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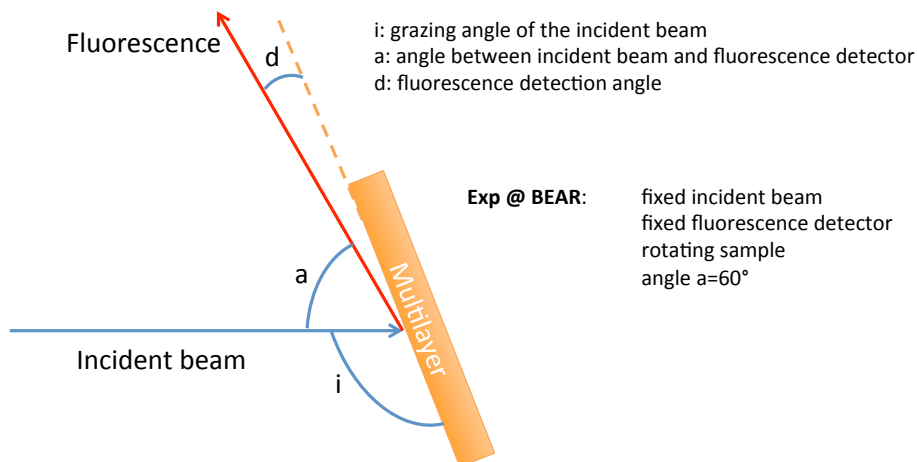
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## Measurement of fluorescence induced by x-ray standing waves in bi- and tri-layer systems

Le 17 octobre 2013

We performed x-ray fluorescence measurements induced by x-ray standing waves (XSW) in Co/Mg based periodic multilayers in the Elettra synchrotron radiation facility, on the BEAR beam line. There are  $60^\circ$  between the direction of the synchrotron beam and the direction of the fluorescence detection. Two different experiments were done when recording the intensity of the CoLa and MgKa emissions as a function of the glancing angle:

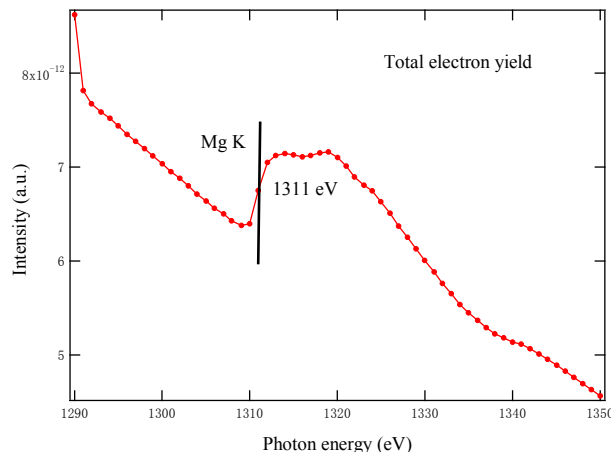
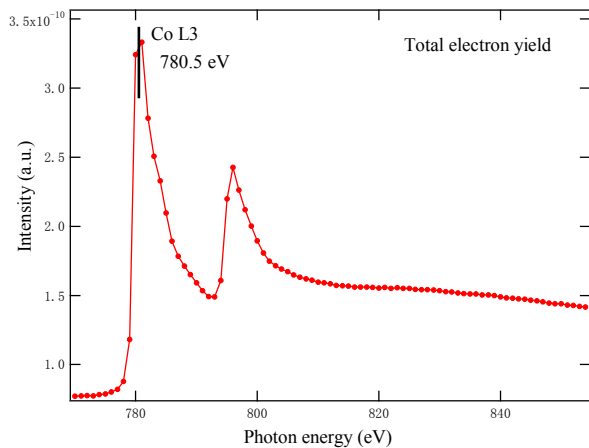
- (1) the glancing angle was varied in the range of the 1<sup>st</sup> Bragg peak of the *incident* radiation, i.e. rather grazing (between  $0$  to  $10^\circ$ );
- (2) the glancing angle was varied in the range of the 1<sup>st</sup> Bragg peak of the *fluorescence* radiation, i.e. at a large glancing angle (between  $110$  and  $120^\circ$ ). Indeed, in this case it is necessary to put the sample surface close to the detection direction (see the figure below).



