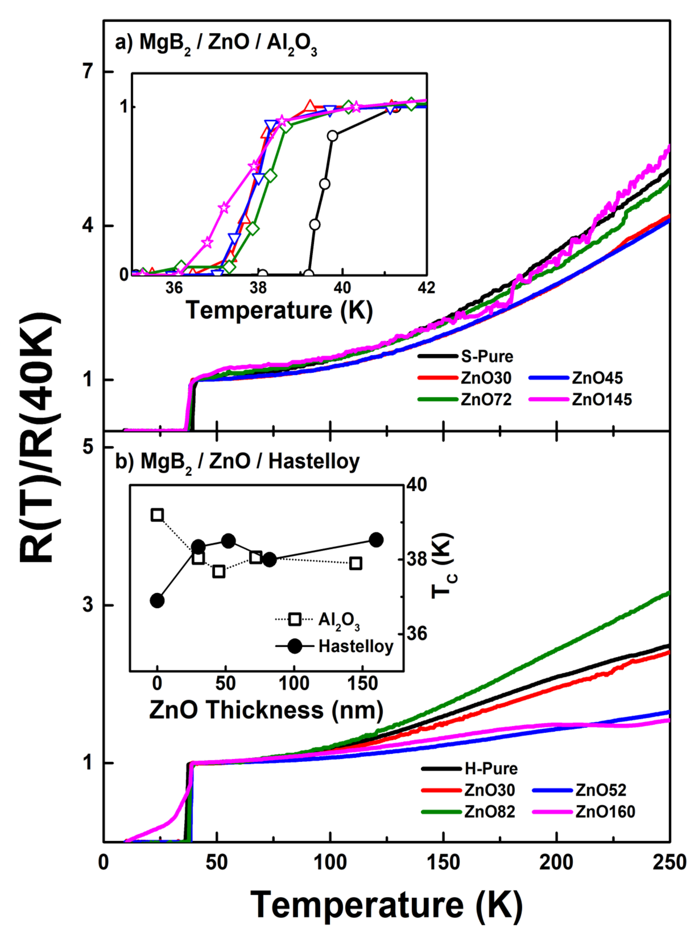
ZnO Buffer thickness→ 30 - 165 nm

MgB_2 thickness→ 1.0 – 2.0 µm

- Epitaxial ZnO Buffer layer was deposited by Pulsed Laser Deposition (PLD)
- MgB_2 superconducting layer was deposited by Hybrid Physical-Chemical Vapor Deposition (HPCVD) technique