The detailed informations on the sample structures are the following:

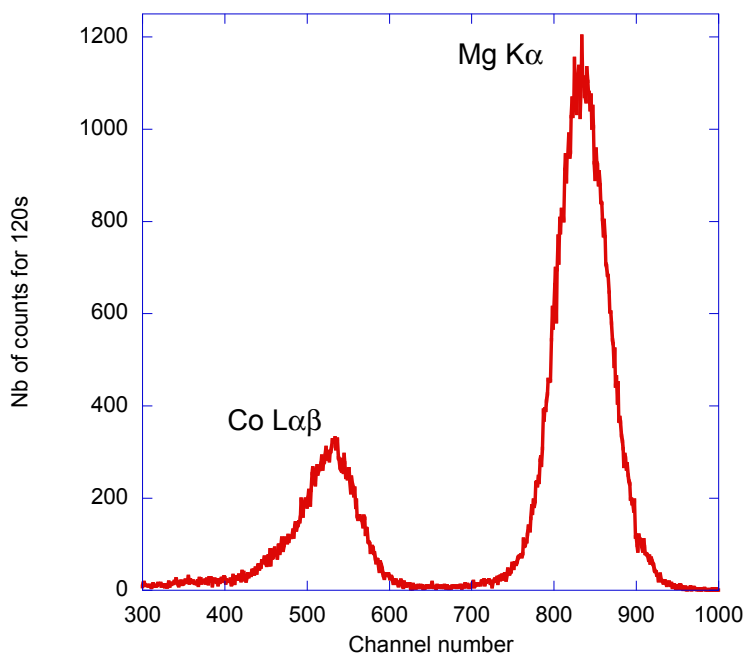
- |   |                 |
|---|-----------------|
| (1) Si/Cr 2.7 nm/[Mg 5.2 nm/Co 3.5 nm/B4C 0.1 nm] <sub>30</sub> /B4C 3.4 nm | noted Mg/Co/B4C |
| (2) Si/[Mg 5.45 nm/Co 2.55 nm] <sub>30</sub> /B4C 3.5 nm                    | noted Mg/Co     |
| (3) Si/[Mg 5.45 nm/Zr 1.5 nm/Co 2.55 nm] <sub>10</sub> /B4C 3.5 nm          | noted Mg/Zr/Co  |
| (4) Si/[Mg 5.45 nm /Co 2.55 nm/Zr 1.5 nm] <sub>10</sub> /B4C 3.5 nm         | noted Mg/Co/Zr  |

We worked with *s*-polarized radiation. The photon energy was calibrated by measuring the Co L3 and Mg K absorption edges obtained in the TEY mode. The figures are shown below. Comparing to tabulated values of Co L3 (778.1 eV) and Mg K (1303 eV) absorption edges, the photon energy shift is 2.4 eV and 8 eV in the Co and Mg ranges respectively.



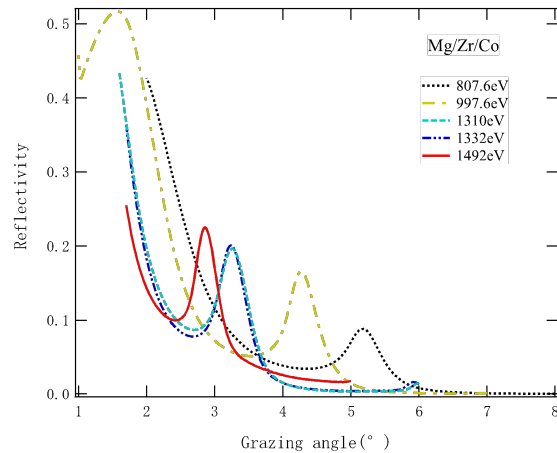
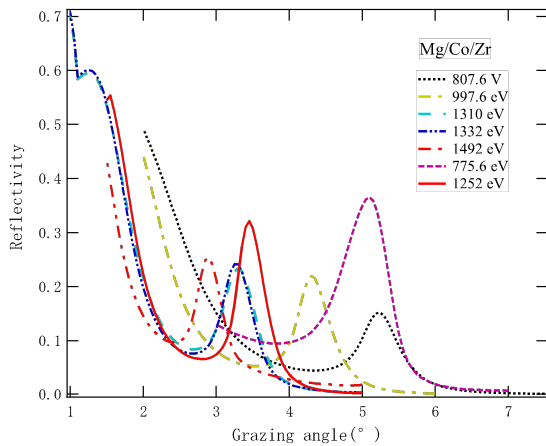
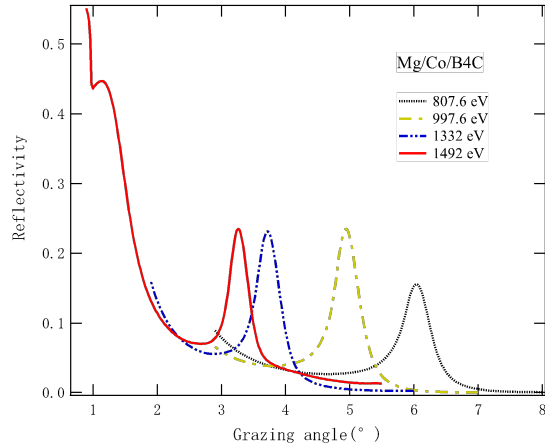
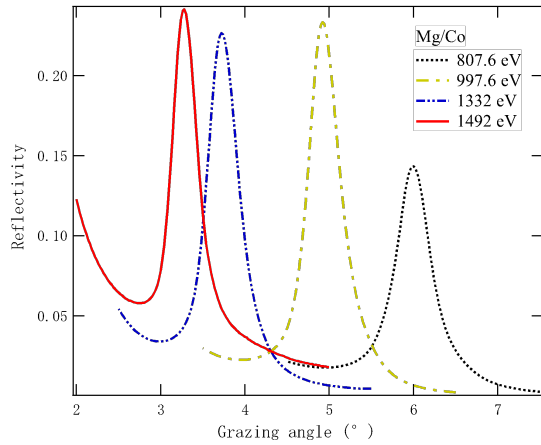
The detection of the characteristic emissions was done by an SDD. We show in the figure below a typical spectrum obtained when both Co 2p and Mg 1s electron levels can be ionized. In this case the photon energy was 1332 eV. The low energy peak (small channel number) is the Co La emission (in fact unresolved Co La and Lb emissions); the high energy emission (large channel number) is the Mg Ka emission. During the experiments with excitation incident photon energies of 807.6 and 997.6 eV, only the channels corresponding to the Co La emission were taken into account. With excitation incident photon energies of 1310, 1332 and 1492 eV, only the channels corresponding to the Mg Ka emission were taken into account

**MgCoZr sample  
Excitation @ 1332 eV**

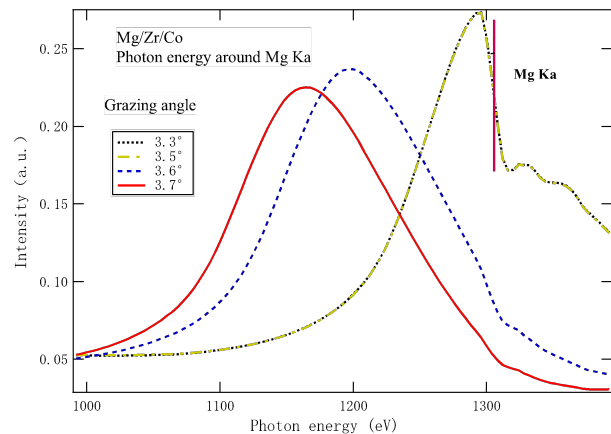
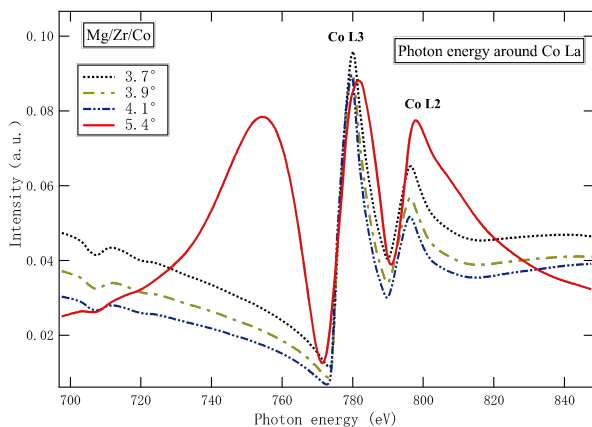