X-RAY Diffraction & Resistance Measurement

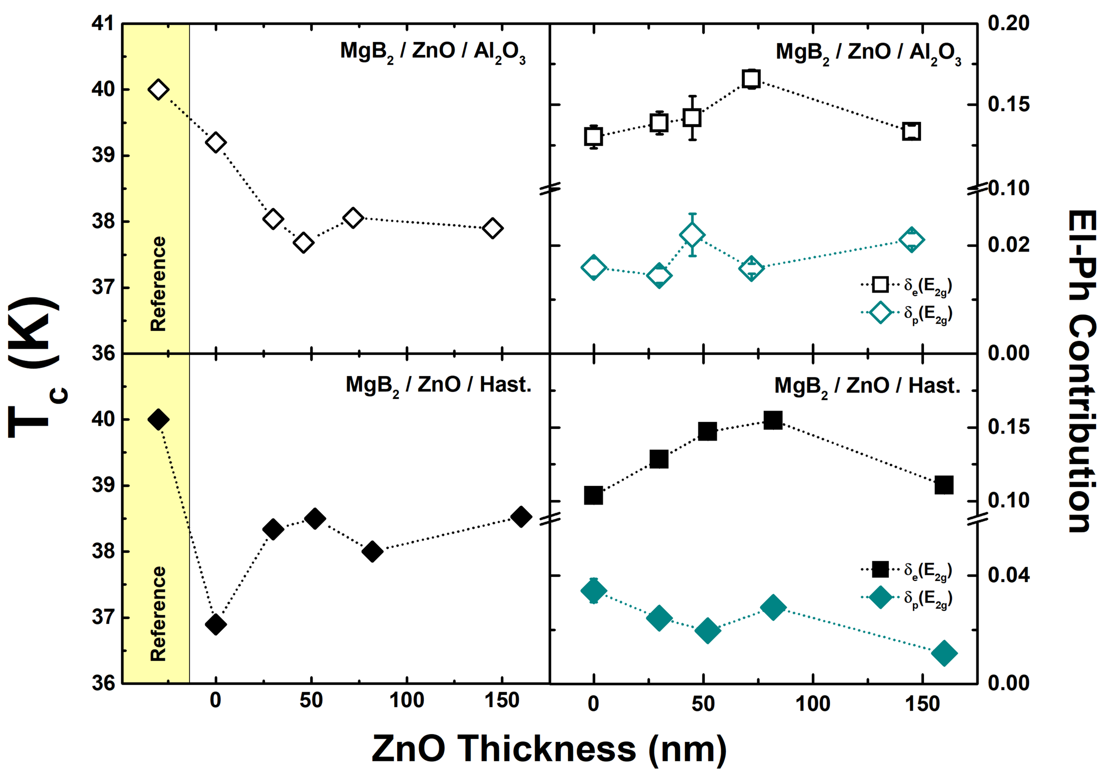




- Calculation of *c*-axis lattice parameters from XRD data are presenting out-of-plane lattice mismatch between 0.05 to 0.15% on Al_2O_3 and 0.01 to 0.07 on Hastelloy compared to the single crystal sample by **Zheng et.al., [PhysRevB. 73.024509]** 3.521 Å
- There are weak relations between the *c*-axis parameter and T_c that we have measured
- With c-axis oriented films on all samples, *a/b*-axis from hexagonal structure of MgB_2 and in-plane strain should be calculated

T_c , EPC and Strain Relation

- It is known that T_c of MgB_2 is controlled collectivity by three components: phonon frequency, density of states (DOS) and deformation potential which can be simplified by electronic and phononic contribution.



Electronic and Phononic Contribution Relation:

$$\delta_{T_C} = \frac{\Delta T_C}{T_{C0}} = \beta\delta_e + (1-2\beta)\delta_p$$

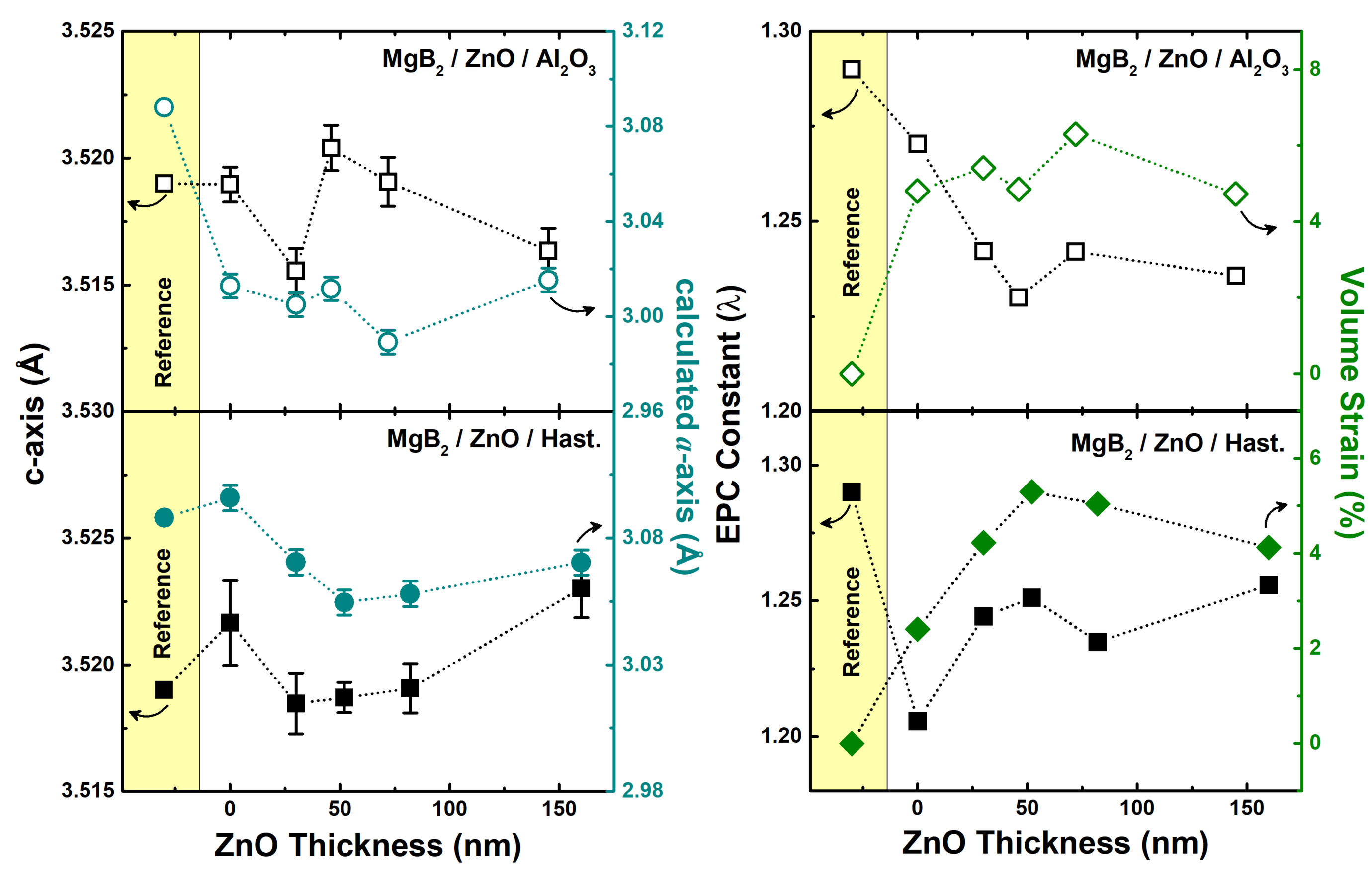
- The data shows higher electronic contribution leads to a higher T_c while it is vice versa for phononic contribution case
- Higher electronic contribution will also affect to increasing electron-phonon coupling across all samples