## 1. Reflectivity, $\theta$ - $2\theta$ scans at fixed photon energy



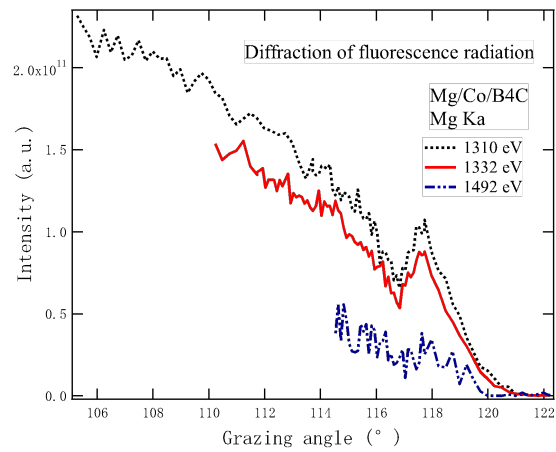
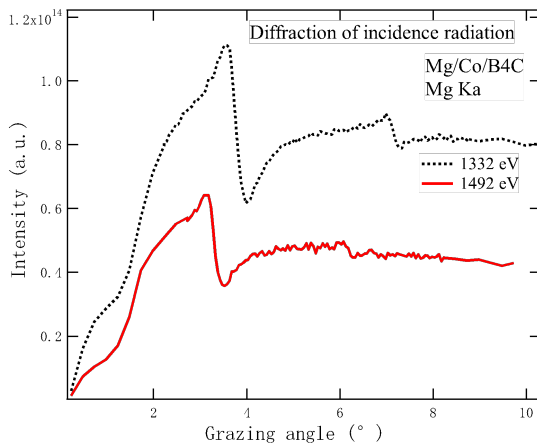
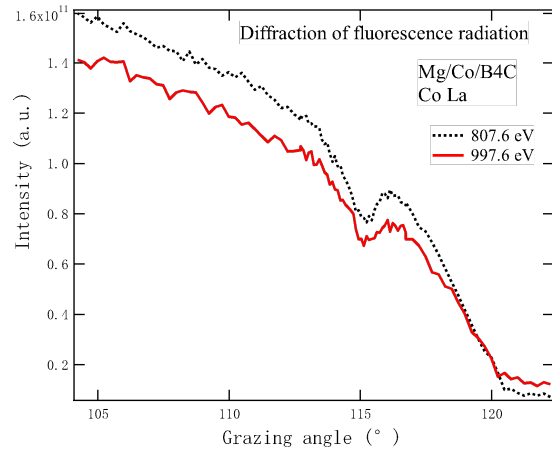
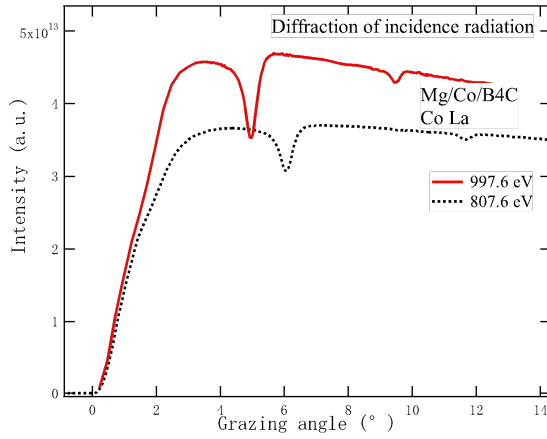
## 2. Reflectivity, photon energy scans around the photon energies of the Co La and Mg Ka emissions at fixed angle



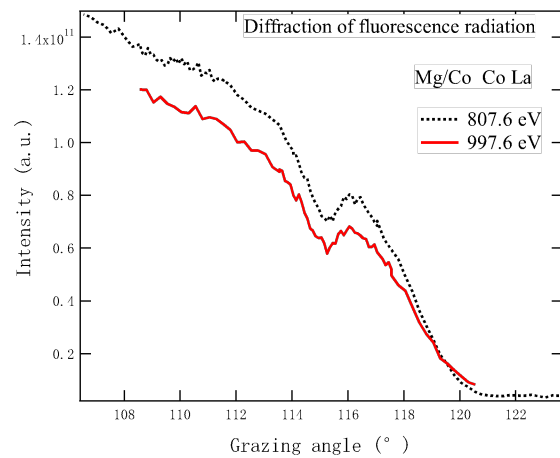
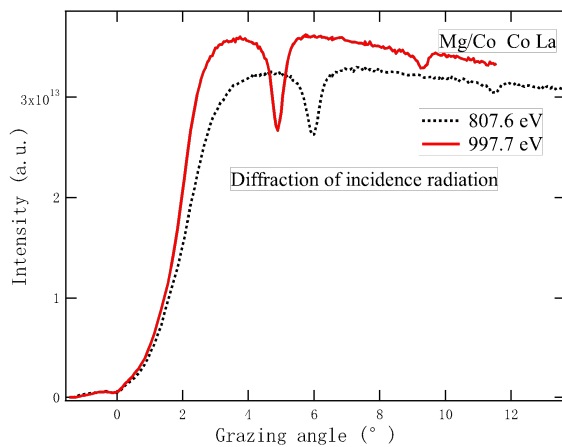


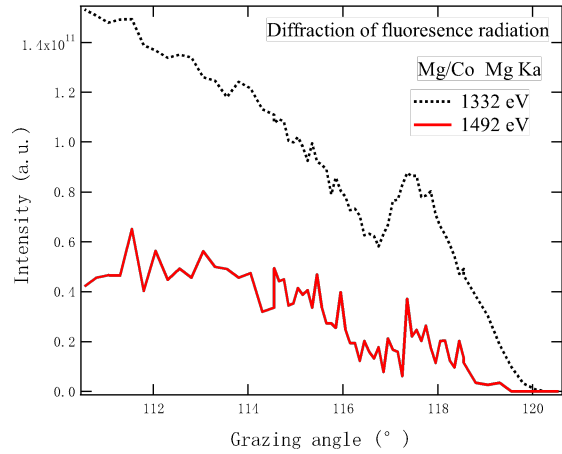
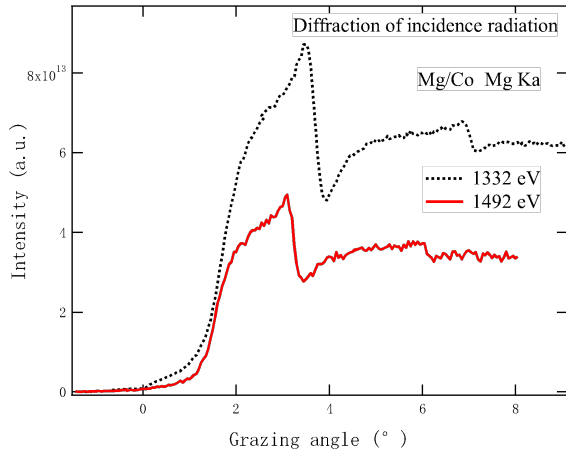
### 3. Comparison for a same sample of XSW with incident and fluorescence radiations

#### 3.1 Mg/Co/B4C multilayer

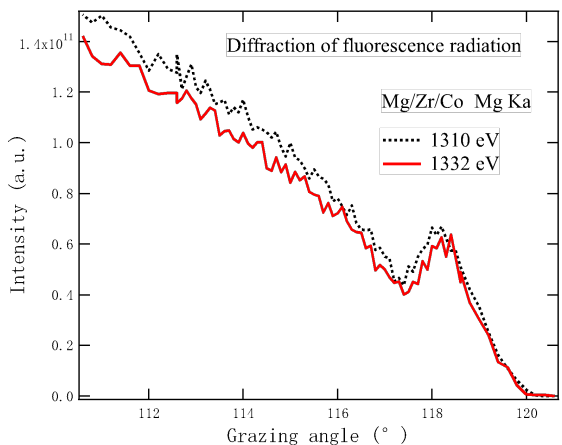
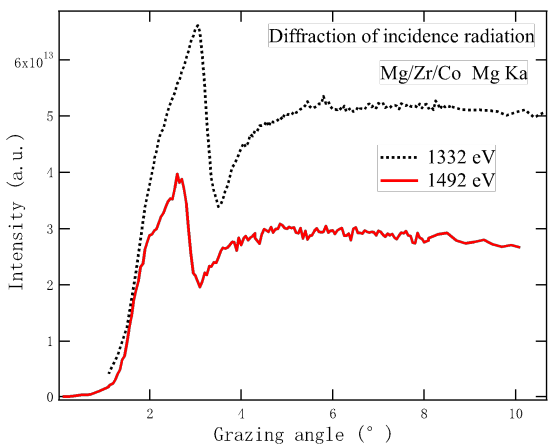
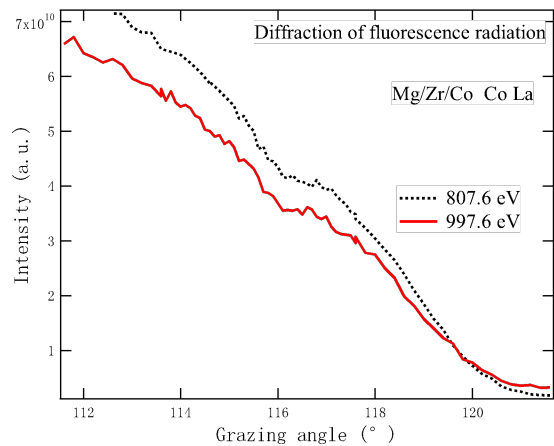
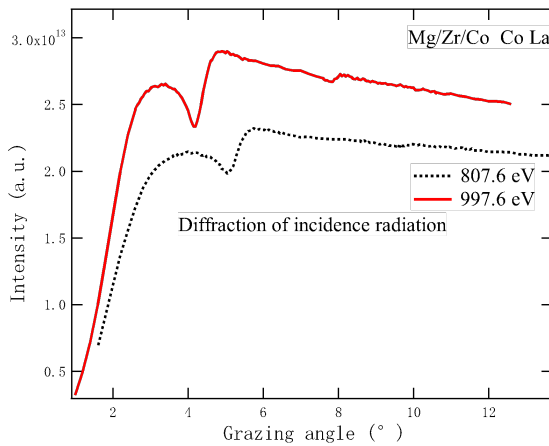