McMillan modified by Allen-Dynes Formula :

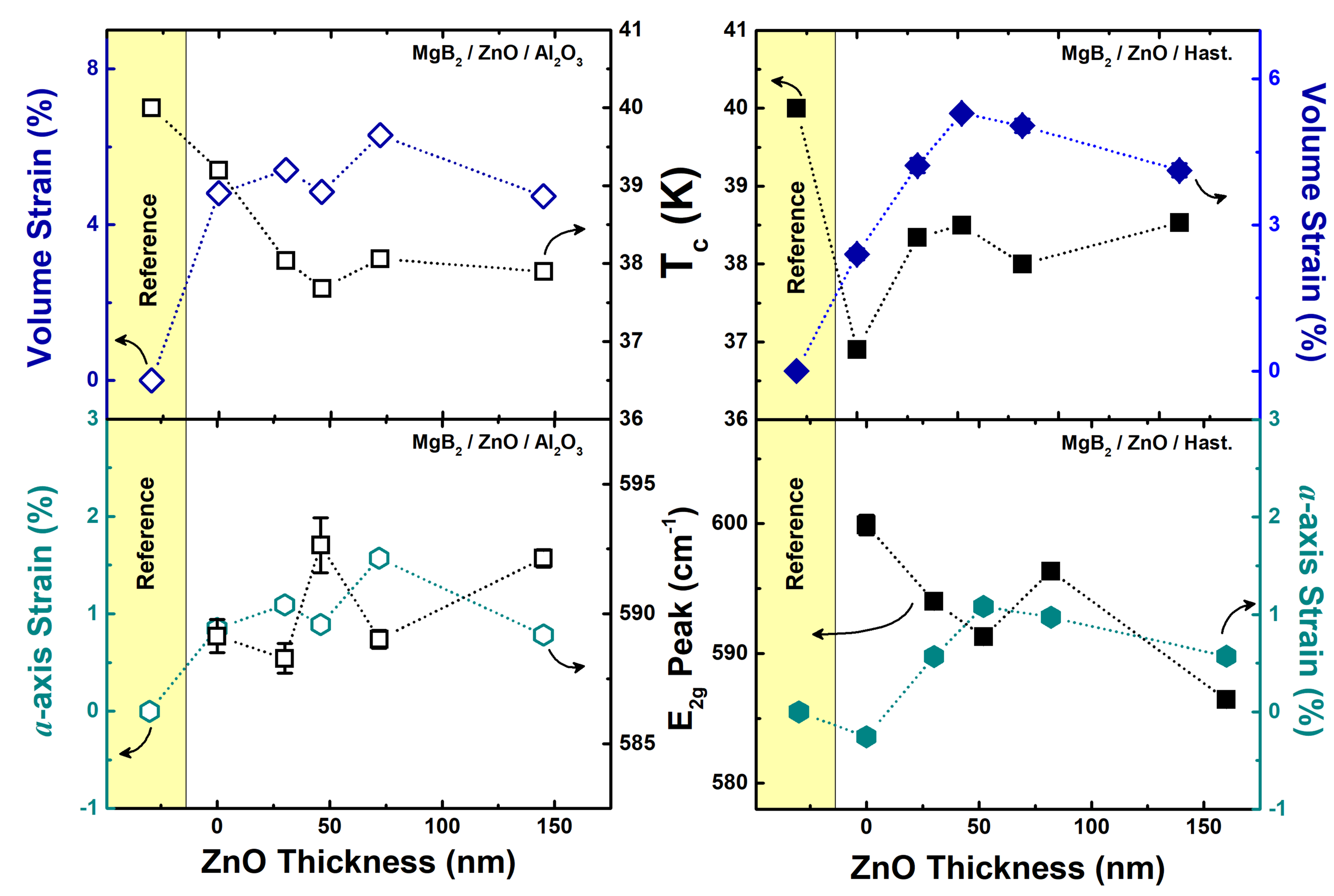
$$T_c = \frac{\langle\omega_{log}\rangle}{1.2}\exp\left(-\frac{1.04(1+\lambda)}{\lambda-\mu^*(1+0.62\lambda)}\right)$$

Coupling Quadratic Formula adapted from DFT Calculation:

$$\delta_{T_C} = a_1x + a_2x^2 + b_1x + b_2x^2 + c_1xy$$



- Relation between E_{2g} and *a*-axis parameter explained that changes of E_{2g} frequencies are caused by in plane axis change in MgB_2 films
- Direct relation between EPC and volume strain can be observed which shows increasing volume strain will increase the number of EPC



Conclusion

- ZnO buffer layer introduces an in-plane strain in MgB_2 crystal which can observed from phonon hardening and softening carried out by Raman spectra
- Higher volume strain drive to a higher coupling between phonon and electron (electronic contribution) which lead to a higher T_c