#### 3.2 Mg/Co multilayer



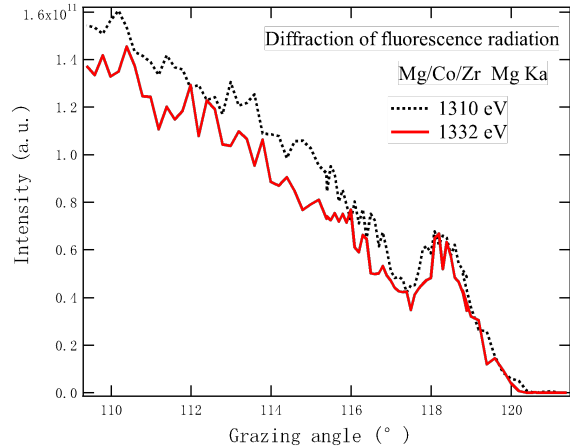
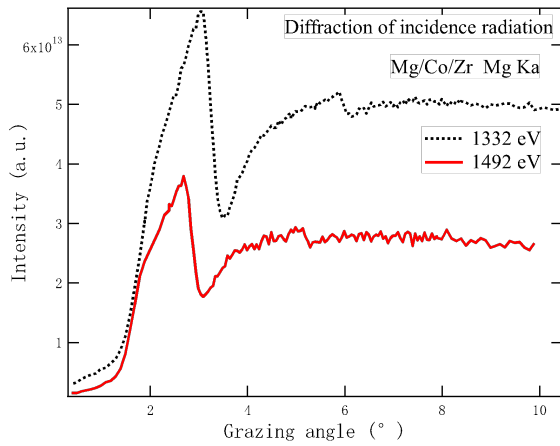
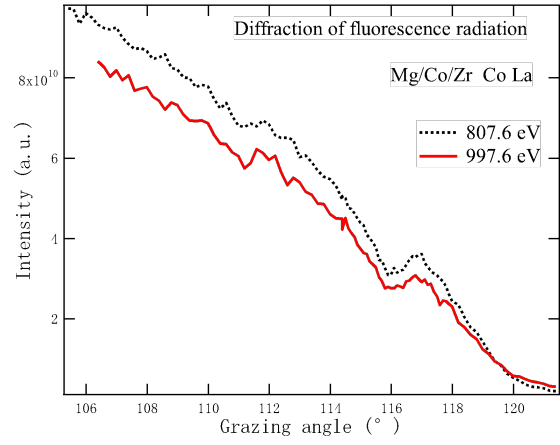
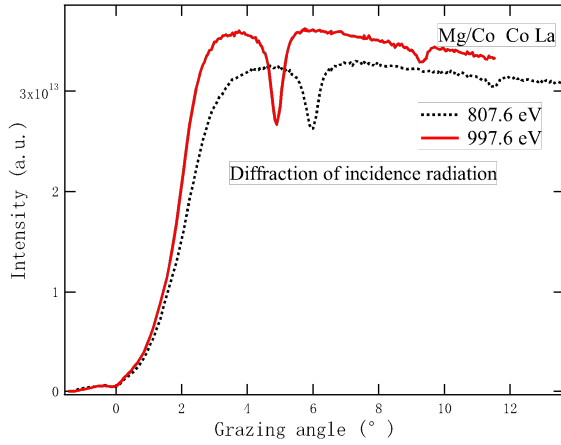


### 3.3 Mg/Zr/Co multilayer



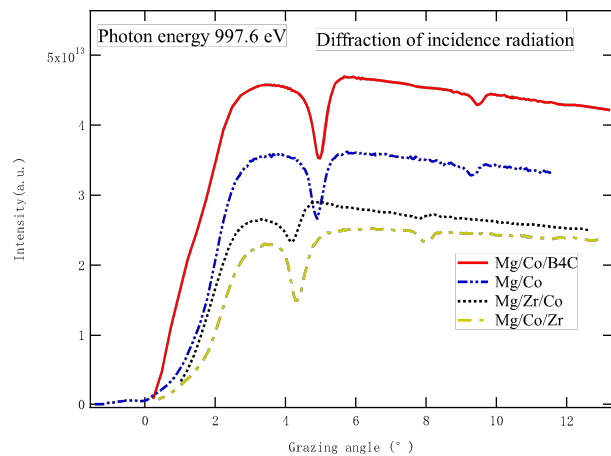
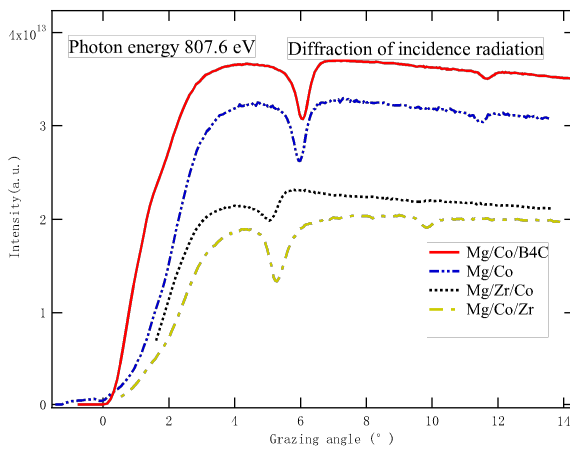


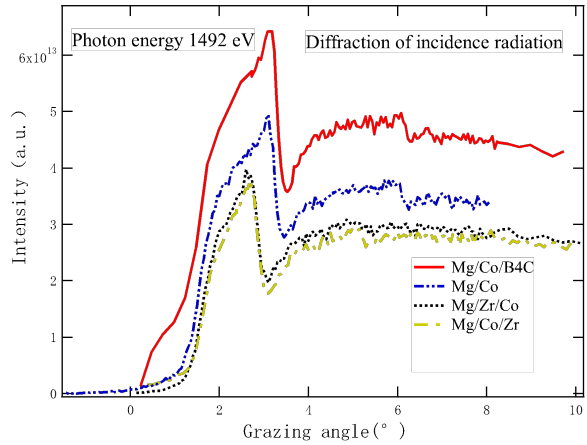
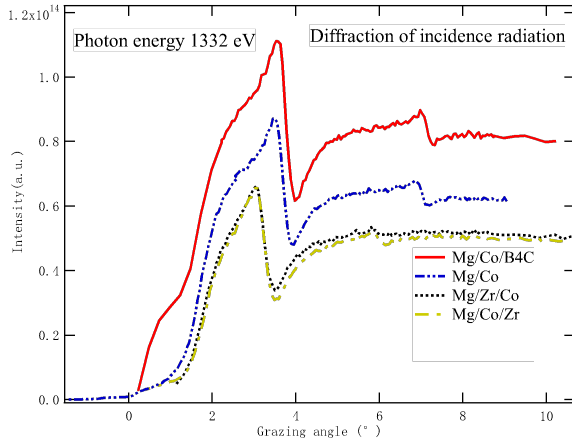
### 3.4 Mg/Co/Zr multilayer



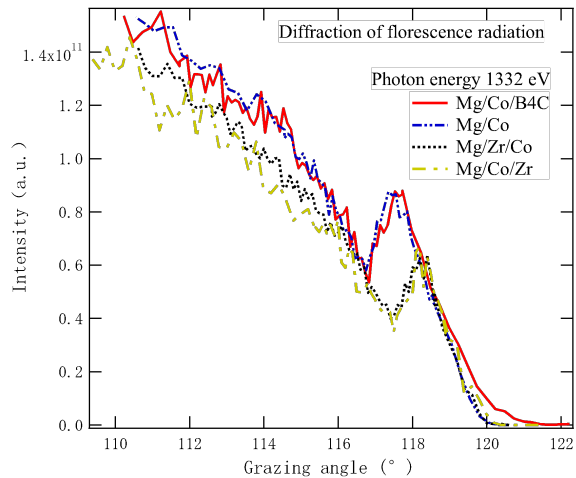
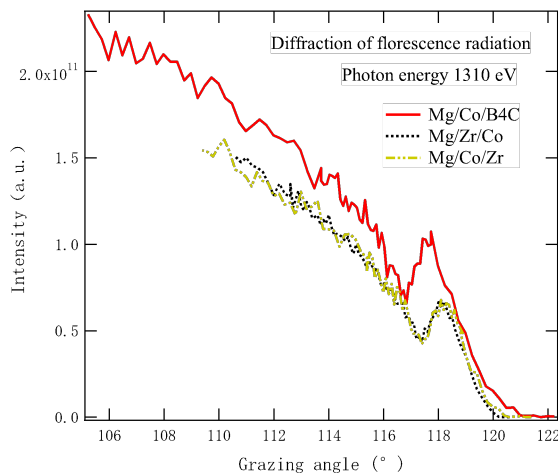
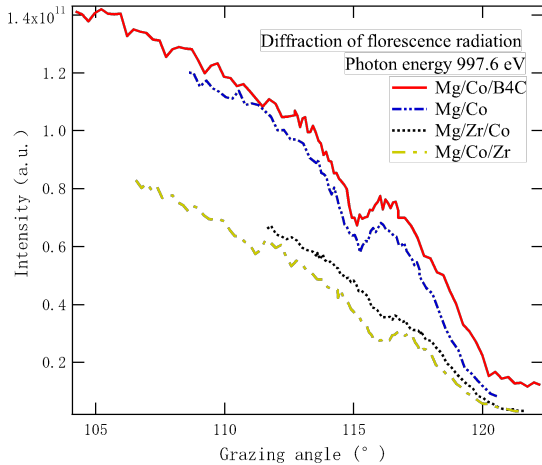
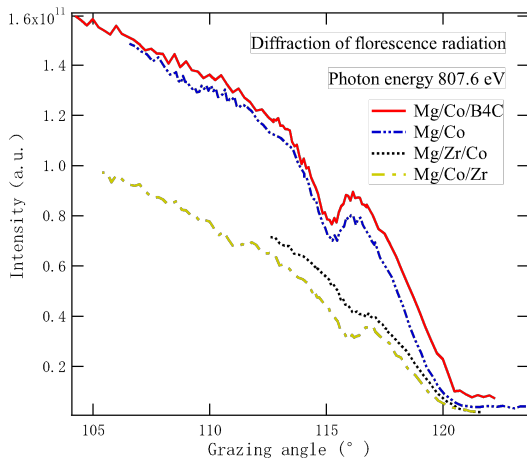
## 4. Comparison between samples of XSW with incident and fluorescence radiations

### 4.1 diffraction of incidence radiation for all samples (small grazing angle)





#### 4.2 diffraction of fluorescence radiation for all samples (large grazing angle)







## 5. Conclusion

(1) We observed the modulation of the detected fluorescence emissions in the standing wave mode when the angular range is explored around the Bragg peak of the fluorescence radiation. That is to say the intensity of the characteristics emission produced within the multilayer is modulated owing to the periodic structure of the multilayer.

(2) We observed the modulation of the fluorescence emissions in the standing wave mode for both bi-layer and tri-layer systems when working in both angular ranges to diffract the incident radiation or the fluorescence emission. That is to say, fluorescence excited by standing wave can also be applied to tri-layer systems.

(3) We have to run our simulation codes, to interpret the data from the material science point of view to determine if interdiffusion can be evidenced this way. This will be important particularly for the two systems with Zr, which we know from previous studies that they present different behaviors with respect to interdiffusion, depending on the position of the Zr layer within the period.